RIFE - 4

Radioactivity in Food and the Environment, 1998

Ministry of Agriculture, Fisheries and Food

SCOTTISH ENVIRONMENT PROTECTION AGENCY

1999

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
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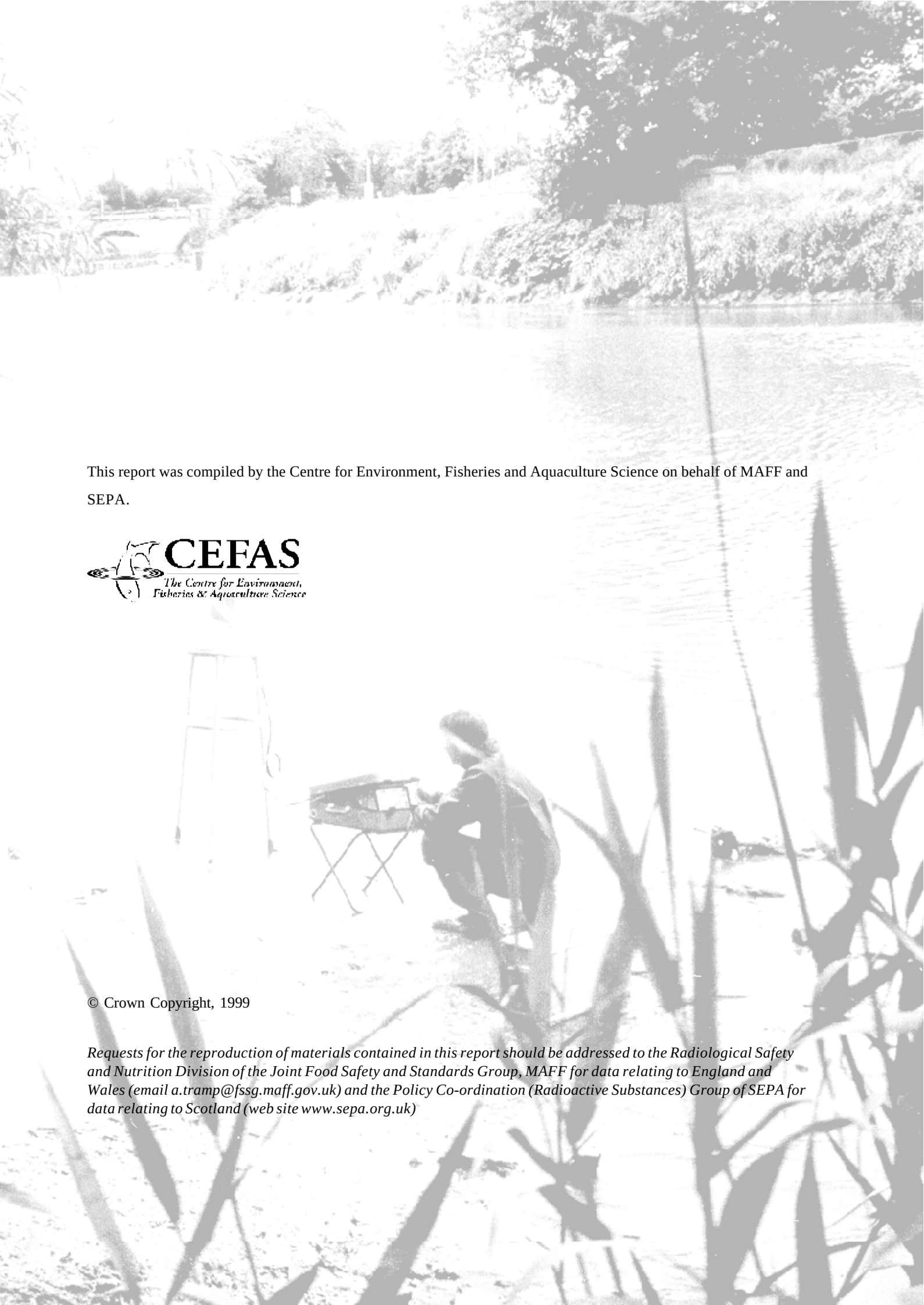


This report was compiled by the Centre for Environment, Fisheries and Aquaculture Science on behalf of MAFF and SEPA.

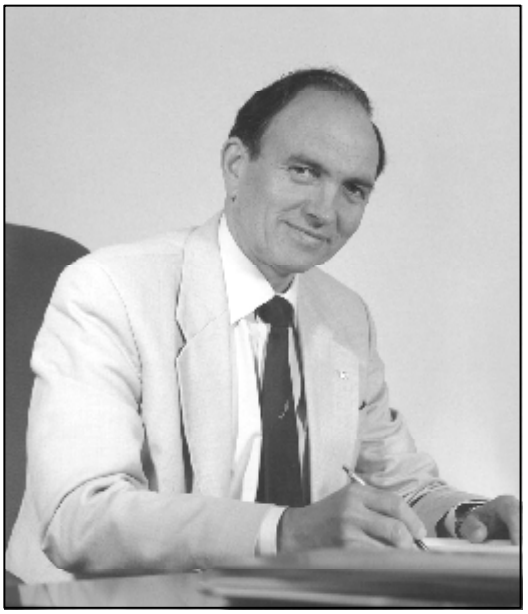
CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

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 environment is effectively protected. The Government makes the results of such surveillance widely available through publication of this report and through regular updates on the MAFF Web site. This technical report presents the scope and results of our radiological surveillance programmes for 1998. It is complemented in England and Wales by the Environment Agency's surveillance report on non-food pathways.

Sponsored by the Joint Food Safety and Standards Group of the Ministry of Agriculture, Fisheries and Food and the Scottish Environment Protection Agency, measurements of radioactivity have been carried out in a wide range of foodstuffs and in the environment around nuclear sites and other potential sources of elevated radioactivity throughout the United Kingdom, and also at locations remote from these sources.

This report demonstrates that the public is being protected against unacceptable contamination of the foodchain and that the UK is fully meeting public safety targets. We remain committed to ensuring that a proper and rigorous surveillance programme is continued to ensure that this remains the case.



The Baroness Hayman
Minister for Food Safety
MAFF

Mr Alasdair Paton
Chief Executive, SEPA

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EXECUTIVE SUMMARY

Radiation Safety – Food and the Environment at Nuclear Sites

This report combines data from both SEPA's and MAFF's monitoring programmes for radioactivity in food and the environment in 1998. Both programmes demonstrate that, in terms of radioactive contamination, terrestrial foodstuffs and seafood produced in and around the UK are considered safe to eat. Exposure of consumers to artificially produced radioactivity via the food chain remained well below the statutory UK limit of 1 mSv (millisievert) for the public, EU limits and Government targets.

In Scotland SEPA's monitoring programme also sets out to determine levels of anthropogenic (man-made) radioactivity within the environment itself 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 as well as verifying that the levels of radioactivity present within foodstuffs have low radiological significance.

The highest estimated doses were due to liquid discharges from the reprocessing plant at Sellafield where high-rate fish and shellfish consumers received 0.20 mSv in 1998 as compared with 0.10 mSv in 1997. The calculated increase was largely due to changes in the habits of high-rate consumers of seafood and the inclusion of direct exposure, rather than increases in measured contamination. This critical group also received an estimated dose of up to 0.37 mSv from enhanced levels of natural radioactivity due to operations at the Albright and Wilson Ltd works at Whitehaven. Consumption of uncommon foodstuffs taken as by-catches of fishing activities in the Sellafield area was also identified. Preliminary information suggests that doses up to 0.33 mSv could be received by a few individuals. The by-catches contain species which are rarely eaten such as sea mice (a marine worm), common shore crabs and sea urchins. Further information is being sought on this pathway.

The highest doses in Scotland 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. Their radiological dose was 0.048 mSv, similar to the estimate for 1997 of 0.047 mSv. There was a small reduction in the contribution to this dose made by technetium-99 discharged by Sellafield but it remains one of the most significant radionuclides for this group.

External exposure resulting from discharges was highest for people on a houseboat in the Ribble estuary. Their assessed dose was 0.15 mSv in 1998, a small increase from the value for 1997. The highest doses from gaseous discharges were also seen at Sellafield. High-rate consumers of milk, vegetables, fruit and meat received an estimated dose of 0.042 mSv, similar to the value for 1997.

Most of the seafood and external exposure due to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed around 12% of the dose to the Sellafield sea food consumers.

The nuclear site of next importance with regards to public exposures was Nycomed Amersham in Cardiff where sources of radionuclides for research, medicine and industry are produced. Doses to high-rate seafood consumers at Cardiff were estimated to be 0.060 mSv in 1998. Most of this 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 is not observed at other sites in the UK.

Assessed doses at all major sites in the UK are shown in Figure S and are detailed in the Table below.

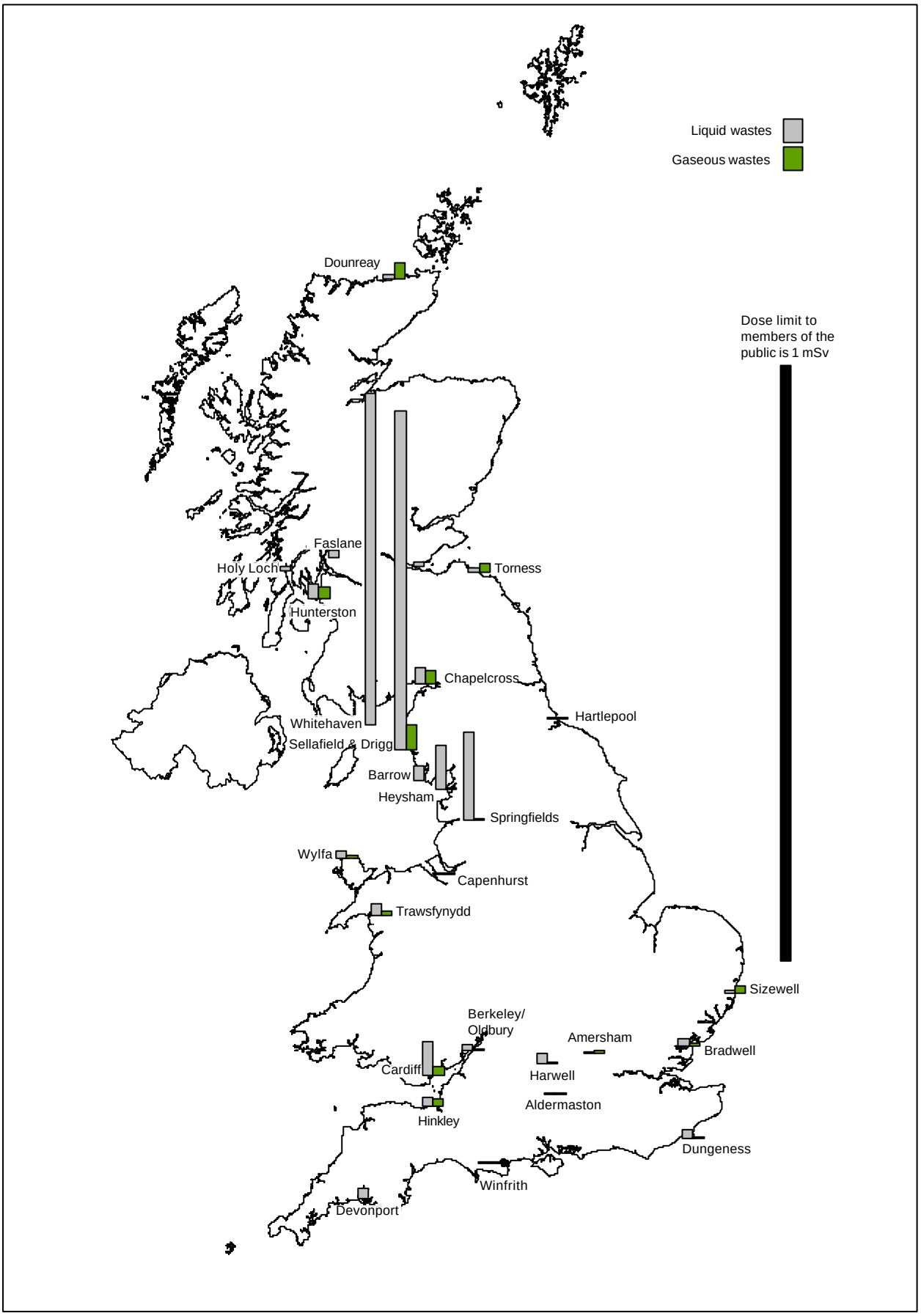

Figure S. Radiation exposures in the UK due to radioactive waste discharges, 1998 (Exposures at Whitehaven and Sellafield include the effects of artificial and enhanced natural nuclides from nuclear and non-nuclear industries)

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 1998

Establishment	Radiation exposure pathway	Critical group	Exposure, mSv [a]
British Nuclear Fuels plc[h]			
Sellafield and Drigg[b]	Fish and shellfish consumption and external	Local fishing community	0.20
	Terrestrial foods	Local consumers at Sellafield	0.042
	Terrestrial foods	Local consumers at Drigg	0.017
	Terrestrial foods	Local consumers at Ravenglass	0.028
	External	Farmers	0.081
	External	Houseboat dwellers (River Ribble)	0.15
	External[c]	Yachtsman (Whitehaven)	0.034
	External (skin)	Anglers	0.30[d]
	Handling of fishing gear	Local fishing community	0.07[d]
	Porphyra/laverbread consumption	Consumers in South Wales	<0.005
	Trout consumption	Local consumers at Sellafield	0.017
	Seaweed/crops	Local consumers at Sellafield	0.030
	Consumption of fishing by-catches	Local consumers	0.33
Springfields	External	Houseboat dwellers (River Ribble)	0.15
	External	Farmers	0.019
	External (skin)	Local fishermen	0.19[d]
	Fish and shellfish consumption and external	Local fishing community	0.036
	Terrestrial foods	Local consumers[g]	<0.005[f]
	Wildfowl consumption and external	Wildfowlers	0.039
	External (skin)	Wildfowlers	1.2[d]
Capenhurst	Inadvertent ingestion of water and sediment	Local community	<0.005
	Terrestrial foods	Local consumers[g]	<0.005
Chapelcross	Fish and shellfish consumption and external	Local fishing community	0.027
	External	Wildfowlers	0.018
	Terrestrial foods	Local consumers	0.022
United Kingdom Atomic Energy Authority			
Dounreay	Fish and shellfish consumption	Local fishing community	<0.005
	Mollusc consumption and external	Mollusc collectors	0.008
	External	Local community	0.005
	Terrestrial foods	Local consumers[j]	0.030
Harwell	Fish consumption and external	Anglers	0.017
	Terrestrial foods	Local consumers	<0.005
Winfrith	Fish and shellfish consumption	Local fishing community	<0.005
	Terrestrial foods	Local consumers	<0.005
Electricity Companies[h]			
Berkeley and Oldbury	Fish and shellfish consumption and external	Local fishing community	0.009
	Terrestrial foods	Local consumers	<0.005
Bradwell	Fish and shellfish consumption and external	Houseboat dwellers	0.011
	Terrestrial foods	Local consumers	<0.005
Dungeness	Fish and shellfish consumption and external	Bait diggers	0.014
	Terrestrial foods	Local consumers[g]	<0.005
Hartlepool	Fish and shellfish consumption and external	Local fishing community	0.005
	Terrestrial foods	Local consumers	<0.005
Heysham	Fish and shellfish consumption and external	Local fishing community	0.074
	Terrestrial foods	Local consumers	0.005
Hinkley Point	Fish and shellfish consumption and external	Local fishing community	0.013[i]
	Terrestrial foods	Local consumers	0.011
Hunterston	Fish and shellfish consumption and external	Local fishing community	0.025
	Terrestrial foods	Local consumers	0.020
Sizewell	Fish and shellfish consumption and external	Local fishing community	<0.005
	Terrestrial foods	Local consumers	0.009

Summary Table: continued

Establishment	Radiation exposure pathway[h]	Critical group	Exposure, mSv[a]
Electricity Companies *continued*			
Torness	Fish and shellfish consumption	Local fishing community	0.006
	External	Local community	<0.005
	Terrestrial foods	Local consumers	0.016
Trawsfynydd	Fish consumption and external	Local fishing community	0.023
	Terrestrial foods	Local consumers[j]	0.006
Wylfa	Fish and shellfish consumption and external	Local fishing community	0.010
	Terrestrial foods	Local consumers	<0.005
Defence Establishments			
Aldermaston	Fish consumption and external	Anglers	<0.005
	Terrestrial foods	Local consumers[g]	0.005[f]
Barrow	External	Local community	0.025
Devonport	Fish and shellfish consumption and external	Local community	0.019
Faslane	External	Local community	0.011
Holy Loch	External	Local community	0.006
Rosyth	External	Local community	0.008
Nycomed Amersham plc			
Amersham	Fish consumption and external	Anglers	<0.005
	Terrestrial foods	Local consumers	0.007
Cardiff	Fish and shellfish consumption and external	Local fishing community	0.057
	Terrestrial foods	Local consumers	0.015
Albright and Wilson Ltd			
Whitehaven[e]	Fish and shellfish consumption	Local fishing community	0.49

[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 6). 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 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 1998 was 0.37 mSv*

[c] *Includes a small contribution due to consumption of seafood*

[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 6)*

[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 6). The exposure due to artificial radionuclides in 1998 was 0.074 mSv*

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

[g] *Adults*

[h] *With effect from 1/4/98, power stations within Magnox Electric plc became part of Magnox Generation Business Group, BNFL plc. For reasons of continuity with previous reports, such power stations are included in the category 'Electricity Companies'*

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

[j] *15 y old*

Radioactivity levels at nuclear sites

No significant changes in radioactive contamination of food or external dose rates were observed in 1998. 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 3% of the dose limit of 1 mSv. Sea-to-land transfer of technetium-99 took place on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser.

Site incidents

In February 1998, MAFF was informed of contaminated feral pigeons near the Sellafield site. A special study of the levels and consequential doses from the potential consumption of pigeon meat was undertaken. People were advised not to handle, slaughter or consume pigeons within a 10 mile radius of the Sellafield site. This advice remains in place.

Other incidents occurred at Sellafield and at Hinkley Point. Reassurance monitoring showed that levels and doses were low.

In Scotland in 1998, a 'snapshot' study of technetium-99 levels in the environment was commissioned by SEPA, including 10 samples of the seaweed *Fucus vesiculosus*, as it is abundant as well as being a good environmental indicator of this radionuclide in the marine environment.

In 1998, SEPA and NRPB published the findings of an extensive study into the fragments that had been appearing in the environment around Dounreay (SEPA, 1998). SEPA's advice to the Scottish Office was that the 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. SEPA's advice was accepted by Government.

Following the discovery of the potential for activity to be transferred off-site by wildlife, SEPA initiated studies to determine whether a comparable pathway might exist at nuclear licensed sites in Scotland. Operators were required to take samples of wildlife that could provide a similar pathway. These studies did not produce any evidence to support the existence, at these sites, of such a pathway.

Radiation doses and levels at other locations in the UK

Analyses of food throughout the UK demonstrated that natural radionuclides are by far the most significant source of exposure 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 2% 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 (Albright and Wilson 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 radionuclides from the Sellafield site nearby, were estimated to be up to 0.56 mSv. There was no conclusive evidence for enhancement of natural radionuclides near other non-nuclear industrial sites. Tritium was found to leach from some landfill sites but the radiological significance of the levels was negligible.

** 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 surveillance programmes

The programmes involved the collaboration of five specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the UK. They were organised independently of the industries discharging wastes by SEPA and by MAFF on behalf of the Channel Island States, the Environment and Heritage Service for Northern Ireland, the Manx Government and the Welsh Office. 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.maff.gov.uk.). Further details of all programmes described in this report can be obtained by telephoning MAFF on **0171 238 6177** or SEPA on **01786 457 700**.

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 1998. This is the fourth in the series which combines the results of the radioactivity monitoring programmes previously published by the Ministry of Agriculture, Fisheries and Food (MAFF) in two documents: the 'Terrestrial Radioactivity Monitoring Programme (TRAMP) Report: Radioactivity in food and agricultural products in England and Wales' (e.g. MAFF, 1995) and the 'Aquatic Environment Monitoring Report: Radioactivity in surface and coastal waters of the British Isles' (e.g. Camplin, 1995). Monitoring results from around nuclear licensed sites are published regularly on MAFF's Internet site (www.maff.gov.uk).

The report is the third in the series which also includes the results of all environmental monitoring for radioactivity carried out in Scotland on behalf of the Scottish Environment Protection Agency (SEPA). These results were previously presented in the 'Statistical Bulletin: Environmental Monitoring for Radioactivity in Scotland' (e.g. The Scottish Office, 1996). It is intended that data for monitoring in Scotland will be published on SEPA's web site (www.sepa.org.uk).

For nuclear sites in Wales MAFF act on behalf of the National Assembly for Wales.*

This report is jointly published by MAFF and SEPA.

The data in this report cover the calendar year of 1998 and the results of the programmes are assessed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of MAFF, SEPA, the Welsh Office, the Environment and Heritage Service (Northern Ireland), the Manx Government and the Channel Island States.

The purpose of the programme is to verify that the levels of radioactivity present within foodstuffs are acceptable and to ensure that public radiation exposure from the consumption of these foods is within UK and internationally accepted limits. In Scotland, SEPA has a broader responsibility (under the Environment Act 1995) for protecting (and determining general levels of pollution in) the environment and here the data are also used for this purpose.

The monitoring is independent of similar programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. 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 UK remote from nuclear sites, is included. For Scotland, all monitoring of the environment that is carried out is also included in this report (some of the other environmental monitoring data from outwith Scotland are included in other publications). Where appropriate, the monitoring data for nuclear sites are supplemented by results from other projects related to the behaviour of radioactivity in the environment. A 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 1998 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 at Appendix 3.

** Prior to 1 July 1999 MAFF acted on behalf of the Welsh Office, reference is therefore made to this former Department in this report.*

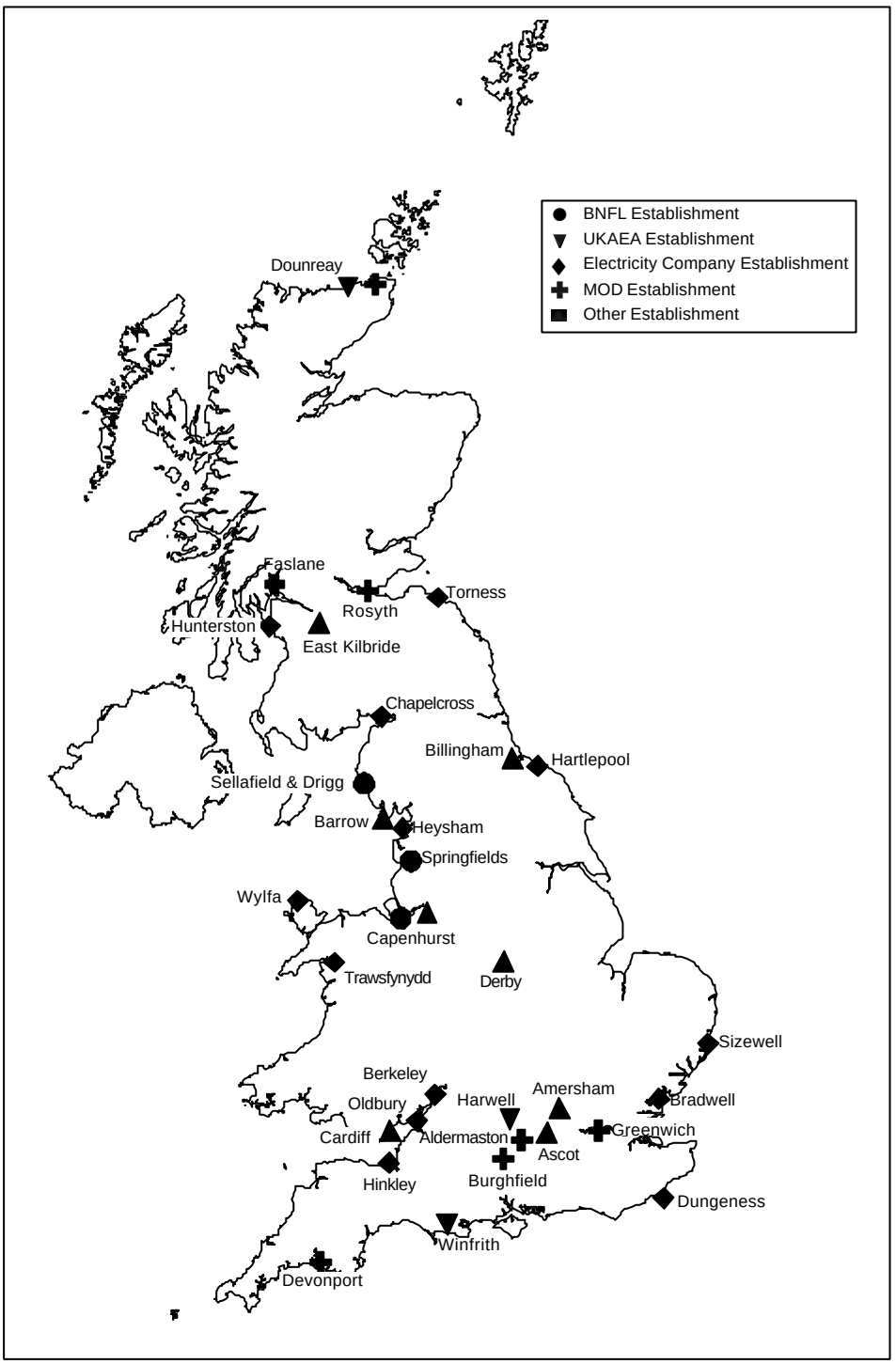

Figure 1.1. Principal sources of radioactive waste disposal in the UK

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

Data on 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. A summary of 1998 disposals is included in Appendix 1; this enables the results of monitoring presented in this report to be considered in the context of the relevant disposals. The sites which 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 from other sites such as hospitals, chemical works and research establishments. These authorisations are made under the Radioactive Substances Act 1993 (United Kingdom - Parliament, 1993). The non-nuclear licensed sites are not subject to the additional controls provided for by the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). 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 solid waste are also disposed of in specified landfill sites. In general these disposals are so insignificant that environmental monitoring of their effects is 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 1998. The Tables also list the disposal limits which 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, 1995). The percentages of the authorised (or agreed) limits taken up in 1998 are also stated in the tables.

Where changes in the rates of disposal in 1998 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

1.2.2 Solid radioactive waste disposal 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 withdrew from this disposal option at the OSPAR Ministerial meeting held in Portugal in July 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 1998 are presented in Section 11.3, which confirms that the radiological impact of these disposals was insignificant.

Small amounts of radioactive waste have also been dumped in other coastal locations, details of which were given in Parliamentary replies (United Kingdom – Parliament, 1997a). These wastes were from a variety of industrial and university sources and not the nuclear power industry. The Government asked the National Radiological Protection Board (NRPB) to carry out an independent assessment of the radiological significance of the disposals. The assessment (Titley et al., 1997) concluded that the estimated doses from the dispersion of radionuclides in marine waters were not significant in radiological protection terms and that there was no need for additional environmental monitoring in connection with the disposals. The results of the assessment were given in a further written Parliamentary reply (United Kingdom – Parliament, 1997b).

The NRPB considered that the only eventuality which could give rise to a significant calculated dose was if one of two anti-static devices dumped off the Isle of Arran in 1958 were to be recovered by fishermen or washed ashore. The likelihood of this occurring is extremely low; however in the interests of the local populations precautionary advice has been issued, by The Scottish Office and MAFF, to fishermen's organisations, local authorities and other relevant bodies (MAFF 1998). Copies of this advice, and of the NRPB report, are available from MAFF Rural and Marine Environment Division, Room 150 Nobel House, 17 Smith Square, London SW1P 3JR.

1.2.3 Other sources of radioactivity

There are several other possible sources of radioactivity which may affect the marine food chain and the environment. These include transport incidents, satellite re-entry, release from overseas installations and the operation of nuclear powered submarines. Submarine berths in the UK 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 1998. 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 MAFF 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 anthropogenic radionuclides in the environment in order to assess their affects on human health (including via the food chain) as well as that of the environment. Subsidiary objectives for the programme are: (i) to act as an additional check for compliance with conditions in an authorisation and provide a baseline dataset from which to judge the importance of accidental releases of radioactivity, should they occur; and (ii) to provide information on radioactivity in the environment and diet of the general 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). Here the programme also serves to provide information to assist the Environment Agency (and SEPA in Scotland) to fulfil its statutory duties under the Radioactive Substances Act, 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 which 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 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. Supplementary information can be found on the internet (www.maff.gov.uk/food/radintro/radintro.htm, www.maff.gov.uk/food/incid_1/bnfp23.htm and www.maff.gov.uk/food.incid_1/bnfl_s35.htm).

The main aim of the programme is to monitor the diet of consumers who live 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 which 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 in England and Wales passed to the Environment Agency who will publish their results in a separate report. However, as part of SEPA's programme the RIFE report will continue to provide external exposure information for Scotland. Also data will be presented for external exposure in 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 1998 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. Selected large area contamination monitoring is carried out in Scotland. This is to establish whether there is any unusual localised radioactivity which may be missed by the sediment sampling and measurement regime, which by definition is selective. The Environment Agency carry out this function for sites in England and Wales. Measurements of indicator materials, such as sediments and seaweeds, perform an important function by, for example, providing 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 1998 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of foodstuffs which may be affected by disposals to atmosphere, although in some cases where food availability is limited, environmental indicator materials such as grass are monitored in place of food.

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 on: (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, are also sampled when available.

For monitoring purposes, cows' milk is generally the most important foodstuff as grass is an efficient collector of atmospheric contaminants and many of the more important radionuclides are rapidly passed from grass into milk. Milk is also a convenient product to regularly sample 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. 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 a range of sample types. 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 8 km.

'Dry cloth' detectors, positioned around the nuclear sites are analysed for airborne radionuclides which 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 1998 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 which has potential effects on the environment/food chain. These sites do not require licensing under the Nuclear Installations Act. In 1998, the industrial sites studied were:

- Whitehaven, Cumbria (a phosphate plant)
- Aberdeen, Grampian (gas and oil industry)
- Port Talbot, West Glamorgan (steel works)
- Scunthorpe, Humberside (steel works)
- Pontypool, Gwent (industrial waste incinerator)
- Sidcup, Kent (hospital waste incinerator)

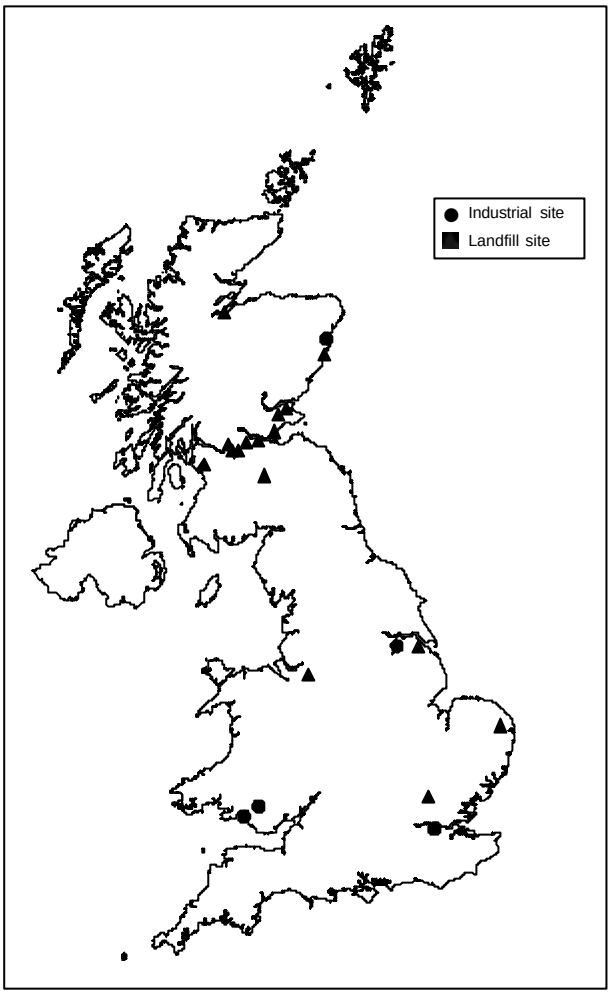

Figure 2.1. Industrial and landfill sites studied in 1998

In the case of the Whitehaven and Aberdeen sites, 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.

Four landfill sites were monitored in England and Wales and twelve in Scotland. These sites are amongst those that have been 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.

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 radio-caesium 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 remote 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 air 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 which 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 which 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 thirteen regions throughout the United Kingdom. Normal culinary techniques are used in preparing samples (eg removal of outer leaves) and samples are combined in amounts which reflect the relative importance of each food in the average UK 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 30 dairies throughout the United Kingdom in 1998. Samples are taken monthly and are reported to the EU to allow comparison of results with those from other member states.

Other food sampling complements the regional dairy programme described above. Crop samples were taken from 24 locations covering areas throughout the United Kingdom. Bread and meat samples were taken from 4 areas in Scotland. The results are used to give an indication of background levels of radioactive contamination from natural and anthropogenic sources (nuclear weapon tests and Chernobyl fallout) for comparison with samples collected from around nuclear sites.

Drinking water was sampled from 29 locations throughout Scotland. The results of monitoring of drinking water in England and Wales have been published by the Department of the Environment, Transport and the Regions (DETR, 1998) and are summarised in the Environment Agency's Annual Report (Environment Agency, 1999). Airborne particulates are sampled monthly in Glasgow by the NRPB for SEPA.

Seawater surveys

Seawater surveys are carried out in the Irish Sea, Scottish waters and the North Sea 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 methods but costly. They are therefore only used when there is clear expectation that information is needed on specific radionuclides which are not detectable using gamma spectrometry.

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

- CEFAS analysis of dry cloths and aquatic samples excluding those from Scotland
- VLA gamma spectrometry and radiochemistry (excluding total uranium analysis) of terrestrial samples excluding those from Scotland
- NRPB gamma spectrometry and radiochemistry of Scottish samples, and diet and industrial samples from England and Wales
- IC total uranium analysis of terrestrial samples

Each laboratory operates a quality control procedure to the standards required by MAFF 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 radionuclides between the time of sample collection and measurement in the laboratory. This is particularly important for radionuclides with relatively short half-lives such as 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 in-growth of activity 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 which is normally eaten. The shells of shellfish and the pods of legumes are usually discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish

** Abbreviations are explained in Appendix 3.*

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 each 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.

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

Table 2.1. Scope of the monitoring programmes

Programme	Sub-programme	Main purpose
Nuclear sites[a]		Support for RSA 93, assessment of waste disposal
Industrial sites[b]	Chemical works	Support for RSA 93, assessment of waste disposal
	Landfill sites	Support for RSA 93, assessment of waste disposal
Chernobyl fallout	Sheep monitoring	Support for FEPA 85, guidance on restrictions
	Freshwater fish	Support for FEPA 85, trend analysis
Regional[b]	Milk, crops, bread and meat	General food safety, support for EURATOM Treaty[c]
	Diet	General food safety, support for EURATOM Treaty[c]
	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*

Table 2.2. Scope of the nuclear site sampling in 1998

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, ^{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, saithe, mackerel, haddock, hake, eel, crabs, lobsters, squat lobsters, winkles, native oysters, mussels, limpets, whelks, cockles, *Nephrops*, pacific oysters, shrimps, squid, scallops, queens, ormers, *Porphyra* laverbread, samphire, pike, brown trout, rainbow trout, perch, sea mice 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, coal, clay, salt marsh, peat, turf, sludge, seawater, freshwater, *Fucus spp.*, *Rhodymenia spp.*, *Fontinalis*, *Laminaria digitata*, *Elodia canadensis*, *Nupha lutea* and rudd
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, ^{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, pheasant, rabbits, honey, mushrooms, hazelnuts, beetroot, wheat, barley, elderberries, apples, crab apples, blackberries, strawberries, raspberries, abbage, sea kale, lettuce, potatoes, runner beans, turnips, leeks, carrots, swede, sprouts, sprout tops, broad beans, kale, peas, cauliflower, spinach, marrow, asparagus, pumpkin, sugar beet, sugar beet tops
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, ^{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, compost 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 which 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 of a given quantity may vary throughout the year. 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 over the year.

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 1998 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, silage and other fodder collected over a distance of a few kilometres of the farm. In the case of dose rate measurements, the position where the measurement is carried out is within a few metres of other measurements made within a year. Each observation consists of the mean of a number of instrument readings at a given location.

The numbers of farms which are sampled to provide information on activities in milk at nuclear sites in England and Wales are indicated in the tables of results. 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 which 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 1998.

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 MAFF 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.maff.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 which apply in ensuring protection of the public.

The dose standards are embodied in national policy on radioactive waste (United Kingdom - Parliament, 1995). The National Radiological Protection Board (NRPB) advises the UK Government on appropriate standards, including the recommendations of the International Commission on Radiological Protection (ICRP). Current UK practice relevant to the general public is based on the recommendations of the ICRP as set out in ICRP Publications 26 (ICRP, 1977) and 60 (ICRP, 1991). The Euratom Directive on basic radiation safety standards (Commission of the European Communities, 1984), with which UK legislation complies, is based on the recommendations of ICRP-26, but has been revised to take account of the changes in radiological protection criteria recommended in ICRP-60 (Commission of the European Communities, 1996); the directive will be mainly implemented through amendments to the Radioactive Substances Act (RSA 93) and the Ionising Radiation Regulations (IRR85); the Department of Environment, Transport and the Regions (DETR) is acting as the lead Government department for making amendments to the Radioactive Substances Act and the Health and Safety Executive (HSE) has already consulted on draft legislation to place the IRRs. Together these legislative amendments will ensure the directive is implemented in the UK. The International Atomic Energy Agency (IAEA) and its related inter-governmental organisations have now published their own revised Basic Safety Standards for Radiation Protection based on ICRP-60 (IAEA, 1996).

There are two limits on individual dose which apply in this report. The limit for whole-body dose (more formally 'committed effective dose') is 1 mSv* (millisievert) per year (United Kingdom - Parliament, 1995). For skin, an alternative limit of 50 mSv per year to the skin, applies. 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, 1995).

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. It therefore follows that intervention levels are taken into account and used as a yardstick 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 1998. 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

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* *Strictly the statutory limit is 5 mSv in any one year, and 1 mSv a year averaged over five years. 1 mSv has effectively been adopted as a limit in the UK, and this has been endorsed in recent white papers.*

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 mathematical 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 a radionuclide is specified in the relevant authorisation and (ii) when a positive determination is found in another foodstuff from the site. This accounts for the possibility that some activity is present when no positive determination is found. 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 without the symbol.

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 grouped 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., in press). 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.

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 by MAFF 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, personal communication). 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 nuclear 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 fire alarms 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, though the simple addition of 'liquid' and 'gaseous' doses will overestimate the dose received at a site due to radioactive waste disposal. This is because an individual is unlikely to consume both aquatic and terrestrial foods at such high rates. Development of a robust method for calculating a combined aquatic and terrestrial dose is a high priority. Surveys of consumption in locations close to nuclear sites has demonstrated that the use of national data, particularly for seafood consumption, is not appropriate. In future reports consumption rate data may be derived from the total habit survey data; how representative groups will be defined is currently under consideration. In addition, it should be noted that the age groups receiving the highest doses from liquid and gaseous disposals are often not the same, this provides a further complication.

As a consequence of the Euratom Basic Safety Standard Directive it is anticipated that the Environment Agencies in conjunction with the Nuclear Installations Inspectorate (NII) will be required to determine cumulative exposures (doses), in order to demonstrate compliance with the principal dose limit of 1 mSv (for members of the public from all anthropogenic sources). It is likely that this will involve an appraisal of 'true' total critical exposure from multiple sources, and the issue of summation across different pathways will need to be addressed. The directive has to be implemented by 13th May 2000.

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 consideration of children and the use of appropriate gut transfer factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut transfer 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 factor of 0.5 is appropriate for dietary intakes of polonium by adults (ICRP, 1994). A study involving the consumption of crab meat 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 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 gut transfer 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 transfer 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 measured quantity is air kerma rate. 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 which excludes natural sources of radiation.

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 food chain and environmental* consequences of disposals of radioactive waste from all BNFL sites by MAFF. For continuity with previous reports, this Section comprises the results for five BNFL sites, namely Sellafield, Drigg, Springfields, Capenhurst and Chapelcross. The power stations within Magnox Electric plc became part of Magnox Generation Business Group, BNFL with effect from 1 April 1998. These sites 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, 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 and AEA Technology facilities. 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 UK nuclear power programme, and some fuel from abroad. 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 UK. 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 1998 are summarised in Appendix 1. Total alpha and beta disposals were 0.174 and 85.5 TBq respectively (1997: 0.185 and 138 TBq respectively). The reduction in beta disposals was due to reduced treatment of stored wastes and improved performance of the Site Ion Exchange Effluent Plant (SIXEP).

There were also reductions in discharges of particular radionuclides (strontium-90 and technetium-99; reasons as for beta activity) and an increase in cobalt-60 discharges (due to inputs from fuel stored in the oxide reprocessing plant ponds). 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 UK 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 which 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 1998 above those due to Sellafield. Regulatory monitoring of the Drigg Stream is carried out by the Environment Agency.

**The Environment Agency has the principal responsibility for non-food pathways in England and Wales.*

Regular monitoring of the marine environment near Sellafield continued during 1998. 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 1998, 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 *et al.*(in press).

In Scotland in 1998, a 'snapshot' study of technetium-99 levels in the environment was commissioned by SEPA, to demonstrate explicitly that activities reduced with distance around the Scottish coast from the point of discharge (also to make comparisons possible with environmental levels at sites that were routinely monitored; predominantly on the South West Scottish coast and in the Solway Firth). The study included 10 samples of the seaweed *Fucus vesiculosus*, as it is a good accumulator and hence environmental indicator of this radionuclide, around the coast of Scotland. The results of this study are included in Table 4.13 and demonstrate a fall-off in environmental levels with distance from Sellafield.

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. Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments which reflect Sellafield disposals are given later in this report. The 'Sellafield Coastal Area' extends 15 km north and 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 0.3 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 (Hunt and Kershaw, 1990). 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. The caesium-137 concentration in the sample, 180 Bq kg^{-1}, was greater than in 1997 (39 Bq kg^{-1}); however the variability of activities in samples of freshwater fish is known to be high (Camplin *et al*., 1989).

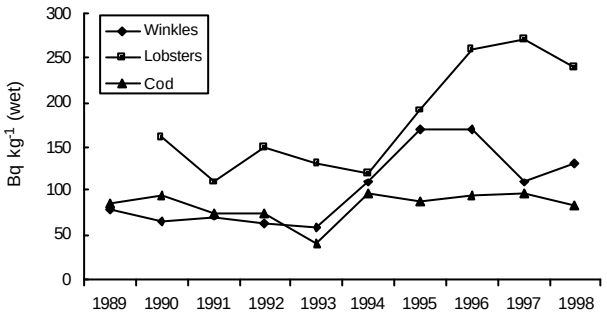

Figure 4.1. The trend in carbon-14 concentrations in cod, lobsters and winkles from Sellafield

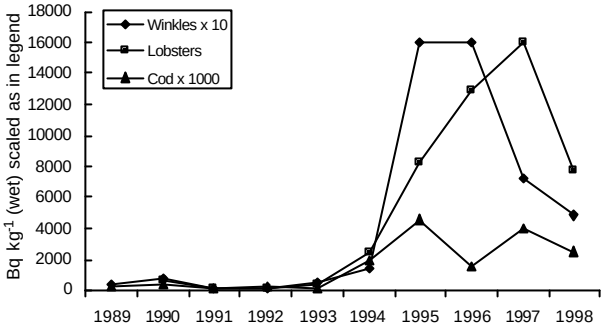

Figure 4.2. The trend in technetium-99 concentrations in cod, lobsters and winkles from Sellafield

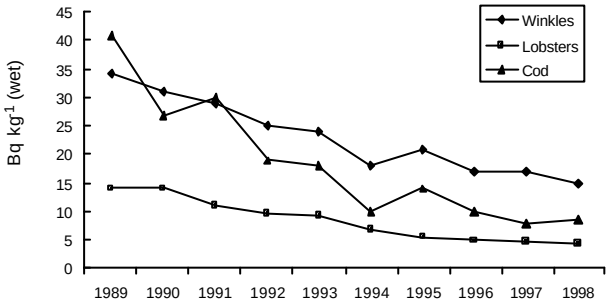

Figure 4.3. The trend in caesium-137 concentrations in cod, lobsters and winkles from Sellafield

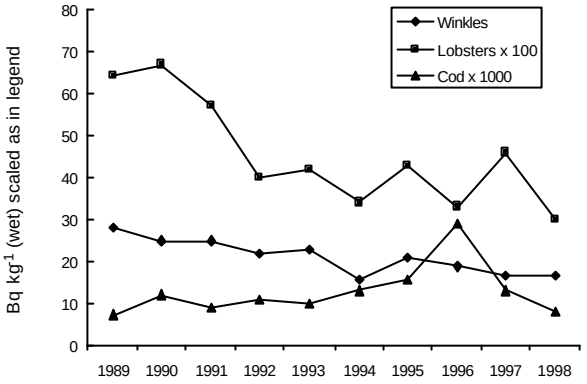

Figure 4.4. The trend in plutonium-239/240 concentrations in cod, lobsters and winkles from Sellafield

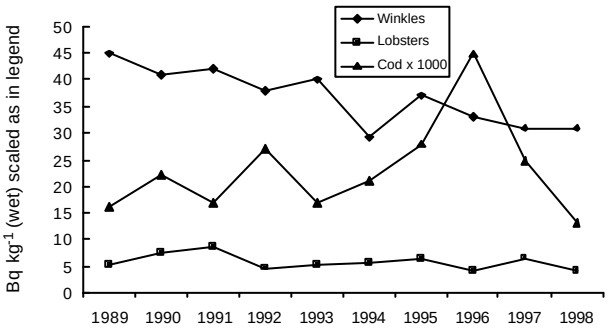

Figure 4.5. The trend in americium-241 concentrations in cod, lobsters and winkles from Sellafield

The absence of any detected caesium-134 in the sample suggests that fallout from Chernobyl, which is detected in other freshwater fish in Cumbria, is unlikely to be the source of activity nor would fallout from atmospheric weapon tests be the source at these concentrations.

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 MAFF, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield coastal area.

Concentrations of artificial radionuclides in shellfish, as with fish, diminish with increasing distance from Sellafield. There are substantial variations between species: for example, lobsters tend to concentrate more technetium-99 in comparison to 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. When comparing 1997 and 1998 data across a wide range of sampling locations and shellfish species, it is apparent that increases occurred for cobalt-60 and decreases for technetium-99 (Figure 4.2). These changes appear to reflect changes in disposals of these radionuclides.

The shellfish table includes data for an annelid worm, A*phrodite aculeata*, commonly known as the sea mouse. This animal is caught as part of by-catches from fishing in the Sellafield area and is rarely eaten.

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 1998 are presented in Table 4.3. Transuranics are less mobile than radiocaesium in sea water; 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 1998 were similar to those in 1997 (Figures 4.4 and 4.5). Those in samples from the north-eastern Irish Sea remain the highest levels of such nuclides to be found in foodstuffs in the UK

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 1998 from artificial radionuclides in fish and shellfish. The dose to the local most exposed group of consumers was 0.20 mSv. This includes a contribution due to external exposure**.** The increase in dose from 0.10 mSv reported for 1997 (MAFF and SEPA, 1998) 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 and the explicit inclusion of external exposure in the group. Most of the seafood and external dose due to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed about 12% of the dose to the Sellafield seafood consumers.

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, Albright and Wilson Ltd, Whitehaven, are considered here to enable the total dose to be compared to the limit of 1 mSv. The dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 1998 was 0.37 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

0.57 mSv. These doses may be compared with an average dose rate of approximately 2.2 mSv year^{-1} to members of the UK public from all natural sources of radiation (NRPB, 1998) and are well within the limit of 1 mSv.

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). The doses received by 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 1997 (see text table). All doses were well within the 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 critical pathways in Scotland. As indicated in Table 4.4, the 1998 dose is only slightly higher than that for the previous year. In spite of a reduction in the contribution of technetium-99 this remains one of the most significant radionuclides in the local environment. The dominant radionuclide for this pathway is now americium-241.

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 1998 was 0.002 mSv, the same as that for 1997 (MAFF and SEPA, 1998).

Seafood doses from artificial radionuclides in the Irish Sea

Group	Dose, mSv	
	1997	1998
Northern Ireland	0.012	0.014
Dumfries and Galloway	0.047	0.048
Whitehaven	0.037	0.023
Sellafield	0.10	0.20
Isle of Man	0.010	0.010
Morecambe Bay	0.073	0.074
Fleetwood	0.030	0.027

A full review of seafood consumption rates at Sellafield was undertaken in 1998. Changes to the consumption rates for fish and shellfish were included in the assessments whose results are given above. The review revealed consumption of material caught as by-catches of fishing in the local area. A single family was involved. The material includes species which are not normally eaten, for example sea mice, sea urchins (*Echinoidea*), brittle stars (*Ophiuroidea*), common shore crabs (*Carcinus maenas*), and hermit crabs (*Eupagurus spp.*). Some of these species are consumed directly after cooking, other material is used in soups. At the time of writing, it has not been possible to obtain precise information on the amount of radioactivity eaten by the few individuals making use of these materials. Therefore we have made a speculative calculation of the maximum dose that could be received using pessimistic assumptions based on the mass of material provided to the family in question. The dose estimate is 0.33 mSv, the largest contribution coming from the direct consumption of sea mice, in which relatively high concentrations of actinides have been found (Table 4.3). Although this pathway is no longer detected, it will be kept under review in 1999.

The exposure of consumers of trout from a local fish farm was also considered in 1998. Their dose was 0.017 mSv or 2% of the dose limit of 1 mSv. This includes a contribution due to Chernobyl and weapon test fallout.

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 portable gamma-radiation dosimeters. Table 4.5 lists the locations monitored by MAFF and SEPA together with the dose rates in air at 1 m above ground. Dose rates on Irish Sea shorelines, near other nuclear establishments which 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 1998 were similar to those data for the same locations in 1997.

Radioactivity concentrations 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 1997 (MAFF and SEPA, 1998) shows similar amounts of radioactivity. Kershaw *et al.* (1999) have recently published a review of plutonium and americium in Irish Sea sediments.

In western Cumbria the dose in 1998 to a yachtsman living on a boat in Whitehaven harbour was 0.034 mSv. This exposure includes a component due to consumption of fish and shellfish. The reduction from the value for 1997, 0.16 mSv, was mainly due to a reduction in the occupancy of the boat. The dose to anglers who dig bait near to Sellafield and who fish in the Cumbrian coastal area is included in the assessment of seafood consumers (Table 4.4). In the wider area, including Cumbria, Lancashire and the north Solway coast it was confirmed that houseboat dwellers in the Ribble estuary are representative of those who receive the highest external exposures from the effects of disposals from Sellafield. Making an allowance for natural background using a dose rate of 0.07 μGy h^{-1}, their external dose in 1998 was 0.15 mSv, similar to the value for 1997 (MAFF and SEPA, 1998). In terms of occupancy over tide-washed pasture, farmers are representative of those most exposed. In northern Cumbria their dose was 0.081 mSv in 1998.

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 sub-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. Doses including external radiation in such areas were cautiously assessed for 1989 to be well within the dose limit of 1 mSv (Wilkins *et al.*, 1994). This would also have been the case in 1998 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 4.1.5.

Fishing gear

During immersion in sea water, 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 1998 are

presented in Table 4.7. Measured dose rates were generally less than those for 1997. 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 1998, including a component due to natural radiation, was 0.067 mSv, which is less than 1% of the appropriate dose limit. Handling of fishing gear therefore continues to be a minor radiation exposure pathway.

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 decreases in the overall discharges of alpha and beta activities from the site and larger 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 three potential issues of concern:

- enhanced releases of sulphur-35 from Calder Hall in January 1998
- contamination of feral pigeons and
- caesium-137 releases from the Magnox encapsulation plant in July 1998.

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 1998 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 caesium indicated a factor nearer 2. Some evidence for a site-related effect was also found by examination of the maximum concentrations at single farms. Concentrations in milk were generally similar to those in 1997 (MAFF and SEPA, 1998).

As part of the routine surveillance programme samples of apples and blackberries were analysed in 1998. Both fruits were good indicators of the local effects of disposals from Sellafield. 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. Concentrations of carbon-14 in fruit samples were also in excess of the concentrations assumed as representative of background values (Appendix 6). Concentrations of other radionuclides, for example tritium, sulphur-35, and strontium-90, also provided evidence of a local effect. Where it was possible to compare data for fruit in 1998 with those for 1997, similar concentrations of activity were found.

4. British Nuclear Fuels plc

Levels of activity in bovine and ovine meat and offal continued to be analysed in 1998. Concentrations of radionuclides were low, with limited evidence for the effects of Sellafield disposals in data for tritium, carbon-14, sulphur-35, strontium-90 and the plutonium isotopic ratio.

Barley was sampled as being representative of cereals in 1998. Sulphur-35 was detected, although at lower levels than those found in wheat in 1997. In common with meat and offal samples, limited evidence for the effects of Sellafield disposals was also found in data for the plutonium isotopic ratio. The vegetables sampled in 1998 were cabbage, carrots, cauliflower, lettuce, potatoes, runner beans, swede and turnips. Concentrations of transuranic radionuclides in vegetables were very low and did not provide as distinct a Sellafield signal in the plutonium isotopic ratio as some other food groups. Evidence of the effects of Sellafield was also weak for other radionuclides in vegetables. Data for game and honey also showed little indication of Sellafield discharges.

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 age groups (adults, 15y, 10y and 1y) and the doses received by the 1-year-old age group were found to be the highest, at 0.042 mSv (Adult: 0.026; 15y: 0.041: 10y: 0.031). The most significant contributions to this dose were from sulphur-35, cobalt-60, strontium-90 and ruthenium-106. The most important foodstuff was milk which accounted for 50% of the dose. The exposure is 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 1998 were similar to those in 1997, the highest dose being to an infant, 0.044 mSv. The dose received by a typical adult consumer obtaining food from the vicinity of Sellafield, 0.014 mSv, was much less than this.

A boiler tube leak in one of the Calder Hall Magnox reactors led to an enhanced discharge of sulphur-35 in January 1998. A number of controlled releases were required to remove moisture from inside the reactor. Increased levels of sulphur-35 were present in these discharges because moisture in the reactor draws sulphur-35 from the reactor surfaces. Over the week beginning the 3rd January 1998 discharges of about 30 GBq sulphur-35 were made; this is 75% of the weekly limit of 40 GBq and 14% of the annual limit of 210 GBq. A sampling programme over the likely affected area was immediately initiated to establish whether there had been a significant impact on the food chain. The results are available on the internet at www.gov.uk/food/incid_1/bnfl_s35.htm.

Samples of grass and winter barley (animal fodder) were taken from the area over which the activity was predicted to have travelled. The highest level of deposition found to be 87 Bq kg^{-1} in grass. For comparison purposes, this represents only a small fraction of the EU Food Intervention Level of 1250 Bq kg^{-1} . The assessed radiation dose to consumers was less than 0.005 mSv and confirmed that there was no significant risk to consumers of locally grown foodstuffs.

On 6th February 1998 MAFF was informed of contaminated feral pigeons in Seascale village, situated near the Sellafield site. The birds were part of a group of 700 that had been fed by a pigeon sanctuary in Seascale. 150 birds were culled humanely by the RSPCA in order to reduce numbers and a few were taken to the Sellafield site for monitoring, as it was thought the birds might roost on site. Surface dose rates of 1.4 mSv h^{-1} were found.

MAFF obtained random samples of the 150 culled pigeons and carried out provisional analysis which showed there to be significant internal contamination of up to 0.11 MBq kg^{-1}, which is far in excess of the EU Food Intervention Levels. The study continued using the birds from the initial cull, along with a further group of pigeon samples taken from the sanctuary. The main contaminant was found to be caesium-137; levels in the breast meat of pigeons varied considerably but the highest level found was 40 times the EU Intervention

Level for foodstuffs containing caesium-137. Consuming the breast meat from 20 such contaminated birds would result in a dose of 1 mSv, the annual dose limit for members of the public. Other radioactive contaminants were found in the pigeon meat including plutonium-238, plutonium-239/240, americium-241 and strontium-90. However, they were at levels which would only contribute a few percent to the overall dose as compared with caesium-137.

MAFF issued precautionary advice on 14th February 1998, advising people not to handle, slaughter, or consume pigeons within a 10 mile radius of the Sellafield site.
No evidence could be found for people eating feral pigeons in the Sellafield. Details were provided on the internet (www.maff.gov.uk/food/incid_1/bnfp23.htm).

The company subsequently implemented remediation and dose reduction procedures. Approximately 1500 pigeons were culled from the sanctuary and the Sellafield area. Other measures taken at the bird sanctuary included replacing the top soil, the lawn, roof slates, garden ornaments and gutters, and resurfacing the drive. Possible routes of access of wild life to buildings on the Sellafield site were reviewed and measures were taken to reduce the presence of wildlife on site. In addition possible contamination of other wildlife in the area is currently being investigated.

This incident and the serious issues raised have been considered in detail by MAFF along with other Government departments and agencies and Copeland Borough Council. A combined report was published in June 1999 (CBC *et al.*, 1999). A joint statement was also issued by the Committee on Medical Aspects of Radiation in the Environment (COMARE) and the Radioactive Waste Management Advisory Committee (RWMAC) (COMARE and RWMAC, 1999).

In Scotland SEPA initiated studies to determine whether a comparable pathway for contamination to leave a site could exist at nuclear licensed sites in Scotland. Operators were required to take analyses of wildlife that could provide a similar pathway. These studies did not produce any evidence to support the existence at these sites of a pathway for contamination to leave the site comparable to the feral pigeons at Sellafield.

On the 16 July 1998 an abnormal release of caesium-137 was recorded from the Magnox encapsulation plant. Reassurance monitoring was carried out by MAFF; the highest measurement in grass was 2.1 Bq kg^{-1}. This is comparable to the routine measurements in the RIFE programme.

4.1.3 Drigg

No gaseous disposals are authorised from Drigg. The monitoring programme is therefore primarily directed at the potential migration of radionuclides from the waste burial site via ground water.

Results for 1998 are given in Table 4.10. Low concentrations of tritium which may have leached from the site were found in sheep and blackberries; 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 duck and 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 0.017 mSv or 2% of the dose limit of 1 mSv (Table 4.9).

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 1998 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. The results of the measurements made using portable beta dosimeters 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 0.30 mSv in 1998 which is less than 1% of the appropriate dose limit. The contribution this source of exposure makes to effective dose is included in the assessment in sub-section 4.1.1.

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 1998 are presented in Table 4.12. In general, the data are similar to those for 1997 (MAFF and SEPA, 1998) and show lower concentrations than are found in the Sellafield vicinity. Evidence for sea-to-land transfer is limited. Technetium-99 concentrations in all materials were very low. A small amount of promethium-147 (0.8 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, though the resulting 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 would have been due to gaseous disposals from the site.

The exposure due to consumption of terrestrial foods from Ravenglass in 1998 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 0.028 mSv or 3% of the dose limit of 1 mSv. 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 1998 on marine plants from shorelines of the Irish Sea 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. These clearly showed the effects of increases in disposals of technetium-99 from Sellafield in recent years, though at a reduced level compared with 1997. Such seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 1998. The results are shown in Table 4.14.

The study comprised a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and an assessment of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added. The survey established that seaweed harvesting in the Sellafield area was not widespread. However, three plots of land fertilised by

seaweed were identified which were investigated further (Camplin et al, in press). Samples of soil from them 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 were obtained which had been grown in the soils from these plots. The technetium-99 concentrations in vegetables ranged from about 2 to 220 Bq kg^{-1} in the edible parts. The higher concentrations were found in beetroot. 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 0.030 mSv, most of which was due to the technetium-99 content of the vegetable component of their diet. The mean dose was 0.017 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 1999.

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. 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 1998; 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 UK shorelines of the Irish Sea. Results of analyses for 1998 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 1998 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 1998 (150 TBq) to 1997 (142 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 1997.

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. The most exposed group consists of people who live on a houseboat moored in a muddy creek of the Ribble estuary. Other activities which have been found to have significant occupancies are wildfowling, farming and bird conservation which take place in intertidal areas and marshes bordering the estuary, and angling which is popular in the Preston area. Surveys have also identified consumers of seafood, particularly fish and shrimps, and they are considered as a potential critical group in this report. Gamma and beta dose

rates are regularly monitored in relevant areas including muddy creeks where houseboats are moored, and some of these measurements are supported by analyses of sediments. Locally obtained fish, shellfish, wildfowl and samphire continued to be sampled. A study (Rollo *et al.,* 1994) has shown that exposures due to airborne radionuclides which may have come from disposals to the estuary and are subsequently remobilised are negligible. The MAFF programme of dose rate and sediment monitoring reduced in 1998. Some was undertaken by the Environment Agency. Foodstuff monitoring has been maintained at pre-existing levels.

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 1998 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.

Gamma dose rates over intertidal areas in 1998 were similar to those in 1997. The results of beta dose rate measurements are highly variable but overall the results for 1998 were also unchanged. In 1998, our assessment of the dose to the most exposed group of houseboat dwellers including the Sellafield component was 0.15 mSv, similar to the value for 1997 (0.13 mSv). Most of this exposure was due to the radioactivity already in the environment as a result of past disposals from Sellafield. The whole-body doses of farmers and wildfowlers were assessed as being 0.019 and 0.039 mSv respectively in 1998. A significant proportion of the dose is due to Sellafield disposals. Consumption of wildfowl makes a very small contribution to the dose received by wildfowlers because of the very low concentrations of radionuclides in ducks and geese. Further details of external exposure pathways will be made available in the Environment Agency report for 1998.

Skin irradiation of fishermen handling nets and wildfowlers including a component due to natural radiation was 0.19 and 1.2 mSv in 1998. This is less than 3% of the relevant dose limit for members of the public.

Seafood consumption was found to be 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 0.036 mSv in 1998. Most of this was due to Sellafield disposals with only a small percentage attributable to Springfields.

The most exposed group of terrestrial food consumers were adults consuming vegetables at high rates. Their dose in 1998, including a contribution due to weapon test and Chernobyl fallout and natural sources, was less than 0.005 mSv, a significant part of which was due to thorium radionuclides.

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 1998 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 which 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 1998 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 1997. There was a decrease in the tritium concentration in water from the Brook but this observation is based on very few measurements. 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 1998. The concentrations of artificial radioactivity in marine samples are consistent with values expected at this distance from Sellafield. The dose to the most exposed group of terrestrial food consumers was also low, at less than 0.005 mSv in 1998.

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. Disposals in 1998 were similar to those in 1997. 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 monitoring in 1998 are presented in Tables 4.17(a) and (b). 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 in 1998 were generally similar to, or less than, those in 1997. Concentrations of technetium-99 due to Sellafield reduced as a consequence of a reduction in discharges. The whole-body dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.027 mSv in 1998 which is less than 3% of the dose limit of 1 mSv for members of the public. Measurements of the contact beta dose-rate received whilst handling nets, were below the limit of detection. Wildfowlers received a dose of 0.018 mSv. The magnitude of the Chapelcross disposals indicates that the local contribution to dose was a tiny fraction of these exposures, most of the dose being due to Sellafield 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 the incidence of these particles. However, at the end of 1997 this trend appeared to change and the incidence of detection of these particles during monitoring increased. One of the particles found was more active than normal and analysis indicated that it was likely to have come from degraded fuel, probably discharged in the late 1970s. Analysis of the more active particle indicated that the total activity was less than 10 000 Bq. Assessments carried out estimated that a potential dose of 3 mSv could arise from ingestion of such a particle, although the likelihood of encountering one is considered to be extremely low as the location is not frequented by the public. Following the discovery of this particle, increased monitoring did not reveal further particles of this type. SEPA has requested the operator to consider further improvements to the effluent management system to prevent further release of such particles. During 1998 improvements were made to the operation of the effluent management system and plans prepared to improve discharge equipment No unusual levels of contamination were found in other intertidal areas near the site.

Concentrations of radionuclides in milk and grass were generally similar to those in 1997. 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 0.022 mSv or less than 3% of the dose limit 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, 1998

Location[a]	Material	No. of sampling observations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{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	8		<0.50		<0.42	<0.46		<1.4	<0.17	12	<0.85	170
Sellafield coastal area	Plaice	4		<0.45		<0.42	<0.44		<1.4	<0.17	9.0	<0.78	170
Sellafield coastal area	Grey mullet	1		0.39		<0.48	<0.58		<1.6	<0.17	9.0	<0.67	
Sellafield coastal area	Bass	1		<0.15		<0.47	<0.60		<1.3	<0.14	24	<0.57	
Sellafield offshore area	Cod	2	84	<0.22	0.094	<0.29	<0.24	2.5	<1.2	<0.13	8.6	<0.65	
Sellafield offshore area	Plaice[c]	2	140	<0.21	0.16	<0.11	<0.10	14	<0.41	<0.04	6.6	<0.19	
Sellafield offshore area	Dab	2		<0.28		<0.27	<0.24		<1.2	<0.15	9.1	<0.66	
Sellafield offshore area	Whiting	2		<0.12		<0.23	<0.19		<1.0	<0.11	14	<0.64	
Sellafield offshore area	Haddock	1		<0.12		<0.23	<0.20		<0.93	<0.11	2.7	<0.46	
Ravenglass	Cod	5		<0.43		<0.31	<0.33		<1.0	<0.13	12	<0.51	
Ravenglass	Plaice	4		<0.46		<0.40	<0.41		<1.3	<0.14	10	<0.71	
Ravenglass	Salmon	1		<0.24		<0.71	<0.68		<2.6	<0.26	<0.24	<0.93	
Whitehaven	Cod	4	67	<0.27	0.058	<0.30	<0.34		<0.97	<0.13	7.8	<0.61	
Whitehaven	Plaice	4		<0.13	<0.031	<0.35	<0.43		<1.0	<0.12	5.3	<0.68	
Whitehaven	Ray	4		<0.13		<0.32	<0.30		<1.2	<0.13	9.5	<0.62	
Parton	Cod	4		<0.13		<0.26	<0.24		<1.0	<0.11	11	<0.50	
Morecambe Bay (Flookburgh)	Flounder	4	98	<0.15		<0.56	<0.79		<1.6	<0.15	17	<0.88	
Morecambe Bay (Morecambe)	Plaice	4		<0.11	0.039	<0.29	<0.31	1.6	<0.98	<0.10	6.6	<0.48	
Morecambe Bay (Morecambe)	Bass	2		<0.15		<0.83	<1.6		<1.5	<0.16	18	<0.74	
Morecambe Bay (Sunderland Point)	Whitebait	1		<0.08	0.20	<0.21	<0.22		<0.67	<0.08	5.8	<0.43	
Calder Farm	Rainbow trout	2		1.1		<0.95	<1.6		<3.3	<0.25	180	<1.4	
River Duddon	Sea trout	1		<0.07		<0.30	<0.38		<0.75	<0.08	7.4	<0.51	
River Kent	Sea trout	1		<0.09		<0.32	<0.44		<0.90	<0.09	9.6	<0.56	
River Derwent	Sea trout	1		<0.15		<0.80	<1.3		<1.5	<0.16	6.0	<0.73	
Fleetwood	Cod	4	77	<0.08	0.068	<0.19	<0.18	1.8	<0.68	<0.07	6.5	<0.40	
Fleetwood	Plaice	4		<0.10		<0.21	<0.20		<0.80	<0.09	6.2	<0.38	
Isle of Man	Cod	4		<0.06		<0.17	<0.19		<0.53	<0.06	2.6	<0.28	
Isle of Man	Herring	3		<0.08		<0.31	<0.45		<0.75	<0.08	2.3	<0.41	
Inner Solway	Flounder[e]	1	64	<0.10	0.10	<0.50	<0.10	3.2	<1.0	<0.10	1.1	<0.50	
Inner Solway	Sea trout	1		<0.10	<0.10	<0.50	<0.10		<1.0	<0.10	7.1	<0.50	
Inner Solway	Salmon	1		<0.10	<0.10	<0.50	<0.10		<1.0	<0.10	0.31	<0.50	
Kirkcudbright	Plaice	4		<0.11		<0.48	<0.19		<1.1	<0.11	2.2	<0.56	
Garlieston	Cod	1	54	<0.07	<0.046	<0.19	<0.18	0.32	<0.65	<0.07	3.2	<0.39	
Garlieston	Plaice	1		<0.11		<0.32	<0.34		<0.92	<0.10	5.6	<0.54	
North Anglesey	Ray	4		<0.12		<0.40	<0.58		<1.2	<0.12	3.0	<0.55	
North Anglesey	Plaice	2	52	<0.14		<0.46	<0.77		<1.3	<0.14	1.3	<0.63	
Ribble Estuary	Flounder	1		<0.09		<0.33	<0.48		<0.83	<0.09	9.2	<0.49	
Ribble Estuary	Salmon	1		<0.09		<0.26	<0.25		<0.91	<0.10	0.43	<0.56	
Ribble Estuary	Grey mullet	1		<0.19		<1.4	<3.1		<1.8	<0.21	4.7	<1.3	
Ribble Estuary	Sea trout	1		<0.11		<0.81	<1.7		<1.2	<0.13	6.0	<0.57	
Northern Ireland	Cod	7	36	<0.06		<0.26	<0.39		<0.61	<0.07	2.6	<0.37	
Northern Ireland	Whiting	7		<0.08		<0.26	<0.36		<0.72	<0.08	3.6	<0.41	
Northern Ireland	Herring	1		<0.12		<0.59	<1.1		<1.1	<0.12	2.1	<0.53	
Northern Ireland	Spurdog	8		<0.10		<0.37	<0.53		<0.97	<0.10	3.4	<0.56	
Sound of Mull	Salmon	1		<0.10		<0.43	<0.66		<0.94	<0.10	0.27	<0.63	

Table 4.1. continued

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	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Minch	Cod	4		<0.05		<0.14	<0.17	<0.44	<0.05	0.60	<0.27
Minch	Plaice	4		<0.06		<0.29	<0.52	<0.58	<0.06	0.62	<0.31
Minch	Mackerel	2	69	<0.09	<0.025	<0.64	<1.6	<0.95	<0.10	0.32	<0.52
Minch	Haddock	4		<0.06		<0.17	<0.20	<0.50	<0.06	0.36	<0.27
Minch	Herring	3		<0.07		<0.24	<0.36	<0.61	<0.06	0.49	<0.31
Shetland	Fish meal[d]	4	180	<0.24	<0.028	<0.46	<0.34	<2.0	<0.23	1.0	<1.1
Shetland	Fish oil[d]	4		<0.15		<1.7	<0.49	<2.1	<0.19	<0.16	<1.5
Northern North Sea	Cod	3		<0.06	<0.013	<0.16	<0.16	<0.53	<0.06	0.58	<0.26
Northern North Sea	Plaice	3		<0.06		<0.25	<0.36	<0.58	<0.06	0.32	<0.31
Northern North Sea	Herring	3		<0.17		<0.47	<0.50	<1.6	<0.16	0.41	<0.58
Northern North Sea	Haddock	3	39	<0.05		<0.15	<0.16	<0.49	<0.05	0.51	<0.31
Mid-North Sea	Cod	4	32	<0.06	<0.014	<0.15	<0.14	<0.51	<0.06	0.63	<0.27
Mid-North Sea	Plaice	3	34	<0.05	<0.014	<0.12	<0.12	<0.43	<0.05	0.39	<0.24
Mid-North Sea	Herring	2		<0.09		<0.37	<0.58	<0.84	<0.09	0.61	<0.42
Southern North Sea	Cod	2		<0.05	<0.061	<0.09	<0.07	<0.41	<0.05	0.58	<0.21
Southern North Sea	Plaice	2		<0.04	<0.063	<0.08	<0.05	<0.37	<0.04	0.44	<0.24
Southern North Sea	Herring	2		<0.06		<0.21	<0.24	<0.62	<0.06	0.45	<0.33
English Channel - East	Cod	4		<0.06	0.016	<0.14	<0.15	<0.50	<0.06	0.27	<0.25
English Channel - East	Plaice	4		<0.05	<0.015	<0.12	<0.13	<0.41	<0.05	0.14	<0.20
English Channel - West	Mackerel	2		<0.10		<0.34	<0.38	<1.1	<0.11	0.33	<0.54
English Channel - West	Plaice	2	53	<0.05	<0.061	<0.12	<0.09	<0.51	<0.06	0.50	<0.32
English Channel - West	Whiting	2		<0.06	<0.062	<0.13	<0.11	<0.55	<0.06	0.42	<0.28
Gt Yarmouth (retail shop)	Cod	4		<0.05		<0.15	<0.19	<0.45	<0.05	0.34	<0.23
Gt Yarmouth (retail shop)	Plaice	4		<0.05		<0.20	<0.34	<0.50	<0.05	0.24	<0.30
Skagerrak	Cod	3		<0.05		<0.26	<0.43	<0.51	<0.06	0.44	<0.27
Skagerrak	Herring	3		<0.07		<0.29	<0.45	<0.68	<0.07	0.55	<0.38
Norwegian Sea	Cod	1		<0.04		<0.07	<0.05	<0.31	<0.03	0.26	<0.15
Norwegian Sea	Saithe	1		<0.06		<0.11	<0.08	<0.46	<0.05	0.30	<0.20
Iceland area	Cod	2		<0.04		<0.10	<0.09	<0.36	<0.04	0.17	<0.20
Icelandic processed	Cod	2	27	<0.04		<0.08	<0.06	<0.36	<0.04	0.30	<0.19
Barents Sea	Cod	3		<0.05		<0.30	<0.20	<0.48	<0.05	0.31	<0.28
Baltic Sea	Cod	3		<0.09		<0.28	<0.32	<0.89	<0.13	8.6	<0.47
Baltic Sea	Herring	3		<0.07		<0.31	<0.49	<0.73	<0.11	5.8	<0.34
Celtic Sea	Cod	2	46	<0.08	<0.068	<0.18	<0.17	<0.70	<0.08	0.59	<0.34
Celtic Sea	Pollack	1		<0.04		<0.06	<0.04	<0.31	<0.04	0.51	<0.15
Celtic Sea	Whiting	1		<0.05		<0.14	<0.17	<0.42	<0.05	0.48	<0.19

* *not detected by method used*
[a] *Sampling area or landing point*
[b] *See section 3 for definition*
[c] *The concentration of ^{147}Pm was <0.0089 Bq kg^{-1}*
[d] *Concentrations refer to weight of sample as supplied*
[e] *The concentration of ^{58}Co was 0.10 Bq kg^{-1}*

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 1998

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Sellafield coastal area	Crabs[c]	8	160	3.7	<0.20	1.8	<0.22	<0.29	51	<0.19	<2.7
Sellafield coastal area	Lobsters	8	240	3.1	<0.41	0.42	<0.45	<0.63	7700	<0.40	<2.4
Sellafield coastal area	Winkles[d]	4	150	14	<0.52	5.2	<1.1	<0.95	800	<0.60	59
Sellafield coastal area	Mussels[d]	4		7.8	<0.43	1.5	<1.1	<1.8		<0.88	31
Sellafield coastal area	Limpets[d]	4	88	8.6	<0.31	9.4	<0.37	<0.50	1300	<0.33	45
Sellafield coastal area	Whelks	1	190	5.9	<0.36	<0.090	<0.42	<0.76	130	<0.41	15
Sellafield offshore area	Whelks	2		2.8	<0.37		<0.36	<0.43		<0.29	4.4
Sellafield offshore area	Sea mouse[e]	1		79	<0.43		<0.33	<0.22		<0.16	31
St Bees	Winkles[f]	4	130	17	<0.20	8.4	<0.81	<1.1	350	<0.18	67
St Bees	Mussels	4		11	<0.26		<0.45	<0.73		<0.18	52
St Bees	Limpets	4		5.5	<0.33		<0.35	<0.42		<0.29	36
Nethertown	Winkles[g]	12	130	21	<0.43	7.3	<0.64	<0.86	490	<0.35	69
Nethertown	Mussels	4	180	15	<0.28		<0.74	<1.5	880	<0.17	70
Whitriggs	Shrimps	1		1.7	<0.51		<0.62	<0.56		<0.49	<2.3
Drigg	Winkles	4	160	32	<0.47		<0.46	<0.51	2100	<0.32	96
Ravenglass	Crabs	4		1.4	<0.27	0.96	<0.35	<0.47	28	<0.34	<1.5
Ravenglass	Lobsters	4		2.0	<0.27	0.25	<0.32	<0.42	3600	<0.30	<1.6
Ravenglass	Winkles	2		7.6	<0.23		<0.25	<0.31		<0.21	48
Ravenglass	Cockles	4	180	33	<0.43	2.3	<0.50	<0.75	68	<0.35	28
Ravenglass	Mussels	4		12	<0.32		<0.39	<0.52	990	<0.23	37
Tarn Bay	Winkles	2		9.5	<0.37		<0.53	<0.95		<0.57	47
Saltom Bay	Winkles	4		4.8	<0.31		<0.29	<0.30		<0.22	19
Whitehaven	Whelks	3	79	0.62	<0.26	<0.070	<0.28	<0.31		<0.24	<1.8
Whitehaven	*Nephrops*	3	65	<0.11	<0.17	<0.15	<0.16	<0.14	590	<0.12	<0.64
Silloth	Mussels	4		0.63	<0.20		<0.24	<0.27		<0.23	5.1
Parton	Crabs	4		1.4	<0.23		<0.25	<0.29		<0.22	<1.5
Parton	Lobsters	4		0.42	<0.40		<0.44	<0.45		<0.37	<1.8
Parton	Winkles	4		6.4	<0.34		<0.33	<0.33		<0.25	30
Haverigg	Cockles	2		8.9	<0.22		<0.22	<0.20		<0.17	6.8
Millom	Mussels	2		1.7	<0.24		<0.29	<0.49		<0.26	8.0
Roosebeck	Pacific oysters	2		0.42	<0.16		<0.13	<0.14		<0.11	<2.5
Morecambe Bay (Flookburgh)	Shrimps	4	77	<0.09	<0.22		<0.26	<0.29	11	<0.25	<0.83
Morecambe Bay (Morecambe)	Mussels	4	87	0.66	<0.13		<0.16	<0.18	250	<0.16	1.6

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Sellafield coastal area	Crabs[c]	8	4.0	<0.23	<0.09	2.8	<0.37	0.41	<0.22	<0.14	160
Sellafield coastal area	Lobsters	8	8.1	<0.39	<0.17	4.5	<0.66	0.73	<0.45	<0.30	4700
Sellafield coastal area	Winkles[d]	4	12	<1.2	<0.22	10	<2.0	2.2	<0.63	<0.44	
Sellafield coastal area	Mussels[d]	4	<0.44	<0.57	<0.17	3.2	<1.1		<0.49	<0.34	
Sellafield coastal area	Limpets[d]	4	6.6	2.1	<0.14	14	<0.80		<0.44	<0.29	
Sellafield coastal area	Whelks	1	13	<0.37	<0.14	1.7	<0.59		<0.38	<0.24	
Sellafield offshore area	Whelks	2	3.3	<0.34	<0.15	1.7	<0.57		<0.41	<0.26	
Sellafield offshore area	Sea mouse[e]	1	0.99	11	<0.21	18	3.8		1.4	1.6	730
St Bees	Winkles[f]	4	11	1.3	<0.09	18	<2.2	3.6	<0.49	<0.26	
St Bees	Mussels	4	0.68	1.1	<0.11	5.8	<1.4		<0.35	<0.23	
St Bees	Limpets	4	6.6	2.0	<0.14	12	<1.0		<0.42	<0.35	
Nethertown	Winkles[g]	12	15	<1.3	<0.19	15	<2.1	3.1	<0.57	<0.48	620
Nethertown	Mussels	4	<0.53	<1.0	<0.13	5.1	<2.0		<0.38	<0.31	740
Whitriggs	Shrimps	1	1.8	<0.58	<0.23	2.0	<1.2		<0.59	<0.55	
Drigg	Winkles	4	22	<1.3	<0.22	12	<2.0	3.2	<0.49	<0.54	1700
Ravenglass	Crabs	4	2.3	<0.35	<0.11	2.3	<0.58		<0.31	<0.27	120
Ravenglass	Lobsters	4	5.0	<0.26	<0.10	3.7	<0.48		<0.30	<0.22	2500
Ravenglass	Winkles	2	10	0.78	<0.10	13	<1.4		<0.36	<0.32	
Ravenglass	Cockles	4	0.90	<0.49	<0.19	6.9	<1.3		<0.51	<0.40	220
Ravenglass	Mussels	4	<0.36	<0.73	<0.13	3.0	<1.0		<0.39	<0.29	
Tarn Bay	Winkles	2	9.3	<0.93	<0.15	12	<1.2		<0.41	<0.39	
Saltom Bay	Winkles	4	5.7	1.3	<0.14	10	<0.74		<0.39	<0.31	
Whitehaven	Whelks	3	1.4	<0.26	<0.10	1.8	<0.57		<0.30	<0.28	140
Whitehaven	*Nephrops*	3	<0.14	<0.17	<0.07	5.3	<0.35		<0.22	<0.17	470
Silloth	Mussels	4	<0.16	<0.25	<0.09	6.3	<0.48		<0.25	<0.21	
Parton	Crabs	4	2.3	<0.25	<0.10	2.7	<0.50		<0.28	<0.24	
Parton	Lobsters	4	<0.85	<0.40	<0.17	4.0	<0.71		<0.48	<0.30	
Parton	Winkles	4	3.4	<0.95	<0.16	17	<0.76		<0.44	<0.38	
Haverigg	Cockles	2	<0.18	<0.24	<0.10	7.8	<0.61		<0.33	<0.19	
Millom	Mussels	2	<0.20	<0.25	<0.10	3.1	<0.43		<0.29	<0.19	
Roosebeck	Pacific oysters	2	1.9	<0.12	<0.05	1.9	<0.22		<0.16	<0.10	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.16	<0.22	<0.09	6.8	<0.40		<0.24	<0.18	
Morecambe Bay (Morecambe)	Mussels	4	<0.10	<0.16	<0.06	3.3	<0.33		<0.14	<0.15	

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg[-1]								
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Morecambe Bay (Flookburgh)	Cockles	4	84	1.4	<0.14	0.44	<0.18	<0.23	25	<0.19	<1.5
Morecambe Bay (Middleton Sands)	Cockles	2		1.7	<0.17		<0.21	<0.29		<0.22	1.2
Fleetwood	Lobsters	2		0.27	<0.22		<0.27	<0.34	2500	<0.25	<0.82
Fleetwood	Squid	1		<0.07	<0.16		<0.12	<0.10		<0.08	<0.53
Fleetwood	Whelks	4	100	0.40	<0.19	0.036	<0.24	<0.31	64	<0.24	<0.87
Isle of Man	Lobsters	4		<0.16	<0.35		<0.42	<0.50	220	<0.40	<1.5
Isle of Man	Scallops	4		<0.08	<0.21		<0.23	<0.29		<0.23	<0.71
Inner Solway	Shrimps	4		<0.11	<0.20	<0.10	<0.41	<0.10	5.0	<0.50	<0.87
Southerness	Winkles	4		0.83	<0.20	1.6	<0.40	<0.10	440	<0.50	3.4
Kirkcudbright	Scallops	7		<0.07	<0.08		<0.26	<0.09		<0.05	<0.59
Kirkcudbright	Queens	8		<0.23	<0.16		<0.31	<0.21		<0.22	<0.75
North Solway coast	Crabs	7	85	0.57	<0.24	0.35	<0.37	<0.39	36	<0.43	<0.90
North Solway coast	Lobsters	8	76	<0.23	<0.46	0.13	<0.55	<0.54	1400	<0.69	<1.4
North Solway coast	Winkles	8		1.7	<0.21		<0.33	<0.21		<0.22	6.6
North Solway coast	Cockles	8	50	1.6	<0.12	0.74	<0.28	<0.14	31	<0.14	<2.4
North Solway coast	Mussels	8	64	0.79	<0.12	0.64	<0.28	<0.14	280	<0.14	<3.3
Garlieston	*Nephrops*	1	61	<0.23	<0.83		<4.7	*	660	*	<2.9
Wirral	Shrimps	2		<0.06	<0.16		<0.17	<0.18	1.0	<0.16	<0.57
Wirral	Cockles	4		0.17	<0.12		<0.16	<0.18	36	<0.14	<0.54
Knott End	Cockles	1		1.5	<0.18		<0.19	<0.14		<0.14	<0.97
Conwy	Mussels	2		<0.05	<0.11		<0.10	<0.07		<0.07	<0.48
Northern Ireland	*Nephrops*	7		<0.08	<0.21		<0.33	<0.58	79	<0.43	<0.77
Northern Ireland	Lobsters	6		<0.19	<0.49		<0.99	<1.9	190	<1.3	<2.0
Northern Ireland	Winkles	3		<0.07	<0.17		<0.33	<0.63		<0.46	<0.71
Northern Ireland	Mussels	1		<0.22	<0.61		<1.3	<2.6	61	<1.8	<2.5
Minch	*Nephrops*	3		<0.16	<0.42		<0.68	<1.2	95	<0.80	<1.5
Northern North Sea	*Nephrops*	4		<0.05	<0.13		<0.19	<0.32	16	<0.26	<0.45
Mid North Sea	Mussels[h]	2		<0.05	<0.11		<0.12	<0.12		<0.10	<0.46
Southern North Sea	Cockles	2		0.55	<0.12		<0.15	<0.17		<0.14	<0.46
Southern North Sea	Cockles[i]	2		0.18	<0.09		<0.12	<0.14	0.090	<0.12	<0.38
Southern North Sea	Mussels	4		<0.14	<0.37		<0.67	<1.2	3.5	<0.93	<1.5
English Channel East	Scallops	3	37	<0.13	<0.13		<0.12	<0.12		<0.10	<0.46
English Channel West	Crabs	2	67	<0.08	<0.17		<0.16	<0.13		<0.12	<0.68
English Channel West	Lobsters	1		<0.20	<0.46		<0.41	<0.34	0.14	<0.28	<2.0
English Channel West	Scallops	2	28	<0.08	<0.22		<0.22	<0.24		<0.18	<0.74

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Morecambe Bay (Flookburgh)	Cockles	4	<0.11	<0.16	<0.06	5.7	<0.25	<0.16	<0.11	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.13	<0.17	<0.07	4.0	<0.29	<0.19	<0.13	
Fleetwood	Lobsters	2	0.85	<0.19	<0.09	2.8	<0.34	<0.25	<0.16	1400
Fleetwood	Squid	1	<0.11	<0.14	<0.06	1.4	<0.28	<0.21	<0.15	
Fleetwood	Whelks	4	<0.27	<0.17	<0.07	1.4	<0.35	<0.22	<0.16	
Isle of Man	Lobsters	4	<0.25	<0.33	<0.14	0.51	<0.60	<0.43	<0.26	210
Isle of Man	Scallops	4	<0.14	<0.16	<0.08	0.47	<0.30	<0.24	<0.12	
Inner Solway	Shrimps	4	<0.10	<0.41	<0.10	8.8	<0.44	<0.40	<0.41	
Southerness	Winkles	4	<0.48	<0.35	<0.10	3.2	<0.43	<0.40	<0.40	
Kirkcudbright	Scallops	7	<0.08	<0.26	<0.07	<0.20	<0.30	<0.27	<0.26	
Kirkcudbright	Queens	8	<0.14	<0.27	<0.08	0.52	<0.36	<0.29	<0.26	
North Solway coast	Crabs	7	0.66	<0.29	<0.09	1.9	<0.44	<0.30	<0.27	
North Solway coast	Lobsters	8	<0.50	<0.41	<0.14	2.8	<0.61	<0.46	<0.38	
North Solway coast	Winkles	8	1.1	<0.34	<0.09	3.4	<0.48	<0.33	<0.32	
North Solway coast	Cockles	8	<0.10	<0.27	<0.08	5.0	<0.35	<0.25	<0.22	
North Solway coast	Mussels	8	<0.20	<0.25	<0.08	3.5	<0.34	<0.28	<0.26	
Garlieston	*Nephrops*	1	<0.57	<0.51	<0.23	5.3	<1.2	<0.58	<0.31	
Wirral	Shrimps	2	<0.11	<0.15	<0.06	3.3	<0.26	<0.18	<0.11	
Wirral	Cockles	4	<0.10	<0.13	<0.06	1.1	<0.25	<0.15	<0.12	
Knott End	Cockles	1	<0.17	<0.26	<0.09	3.7	<0.56	<0.25	<0.32	
Conwy	Mussels	2	<0.09	<0.13	<0.05	0.24	<0.26	<0.15	<0.13	
Northern Ireland	*Nephrops*	7	<0.15	<0.19	<0.08	1.2	<0.41	<0.24	<0.18	
Northern Ireland	Lobsters	6	<0.36	<0.43	<0.19	<0.39	<0.94	<0.51	<0.39	
Northern Ireland	Winkles	3	<0.15	<0.18	<0.07	0.37	<0.47	<0.18	<0.21	
Northern Ireland	Mussels	1	<0.44	<0.53	<0.23	1.5	<1.1	<0.65	<0.44	
Minch	*Nephrops*	3	<0.29	<0.32	<0.16	1.0	<0.58	<0.46	<0.24	
Northern North Sea	*Nephrops*	4	<0.09	<0.12	<0.05	0.25	<0.29	<0.14	<0.13	
Mid North Sea	Mussels[h]	2	<0.08	<0.12	<0.05	<0.10	<0.27	<0.13	<0.13	27
Southern North Sea	Cockles	2	<0.09	<0.12	<0.05	0.15	<0.28	<0.14	<0.13	
Southern North Sea	Cockles[i]	2	<0.07	<0.10	<0.04	0.11	<0.24	<0.10	<0.11	
Southern North Sea	Mussels	4	<0.26	<0.32	<0.14	<0.16	<0.64	<0.36	<0.24	
English Channel East	Scallops	3	<0.09	<0.11	<0.05	<0.05	<0.25	<0.16	<0.12	
English Channel West	Crabs	2	<0.13	<0.19	<0.07	0.09	<0.46	<0.20	<0.21	
English Channel West	Lobsters	1	<0.32	<0.47	<0.20	<0.19	<0.96	<0.58	<0.52	
English Channel West	Scallops	2	<0.14	<0.18	<0.08	<0.11	<0.38	<0.26	<0.19	

* *not detected by the method used*
[a] *Sampling area or landing point*
[b] *See section 3 for definition*
[c] *The concentration of ^{129}I was <0.39 Bq kg^{-1}*
[d] *Samples collected by Consumer 116*
[e] *Aphrodite aculeata, an annelid worm. The concentration of ^{54}Mn was 0.29 Bq kg^{-1}*
[f] *The concentration of ^{129}I was <0.70 Bq kg^{-1}*
[g] *The concentration of ^{3}H was <140 Bq kg^{-1}*
[h] *Landed in Denmark*
[i] *Landed in Holland*

Table 4.3. Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 1998

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		0.0028	0.013		0.035	*	0.000064
Sellafield coastal area	Plaice	1		0.0015	0.0067		0.015	*	0.000028
Sellafield coastal area	Grey mullet	1					<0.31		
Sellafield coastal area	Bass	1					<0.14		
Sellafield coastal area	Crabs	2	0.0062	0.071	0.34	4.5	1.5	*	0.0027
Sellafield coastal area	Lobsters	2	0.027	0.067	0.30	3.3	4.2	*	0.0095
Sellafield coastal area	Winkles[c]	1	0.032	2.3	11	130	20	0.039	0.040
Sellafield coastal area	Mussels[c]	1		1.4	6.7	85	16	*	0.025
Sellafield coastal area	Limpets[c]	1		3.2	16	190	28	0.053	0.041
Sellafield coastal area	Whelks	1		0.25	1.1	15	2.3	*	0.0056
Sellafield offshore area	Cod	1		0.0016	0.0081		0.013	*	*
Sellafield offshore area	Plaice	1	0.00029	0.0035	0.017		0.029	0.00013	0.0056
Sellafield offshore area	Dab	1					<0.51		
Sellafield offshore area	Whiting	2					<0.47		
Sellafield offshore area	Haddock	1					<0.35		
Sellafield offshore area	Whelks	1		0.42	2.1	25	5.5	*	0.0077
Sellafield offshore area	Sea mouse[d]	1		7.6	37		110	*	0.38
St Bees	Winkles	1	0.053	3.9	19	230	34	*	0.063
St Bees	Mussels	2		2.8	13	170	23	0.036	0.039
St Bees	Limpets	1		2.6	12		21	0.059	0.043
Nethertown	Winkles	4	0.048	3.4	17	200	31	<0.030	0.054
Nethertown	Mussels	4		2.1	10		18	<0.018	0.053
Whitriggs	Shrimps	1					<0.50		
Drigg	Winkles	4	0.054	3.8	18	210	32	<0.049	0.072
Ravenglass	Cod	1		0.0011	0.0052		0.0068	0.000029	0.000021
Ravenglass	Plaice	1		0.0010	0.0045		0.012	*	0.000034
Ravenglass	Salmon	1					<0.18		
Ravenglass	Crabs	1		0.046	0.23	2.8	1.0	*	0.0026
Ravenglass	Lobsters	1		0.059	0.29	3.5	5.0	*	0.013
Ravenglass	Winkles	2					21		
Ravenglass	Mussels	1		1.5	7.3	89	15	0.025	0.029
Ravenglass	Cockles	1		2.1	10	130	29	*	0.083
Tarn Bay	Winkles	1		2.7	13	150	24	0.030	0.060
Saltom Bay	Winkles	4					14		
Whitehaven	Cod	1		0.00045	0.0024		0.0049	*	0.000018
Whitehaven	Plaice	1		0.0011	0.0051		0.0096	*	0.00013
Whitehaven	Ray	1		0.00075	0.0040		0.0070	*	0.000017
Whitehaven	*Nephrops*	1		0.023	0.12		0.41	*	0.00078
Whitehaven	Whelks	1		0.17	0.89	10	1.3	*	0.0029
Silloth	Mussels	1		0.69	3.7		6.4	*	0.0066
Parton	Cod	4					<0.21		
Parton	Crabs	4					1.0		
Parton	Lobsters	4					1.3		
Parton	Winkles	1		2.3	12	140	20	0.044	0.040
Haverigg	Cockles	1		2.1	10		19	*	0.029
Millom	Mussels	2					6.2		
Roosebeck	Pacific oysters	1		0.14	0.82		0.61	*	0.0013
Morecambe Bay (Flookburgh)	Flounder	1		0.00031	0.0019		0.0034	0.000041	*
Morecambe Bay (Morecambe)	Plaice	4					<0.29		
Morecambe Bay (Morecambe)	Bass	2					<0.25		
Morecambe Bay (Sunderland Point)	Whitebait	1		0.048	0.26	2.8	0.41	*	0.00067

Table 4.3. continued

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
Morecambe Bay (Flookburgh)	Shrimps	1		0.0057	0.031	0.37	0.052	*	0.00019
Morecambe Bay (Morecambe)	Mussels	1		0.33	1.8		3.1	*	0.0042
Morecambe Bay (Flookburgh)	Cockles	1		0.43	2.4	25	6.0	*	0.0094
Morecambe Bay (Middleton Sands)	Cockles	1		0.35	1.9		4.9	*	0.0065
Calder Farm	Rainbow trout	2					<0.59		
River Duddon	Seatrout	1					<0.21		
River Kent	Seatrout	1					<0.42		
River Derwent	Seatrout	1					<0.15		
Fleetwood	Cod	1		0.00027	0.0015		0.0032	*	0.0000045
Fleetwood	Plaice	1		0.00065	0.0034		0.0069	*	0.000010
Fleetwood	Lobsters	4					1.2		
Fleetwood	Whelks	1		0.095	0.51	5.4	0.76	*	*
Fleetwood	Squid	1					<0.19		
Isle of Man	Cod	1		0.00011	0.00060		0.0022	*	0.0000065
Isle of Man	Herring	1		0.00018	0.0010		0.0013	*	*
Isle of Man	Lobsters	4					<0.29		
Isle of Man	Scallops	1		0.022	0.12		0.036	*	0.000091
Inner Solway	Flounder	1		<0.012	0.014		0.034	*	*
Inner Solway	Seatrout	1		0.00058	0.0010		0.0013		
Inner Solway	Salmon	1					<0.50		
Inner Solway	Shrimps	1		0.0042	0.017		0.0023	*	*
Kirkcudbright	Plaice	1		0.0013	0.0028		0.0035		
Kirkcudbright	Scallops	2		0.034	0.18		0.012	*	*
Kirkcudbright	Queens	2		0.0048	0.024		0.026	0.00018	0.000091
Garlieston	Cod	1		0.00024	0.00091		0.0019	*	*
Garlieston	*Nephrops*	1		0.017	0.087		0.69	*	0.00074
Southerness	Winkles	1		0.52	2.5	17	4.3	*	*
North Solway coast	Crabs	2		0.052	0.26	2.4	0.90	*	0.0015
North Solway coast	Lobsters	2		0.026	0.13	1.4	0.92	*	0.0020
North Solway coast	Winkles	2		0.29	1.5	13	4.8	*	0.0037
North Solway coast	Cockles	5		0.79	4.1	45	10	*	<0.019
North Solway coast	Mussels	2		0.50	2.6	33	6.5	*	<0.0024
Wirral	Shrimps	2					<0.06		
Wirral	Cockles	1		0.099	0.56		1.5	*	0.0027
Knott End	Cockles	1		0.41	2.3		6.2	*	0.014
Conwy	Mussels	1		0.021	0.11		0.19	*	0.00041
North Anglesey	Rays	1		0.00023	0.0011		0.0018	0.000032	*
North Anglesey	Plaice	2					<0.31		
North Anglesey	Lobsters	1		0.0015	0.0082		0.079	*	0.00011
Ribble Estuary	Flounder	1					<0.29		
Ribble Estuary	Mullet	1					<0.85		
Ribble Estuary	Salmon	1					<0.24		
Ribble Estuary	Seatrout	1					<0.23		
Ribble Estuary	Shrimps	1	0.00060	0.0034	0.017		0.028	*	0.000072
Ribble Estuary	Cockles	1		0.38	2.0		5.1	*	0.011
Northern Ireland	Cod	7					<0.22		
Northern Ireland	Whiting	1		0.0016	0.0082		0.0064	*	0.0000085
Northern Ireland	Herring	1					<0.21		
Northern Ireland	Spurdog	8					<0.27		
Northern Ireland	Lobsters	6					<0.47		
Northern Ireland	*Nephrops*	1		0.0073	0.039		0.32	0.00020	0.00037
Northern Ireland	Winkles	1		0.029	0.16		0.15	*	0.00014
Northern Ireland	Mussels	1					<0.53		

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
Sound of Mull	Salmon	1			<0.45		
Minch	Cod	1	0.000073	0.00038	0.00058	*	*
Minch	Haddock	1	0.00026	0.0013	0.00084	*	*
Minch	Mackerel	1	0.00021	0.0010	0.0014	*	*
Minch	Plaice	4			<0.15		
Minch	Herring	3			<0.13		
Minch	*Nephrops*	1	0.00096	0.0060	0.0091	*	*
Shetland	Fish meal[e]	1	0.00030	0.0025	0.00092	*	*
Shetland	Fish oil[e]	4			<0.48		
Northern North Sea	Cod	1	0.000085	0.00033	0.00045	*	*
Northern North Sea	Plaice	3			<0.18		
Northern North Sea	Herring	3			<0.22		
Northern North Sea	Haddock	1	0.000070	0.00046	0.00046	*	*
Northern North Sea	*Nephrops*	1	0.00042	0.0027	0.0036	*	*
Mid North Sea	Cod	4			<0.17		
Mid North Sea	Plaice	3			<0.12		
Mid North Sea	Herring	2			<0.22		
Mid North Sea	Mussels[f]	1	0.00053	0.0021	0.0011	*	*
Southern North Sea	Cod	2			<0.15		
Southern North Sea	Plaice	2			<0.12		
Southern North Sea	Herring	2			<0.11		
Southern North Sea	Cockles	1	0.0035	0.0074	0.0098	0.00017	0.00095
Southern North Sea	Cockles[g]	1	0.0028	0.011	0.015	0.00018	0.0014
Southern North Sea	Mussels	1	0.0013	0.0084	0.0034	*	*
English Channel East	Cod	4			<0.11		
English Channel East	Plaice	4			<0.07		
English Channel East	Scallops	1	0.0019	0.0068	0.0027	*	0.00029
English Channel West	Mackerel	2			<0.18		
English Channel West	Plaice	2			<0.15		
English Channel West	Whiting	2			<0.18		
English Channel West	Crabs	1	0.000068	0.00048	0.0011	*	0.00013
English Channel West	Lobsters	1			<0.74		
English Channel West	Scallops	1	0.00026	0.0030	0.0011	0.000052	0.000016
Gt Yarmouth (retail shop)	Cod	4			<0.13		
Gt Yarmouth (retail shop)	Plaice	4			<0.16		
Skagerrak	Cod	3			<0.12		
Skagerrak	Herring	3			<0.16		
Norwegian Sea	Cod	1			<0.04		
Norwegian Sea	Saithe	1			<0.06		
Iceland Area	Cod	2			<0.07		
Icelandic processed	Cod	1	0.000097	0.00050	0.00078	*	*
Barents Sea	Cod	3			<0.09		
Baltic Sea	Cod	3			<0.22		
Baltic Sea	Herring	3			<0.11		
Celtic Sea	Cod	2			<0.22		
Celtic Sea	Pollack	1			<0.04		
Celtic Sea	Whiting	1			<0.05		

** 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] *Aphrodite aculeata, an annelid worm*
[e] *Concentrations refer to weight as supplied*
[f] *Landed in Denmark*
[g] *Landed in Holland*

Table 4.4. Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 1998

Exposed population[b]	Foodstuffs	Exposure mSv[a]										
		Total	^{14}C	^{90}Sr	^{99}Tc	^{106}Ru	^{137}Cs	^{238}Pu	$^{239+240}Pu$	^{241}Pu	^{241}Am	Others
Sellafield fishing community	Plaice and cod Crabs and lobsters Winkles and other molluscs	0.20[f]	0.006	0.003	0.023	0.006	0.008	0.007	0.034	0.008	0.060	<0.004
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.023	0.002		0.005	0.001	0.004	0.001	0.004	0.001	0.005	<0.001
Dumfries and Galloway	Plaice, cod and salmon Crabs, Lobster and *Nephrops* Winkles and mussels	0.048[c]	0.002		0.008	0.001	0.002	0.001	0.005	0.001	0.011	<0.001
Morecambe Bay	Flounders and plaice Shrimps Cockles and mussels	0.074[d]	0.004		0.002	0.001	0.012	0.002	0.011	0.003	0.023	<0.001
Fleetwood	Plaice and cod Shrimps Whelks	0.027	0.005		0.001	0.001	0.011	0.001	0.003	0.001	0.004	<0.001
Isle of Man	Fish and shellfish[e]	0.010			0.003	0.001	0.004		0.001		0.001	<0.001
Northern Ireland	Fish and shellfish[e]	0.014	0.001		0.003	0.001	0.004		0.001		0.003	<0.001
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 1100 h year^{-1} occupancy over intertidal sediments*

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 1998

Location	Ground type	No. of sampling observations[a]	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria			
Rockcliffe Marsh	Saltmarsh	4	0.077
Newton Arlosh	Saltmarsh	4	0.12
Calvo Marsh	Saltmarsh	1	0.092
Parton	Winklebed	4	0.096
Whitehaven - outer harbour	Mud and sand	9	0.098
Whitehaven - outer harbour	Coal and sand	11	0.13
Whitehaven - outer harbour	Sand	2	0.096
Whitehaven - yacht basin	Mud	12	0.17
Whitehaven - yacht basin (boat 4)	Cabin[b]	3	0.12
Fishing vessel A	Cabin[b]	3	0.092
Fishing vessel R	Cabin[b]	2	0.082
Saltom Bay	Winklebed	4	0.10
St Bees	Sand	4	0.072
Nethertown	Winklebed	4	0.097
Sellafield	Sand	4	0.076
Drigg Barn Scar	Mussel bed	4	0.094
Ravenglass - Carleton Marsh	Saltmarsh	4	0.23
Ravenglass - salmon garth	Mud and sand	2	0.12
Ravenglass - salmon garth	Mud, sand and stones	2	0.12
Ravenglass - salmon garth	Sand and stones	4	0.093
Ravenglass - salmon garth	Mussel bed	4	0.097
Ravenglass - ford	Mud and sand	4	0.11
Ravenglass - Raven Villa	Mud	2	0.13
Ravenglass - Raven Villa	Mud and sand	9	0.13
Ravenglass	Saltmarsh	11	0.20
Newbiggin	Mud	3	0.19
Newbiggin	Mud and sand	1	0.18
Newbiggin	Saltmarsh	4	0.24
Tarn Bay	Sand	2	0.073
Tarn Bay	Winklebed	2	0.092
Haverigg	Mud	2	0.093
Haverigg	Mud and sand	3	0.090
Haverigg	Sand	3	0.072
Millom	Mud and sand	3	0.11
Millom	Mud, sand and stones	1	0.12
Walney Channel - Vickerstown Church	Mud and sand	4	0.089
Sand Gate Marsh	Saltmarsh	4	0.10
Flookburgh	Mud and sand	4	0.077
High Foulshaw	Saltmarsh	4	0.094
Arnside	Saltmarsh	4	0.11
Lancashire, Merseyside and North Wales			
Colloway Marsh	Saltmarsh	4	0.16
Aldcliffe Marsh	Saltmarsh	4	0.12
Conder Green	Mud and sand	4	0.11
Conder Green	Saltmarsh	4	0.12
Cockerham Marsh	Saltmarsh	4	0.11
Heads - River Wyre	Saltmarsh	2	0.12
Height o' th' hill - River Wyre	Saltmarsh	4	0.13
Knott End	Mud and sand	2	0.081
Skippool Creek (boat 2)	Cabin[b]	1	0.093
Skippool Creek	Mud	1	0.10
Skippool Creek	Mud and sand	3	0.10
South-west Scotland			
Luce Bay	Sand	4	0.058
Garlieston	Mud	4	0.072
Innerwell	Mud and sand	8	0.084
Creetown	Saltmarsh	4	0.098
Carsluith	Mud	4	0.093
Skyreburn Bay (Water of Fleet)	Saltmarsh	4	0.079
Kirkcudbright	Saltmarsh	4	0.093
Cutters Pool	Winklebed	4	0.092
Rascarrel Bay	Winklebed	4	0.12
Palnackie Harbour	Mud	4	0.086
Gardenburn	Saltmarsh	4	0.10
Kippford - Slipway	Mud	4	0.11
Kippford - Merse	Saltmarsh	4	0.11
Carsethorn	Mud and sand	4	0.074
Glencaple Harbour	Mud and sand	4	0.092

[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, 1998

Location	Material	No. of sampling observations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria											
Newton Arlosh	Turf	4	<0.87	<2.4	<2.8	<3.0	14	<1.5	<5.1	<1.2	700
Whitehaven - yacht basin	Mud	4	<1.1	28	<5.2	<9.3	330	<3.2	<8.2	<1.5	840
St Bees	Sand	4	<0.34	3.2	<1.2	<1.4	<3.9	<0.62	<1.2	<0.39	93
Sellafield	Sand	4	<0.34	3.4	<1.3	<1.5	<6.3	<0.65	<1.3	<0.39	110
Ravenglass - Carleton Marsh	Sand	4	<1.6	34	<13	<20	310	<2.2	<6.5	<1.1	480
Ravenglass - Raven Villa	Mud & sand	4	<0.96	33	<19	<22	170	<1.9	<5.2	<1.2	280
Newbiggin	Mud	3	<1.0	47	<4.1	<6.2	160	<2.0	<6.1	<1.3	320
Newbiggin	Mud & sand	1	<0.70	22	7.5	14	180	<1.3	5.0	<0.89	270
Millom	Mud & sand	4	<0.71	26	<2.7	<3.8	65	<1.4	<2.9	<0.88	270
Flookburgh	Mud & sand	4	<0.44	<0.47	<1.8	<3.4	<4.5	<0.81	<1.4	<0.53	83
Sand Gate marsh	Turf	4	<0.81	<1.1	<2.1	<2.3	<9.7	<1.4	<3.3	<1.0	260
Lancashire, Merseyside and north Wales											
Conder Green	Turf	4	<0.83	<3.4	<2.2	<2.2	<10	<1.3	<3.6	<1.0	360
Cemlyn Bay	Mud	2	<0.56	<0.51	<2.5	<4.6	<5.2	<0.92	<1.6	<0.63	160
South-west Scotland											
Garlieston	Mud	4	<0.10	0.39	<0.45	<0.14	<1.2	<0.11	<0.58	<0.10	58
Innerwell	Mud	6	<0.26	<1.4	<0.87	<0.72	<9.5	<0.42	<1.0	<0.33	100
Carsluith	Mud	4	<0.11	4.3	<0.47	<0.18	28	<0.12	<1.4	<0.16	280
Kippford Merse	Salt marsh	4	<0.18	4.0	<0.90	<0.85	<12	<0.26	<1.4	<0.37	510
Kippford Slipway	Mud	4	<0.13	3.7	<0.51	<0.20	17	<0.14	<1.5	<0.26	400
Palnackie Harbour	Mud	4	<0.12	<1.9	<0.56	<0.70	19	<0.12	<0.88	<0.14	210
Carsethorn	Mud & sand	2	<0.10	<0.10	<0.36	<0.14	<0.89	<0.10	<0.38	<0.10	48
Isle of Man											
Douglas	Sand	1	<0.37	<0.32	<1.4	<2.3	<3.4	<0.67	<0.91	<0.44	9.9
Northern Ireland											
Lough Foyle	Mud	2	<0.51	<0.39	<3.8	<1.0	<4.5	<0.95	<1.0	<0.58	8.4
Portrush	Sand	2	<0.31	<0.26	<1.5	<3.0	<2.9	<0.58	<0.65	<0.33	1.1
Ballymacormick	Mud	2	<0.39	<0.33	<1.7	<2.8	<3.8	<0.69	<1.1	<0.46	46
Strangford Lough - Nickey's Pt	Mud	2	<0.41	<0.32	<1.9	<3.0	<3.5	<0.73	<1.0	<0.47	39
Dundrum Bay	Mud	1	<0.31	<0.25	<0.96	<1.0	<2.6	<0.50	<0.77	<0.34	8.3
Dundrum Bay	Mud & sand	1	<0.48	<0.39	<2.3	<4.3	<4.2	<0.88	<1.0	<0.52	8.1
Carlingford Lough	Mud	2	<0.70	<0.63	<2.0	<2.1	<6.1	<1.1	<1.8	<0.80	79
Oldmill Bay	Mud	2	<0.78	<0.80	<2.7	<3.7	<7.4	<1.4	<2.0	<0.92	66

Table 4.6. continued

Location	Material	No. of sampling observations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Cumbria												
Newton Arlosh	Turf	4	<8.8	<3.7	<4.4				250			
Whitehaven - yacht basin	Mud	4	<30	15	7.6	130	710		1100	*	1.7	2800
St Bees	Sand	4	<2.7	1.8	<1.3				190			
Sellafield	Sand	4	<2.6	<1.6	<1.6				190			
Ravenglass - Carleton Marsh	Sand	4	37	13	<5.9				920			
Ravenglass - Raven Villa	Mud & sand	4	24	8.4	<4.5				590			
Newbiggin	Mud	3	17	9.1	<6.3	86	440	5300	660	*	1.5	1600
Newbiggin	Mud & sand	1	29	6.9	4.3				590			1400
Millom	Mud & sand	4	<6.9	<5.3	<2.7				460			
Flookburgh	Mud & sand	4	<2.9	<1.3	<1.3				39			
Sand Gate marsh	Turf	4	<5.7	<2.6	<2.9				100			
Lancashire, Merseyside and north Wales												
Conder Green	Turf	4	<6.6	<2.8	<3.3				180			
Cemlyn Bay	Mud	2	<2.8	<1.5	<2.0	3.9	22		31	*	0.052	
South-west Scotland												
Garlieston	Mud	4	<0.56	<0.51	<0.60	5.9	30		33			
Innerwell	Mud	6	<1.9	<1.3	<1.3				74			
Carsluith	Mud	4	<0.78	3.2	2.2	43	210		210			2400
Kippford Merse	Salt marsh	4	1.3	5.0	<1.5	54	280		410			
Kippford Slipway	Mud	4	<0.83	3.7	<1.9	42	200		290			
Palnackie Harbour	Mud	4	<0.77	1.9	1.6	28	130		200			
Carsethorn[b]	Mud & sand	2	<0.57	<0.46	<0.39				7.8			
Isle of Man												
Douglas	Sand	1	<2.8	<1.0	<1.4				<2.4			
Northern Ireland												
Lough Foyle	Mud	2	<2.7	<1.1	<1.4	0.36	2.0		3.1	0.0014	*	
Portrush	Sand	2	<1.8	<0.81	<0.77				<0.96			
Ballymacormick	Mud	2	<2.9	<1.1	<1.4	2.7	16		20	*	0.058	
Strangford Lough - Nickey's Pt	Mud	2	<2.7	<1.1	<1.3	1.9	9.7		10	*	0.012	
Dundrum Bay	Mud	1	<2.2	<0.82	<1.1				1.5			
Dundrum Bay	Mud & sand	1	<2.7	<1.3	<1.2				<1.9			
Carlingford Lough	Mud	2	<3.3	<1.9	<1.7	2.0	12		7.7	*	*	
Oldmill Bay	Mud	2	<3.4	<2.3	<1.6	3.1	17		24	*	0.042	

* *not detected by the method used*
[a] *See section 3 for definition*
[b] *The concentration of ^{65}Zn was 0.30 Bq kg^{-1}*

Table 4.7. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 1998

Vessel	Type of gear	No. of sampling observations[a]	Mean beta dose rate in tissue, µSv h^{-1}
A	Nets	6	0.090
	Ropes	6	0.039
R	Nets	4	*
S	Pots	2	*
T	Gill nets	4	0.037
	Pots	3	0.058
W	Gill nets	1	*
X	Gill nets	4	*
	Pots	4	*

[a] *See section 5 for definition*
* *Not detected by the method used*

Table 4.8. Radioactivity in terrestrial food and the environment near Sellafield, 1998[h,i]

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		12	<3.2	<5.3	18	<0.73	<0.40	0.10	<0.0055	<2.8	<0.79
Milk	Near farms	max		<4.5	11	23	<2.2	<0.44	0.15		<3.0	<0.89
Milk	Far farms		4	<3.0	<2.8	15	<0.54	<0.40	0.057	<0.0040	<2.8	<0.80
Milk	Far farms	max			<3.0	16	<0.55	<0.41	0.066		<3.0	<0.90
Apples			5	<2.8	<3.8	13	<0.78	<0.42	0.17	<0.025	<2.8	<0.74
Apples		max		<3.0	7.0	17	1.6	<0.50	0.33		<3.6	<0.90
Barley			2		6.0	110	1.7	<0.55	1.6		<3.4	<0.75
Barley		max			8.0		2.2	<0.60	2.4			<1.0
Blackberries			1	<3.0	23	35	22	<0.80	5.8		<3.4	<0.70
Bovine kidney			1	<4.0	<4.0	20	<0.90	<0.50	1.3	<0.051	<3.9	<1.4
Bovine liver			1	<4.0	<4.0	31	9.7	<0.40	<0.018	<0.032	<2.7	<0.70
Bovine muscle			1	4.0	<4.0	33	<0.90	<0.50	<0.016	<0.031	<1.9	<1.3
Cabbage			1	<3.0	4.0	5.0	<0.40	<0.50	0.94		<2.5	<1.0
Carrots			1	<3.0	<3.0	6.0	<0.40	<0.30	0.70	<0.048	<3.2	<1.0
Cauliflower			1									
Chicken			1	<3.0	<3.0	40	4.8	<0.50	<0.014		<3.7	<1.3
Duck			1	<3.0	6.0	36	<2.0	<0.50	<0.026		<2.4	<1.0
Game birds			1	<4.0	<4.0	30	<0.90	<0.50	<0.022		<3.7	<1.3
Honey			1		5.0	61	<1.1	<0.30	<0.051		<3.7	<0.80
Lettuce			1	<3.0	<3.0	<3.0	<0.40	<0.30	0.30		<2.6	<0.70
Ovine offal			2	<4.0	<7.5	48	7.9	<0.45	0.26	<0.033	<3.0	<1.5
Ovine offal		max		<5.0	10	49	12	<0.50			<3.7	
Ovine muscle			2	<3.5	6.0	31	5.7	<0.40	0.040	<0.034	<2.6	<0.75
Ovine muscle		max		4.0	9.0	34			0.064		<3.0	<1.0
Pheasants			1	3.0	7.0	40	<1.7	<0.40	<0.019	<0.030	<3.9	<1.3
Potatoes			4	<3.3	6.0	23	<0.40	<0.40	0.51		<3.3	<0.90
Potatoes		max		4.0	11	29	0.60	<0.50	1.5		<3.8	<1.0
Runner beans			1	<3.0	5.0	7.0	0.70	<0.40	0.23		<1.6	<0.80
Swede			1	<3.0	<3.0	10	0.50	<0.40	0.73		<3.3	<0.80
Turnips[g]			1	4.0	11	13	0.90	<0.60	<0.031		<3.6	<1.0
Grass[d,e,f]			2							<0.033	<2.7	
Grass[d,e,f]		max								<0.035	<3.7	

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[j]		12	<0.014	<0.44	0.19		<0.00037	<0.00024	<0.16	<0.00033
Milk Near farms	max		<0.020	<0.47	0.28		<0.00063	<0.00030	<0.19	<0.00040
Milk Far farms		4	<0.011	<0.43	0.12		<0.00030	<0.00020	<0.13	<0.00020
Milk Far farms	max		<0.013	<0.44	0.15					
Apples		5	<0.045		<0.13		<0.00058	<0.0016	<0.15	<0.0032
Apples	max		<0.072		0.24		0.00070	0.0032	<0.23	0.0067
Barley		2	<0.066		1.4		0.0020	0.014	0.18	0.017
Barley	max		<0.092		2.6		0.0026	0.020		0.019
Blackberries		1	<0.033		5.0		0.0015	0.0074	<0.14	0.0069
Bovine kidney		1			0.78		<0.00070	<0.00060	<0.11	0.00050
Bovine liver		1	<0.035		0.63		<0.0011	0.0023	<0.28	0.0041
Bovine muscle		1	<0.056		1.1		<0.00040	<0.00040	<0.078	0.00020
Cabbage		1	<0.042		<0.029		<0.00050	0.00050	0.15	0.0015
Carrots		1	<0.033		0.19		<0.00050	0.0052	<0.14	0.0063
Cauliflower		1				<0.030				
Chicken		1	<0.029		0.067		<0.00060	<0.00060	0.34	0.00040
Duck		1	<0.059		0.81		<0.00040	0.0013	0.15	0.00090
Game birds		1			0.71		<0.00040	<0.00040	0.081	<0.00020
Honey		1	<0.017		2.8		<0.0010	0.0015	<0.13	0.00060
Lettuce		1	0.068		0.12		<0.00030	0.00070	0.41	0.00090
Ovine offal		2			0.62		<0.0028	0.040	<0.25	<0.0092
Ovine offal	max						0.0052	0.080	0.37	0.018
Ovine muscle		2	<0.037		0.90		<0.00035	<0.00050	<0.12	<0.00055
Ovine muscle	max		<0.041		1.1		<0.00050	0.00070	<0.13	0.00060
Pheasants		1	<0.037		3.7		<0.00020	0.00030	<0.061	0.00070
Potatoes		4	<0.036		0.20		<0.00040	<0.0028	<0.091	<0.0015
Potatoes	max		<0.039		0.29		0.00050	0.0056	<0.11	0.0033
Runner beans		1	<0.058		0.45		0.00030	0.00070	<0.14	0.0010
Swede		1	<0.042		0.67		<0.00020	0.00070	<0.14	0.0010
Turnips[g]		1	<0.047		0.051	0.012	0.00060	0.0030	<0.089	0.0024

[a] *except for milk where units are Bq l^{-1} and 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 mean concentration of ^{45}Ca was 7.7 Bq kg^{-1}, the maximum was 8.1 Bq kg^{-1}*
[e] *the mean concentration of ^{55}Fe was 4.9 Bq kg^{-1}, the maximum was 6.6 Bq kg^{-1}*
[f] *the mean concentration of ^{63}Ni was <0.30 Bq kg^{-1}*
[g] *the concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0014, <0.00030 and 0.0010 Bq kg^{-1} respectively*
[h] *the concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 36, 7.1, 0.27 and 6.6 Bq kg^{-1} respectively*
[i] *333 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.27, 1.9 and 1.1 Bq per cloth*
[j] *the mean concentration of ^{131}I was <0.030 Bq kg^{-1}; the maximum was <0.032 Bq kg^{-1}*

Table 4.9. Individual radiation exposures due to consumption of terrestrial foodstuffs near Sellafield and Drigg, 1998

Exposed population[b]	Key foodstuffs	Exposure mSv[a]											
		Total	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{129}I	^{131}I	^{137}Cs	^{144}Ce	Others
Consumers near Sellafield aged 1 y	Milk Potatoes	0.042	0.003	0.004	0.005	0.011	0.011	0.002	0.002	0.002	0.002		<0.001
Consumers near Drigg aged 1 y	Milk Potatoes	0.017		0.001	0.004	0.003	0.006		0.001		0.001		<0.002
Consumers near Ravenglass aged 1 y	Milk Potatoes	0.028		0.001	0.004	0.003	0.009	0.002	0.002		0.001	0.005	<0.001
Typical adult member of the public eating food grown near Sellafield	Potatoes Wild fruit	0.014				0.005	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, 1998[f]

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	1	<3.3	15	<0.48	<0.43	0.086	<0.0083	<3.0	<0.76	<0.011
Blackberries	1	4.0	24	0.70	<0.30	0.27		<1.8	<0.60	<0.069
Cabbage	1	2.0	18	1.0	<0.30	0.81	<0.055	<3.0	<0.50	<0.058
Duck	2	<3.0	37	<1.3	<0.45	0.026	0.068	<3.2	<1.1	
Duck max			47	<1.6	<0.50	0.028		<3.3	<1.5	
Ovine muscle	1	5.0	46	5.3	<0.40	0.032	<0.023	<1.7	<0.40	<0.037
Ovine offal	1	<5.0	50	2.5	<0.50	0.36	<0.12	<3.8	<1.3	
Pheasant	1	<3.0	26	<1.4	<0.30	<0.017		<2.0	<0.90	
Potatoes	2	<3.0	14	<0.40	<0.50	<0.041	<0.024	<2.7	<0.70	<0.072
Potatoes max				0.40		0.056		<2.8	<0.90	<0.075
Grass	2						<0.13			
Grass max							0.21			

Material and selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		Total Cs	^{147}Pm	^{238}Pu	^{240}Pu	^{239}Pu + ^{241}Pu	^{241}Am
Milk[d]	1	0.19	<0.35	<0.00015	<0.00025	<0.096	<0.00058
Blackberries	1	0.13		0.00040	0.0015	<0.11	0.0035
Cabbage	1	0.56	0.30	0.00050	0.00070	<0.090	0.0020
Duck	2	4.3		0.0085	0.035	<0.10	0.032
Duck max		5.2		0.015	0.064	0.10	0.050
Ovine muscle	1	0.75		<0.00020	0.00040	<0.077	<0.00040
Ovine offal	1	0.64		0.0028	0.014	0.14	0.011
Pheasant	1	3.7		<0.00030	<0.00040	<0.069	<0.00020
Potatoes	2	0.20	<0.30	<0.00035	<0.00045	<0.11	0.00055
Potatoes max		0.28		<0.00050	<0.00050	<0.13	0.00070
Grass[e]	2		5.9				
Grass max			8.9				

[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 5 for definition.*
[d] *the concentration of ^{137}Cs was <0.48 Bq kg^{-1}*
[e] *the concentrations of U, ^{234}U, ^{235}U and ^{238}U were 0.19, 0.17, 0.030 and 0.16 Bq kg^{-1} respectively*
[f] *the concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 30, 8.6, 0.30 and 8.2 Bq kg^{-1} respectively*

Table 4.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 1998

Location	Ground type	No. of sampling observations[a]	µSv h^{-1}
Whitehaven outer harbour	Mud and sand	1	0.29
Whitehaven outer harbour	Sand	1	0.43
Whitehaven yacht basin	Mud	2	1.4
St Bees	Sand	2	0.29
Nethertown	Winkle bed	2	0.54
Sellafield pipeline	Sand	2	0.31
Drigg Barn Scar	Mussel bed	2	0.34
Ravenglass - Raven Villa	Saltmarsh	2	1.7
Ravenglass - salmon garth	Mussel bed	2	0.60
Tarn Bay	Sand	2	0.23

[a] *See section 3 for definition*

Table 4.12. Radioactivity in terrestrial food and the environment near Ravenglass, 1998[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	16	<0.53		<0.42	0.070	<0.86	<0.84	<0.0089	<2.8	<0.85	<0.010
Milk max			17	<0.55		<0.44	0.079	<0.92	<0.85	<0.011		<0.95	<0.011
Apples	1	<3.0	11	<0.50		<0.40	0.056	<0.40	<0.60	<0.024	<2.5	<0.90	<0.045
Barley	1	<4.0	97	1.1		<0.50	0.047	<0.40	<0.60	<0.045	<2.6	<0.60	<0.049
Blackberries	1	3.0	16	<0.40		<0.30	0.53	<0.40	<0.50	0.034	<1.6	<0.80	<0.043
Bovine kidney	1	6.0	21	<0.90		<0.40	0.028	<0.60	<0.40	<0.031	<3.3	<1.3	
Bovine liver	1	<4.0	37	<0.70		<0.40	0.062	<0.60	<0.40	<0.023	<2.9	<0.50	<0.12
Bovine muscle	1	<4.0	30	<0.90		<0.50	0.093	<0.80	<0.60	<0.025	<3.6	<1.3	
Cabbage	1	<3.0	4.0	2.1		<0.40	0.70	<0.70	<0.80	0.044	<2.4	<0.70	0.085
Carrots	1	<3.0	11	0.60		<0.50	0.33	<0.90	<0.80	<0.036	<3.5	<1.0	<0.065
Duck	1	<3.0	35	<1.6		<0.40	<0.018	<0.90	<0.50	0.091	<3.4	<1.1	<0.042
Honey	1	<4.0	87	<0.90		<0.40	0.023	<0.60	<0.40	<0.029	<2.5	<0.60	<0.018
Lettuce	1									<0.048			
Ovine offal	2	<5.0	39	12		<0.90	0.38	<1.6	<0.95		<3.9	<1.3	
Ovine offal max			45	16		<1.2	0.50	<2.1	<1.2		<4.0	<1.4	
Ovine muscle	2	<4.5	37	6.3		<0.30	<0.019	<0.60	<0.40	<0.029	<2.7	<0.65	<0.034
Ovine muscle max		6.0	44	7.3		<0.40		<0.80		<0.030	<2.9	<0.70	<0.036
Potatoes	2	<3.0	21	<0.40		<0.30	0.071	<0.50	<0.70	<0.029	<2.8	<0.40	<0.059
Potatoes max										<0.030			
Runner beans	1	<3.0	10	<0.40		<0.40	0.22	<0.50	<0.70	<0.028	<4.0	<0.90	<0.069
Grass[d,f]	2				1.4					<0.062			
Grass[d] max					2.0					0.097			

Table 4.12. continued

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	3	0.19	<1.9	<0.61	<0.35	<0.00024	<0.00029	<0.14	<0.00038
Milk	max	0.23		<0.65		<0.00028	<0.00033	<0.21	<0.00040
Apples	1	0.11	<1.7	<0.60		<0.00040	0.00030	0.14	0.00050
Barley	1	0.10	<1.5	<0.60		0.0013	0.0060	<0.22	0.012
Blackberries	1	0.067	<1.3	<0.60		0.0013	0.0070	0.13	0.016
Bovine kidney	1	0.51	<2.8	<2.5		<0.00030	0.00050	<0.047	0.0019
Bovine liver	1	0.40	<1.2	<0.50		<0.00040	0.0039	<0.063	0.0044
Bovine muscle	1	0.53	<2.7	<2.6		0.00020	0.00040	<0.060	
Cabbage	1	0.22	<1.6	<0.60	0.80	<0.00020	0.00030	<0.093	<0.00090
Carrots	1	0.20	<2.1	<0.90		<0.00050	0.0013	<0.11	0.0025
Duck	1	1.6	<3.2	<2.0		0.00070	0.0028	0.11	0.0050
Honey	1	0.53	<1.6	<0.50		<0.00030	0.0017	<0.11	0.0016
Lettuce[i]	1								
Ovine offal	2	0.94	<3.5	<0.90		0.015	0.080	<1.0	0.060
Ovine offal	max	1.0	<4.8	<1.4		0.030	0.16	2.0	0.12
Ovine muscle	2	0.56	<1.6	<0.30		<0.00030	<0.00050	<0.081	<0.00075
Ovine muscle	max		0.61	<1.8		0.00040	0.00070	<0.089	0.0011
Potatoes[j]	2	0.14	<2.1	<0.60	<0.40	<0.00050	0.00030	0.18	0.00070
Potatoes	max								
Runner beans	1	0.14	<1.0	<0.70		<0.00030	0.00040	0.17	0.0015
Grass[d]	2				3.4				
Grass[d]	max				3.6				

[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 6.5 Bq kg^{-1}, the maximum was 8.0 Bq kg^{-1}*
[e] *the concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 39, 10, 0.39 and 9.4 Bq kg^{-1} respectively*
[f] *the mean concentration of ^{63}Ni was <0.35 Bq kg^{-1}, the maximum was <0.40 Bq kg^{-1}*
[g] *the mean concentration of ^{134}Cs was <0.35 Bq kg^{-1}, the maximum was <0.36 Bq kg^{-1}*
[h] *the concentration of ^{137}Cs was <0.45 Bq kg^{-1}*
[i] *the concentrations of U, ^{234}U, ^{235}U and ^{238}U were 0.050, 0.021, 0.0020 and 0.017 Bq kg^{-1} respectively*
[j] *the concentration of U was 0.041 Bq kg^{-1}*

Table 4.13. Radioactivity in aquatic plants from the Cumbrian coast and further afield, 1998

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	^{129}I	^{134}Cs
England													
St Bees	*Fucus vesiculosus*	4	45	12	1.6	<0.14	<0.13	7700	4.0	2.8	0.37	3.6	<0.07
St Bees	*Porphyra*	4	47	1.3	0.13	<0.17	<0.15	9.1	13	<0.19	<0.30		<0.07
St Bees	*Rhodymenia spp.*	2		1.6		1.6	<0.71		22	3.4	<1.7		<0.09
Braystones south	*Porphyra*	4		2.3		<0.18	<0.16		33	<0.37	<0.29		<0.08
Sellafield	*Fucus vesiculosus*	4		34	4.5	<0.49	<0.49	20000	<12	8.5	<0.97		<0.19
Seascale	*Porphyra*	52[c]		3.4		<0.54	<0.33		<31	<0.69	<0.97		<0.34
Rabbit Cat How, Ravenglass	Samphire	1		0.13		<0.09	<0.08	1.6	<0.41	<0.06	<0.10		<0.04
Cockerham Marsh	Samphire	1		<0.04		<0.16	<0.27		<0.34	<0.07	<0.08		<0.04
Marshside Sands	Samphire	1		<0.05		<0.28	<0.49		<0.50	<0.11	<0.12		<0.06
Isle of Man	*Fucus vesiculosus*	3		<0.14		<0.27	<0.24	1500	<1.0	<0.19	<0.24		<0.11
Wales													
Portmadoc	*Fucus vesiculosus*	1		<0.05		<0.16	<0.20		<0.40	<0.09	<0.09		<0.05
Fishguard	*Fucus vesiculosus*	1		<0.10		<0.16	<0.11	21	<0.69	<0.15	<0.18		<0.09
Lavernock Point	*Fucus vesiculosus*	1		<0.10		<0.54	<1.1		<0.86	<0.20	<0.19		<0.10
Lavernock Point	*Fucus serratus*	1		<0.05		<0.13	<0.14		<0.38	<0.08	<0.09		<0.05
South Wales,													
Manufacturer A	Laverbread	3		<0.08		<0.38	<0.78		<0.83	<0.14	<0.17		<0.08
Manufacturer C	Laverbread	3		<0.08		<0.26	<0.43		<0.76	<0.13	<0.17		<0.07
Manufacturer D	Laverbread	3		<0.09		<0.26	<0.35		<0.85	<0.15	<0.16		<0.09
Scotland													
Port William	*Fucus vesiculosus*	8		<0.27		<0.33	<0.18	1900	<0.84	<0.13	<0.30		<0.10
Garlieston	*Fucus vesiculosus*	8		<0.75		<0.32	<0.25	2800	<1.1	<0.18	<0.33		<0.10
Auchencairn	*Fucus vesiculosus*	8		1.0		<0.33	<0.17	3200	<1.1	<0.16	<0.33		<0.10
Dumfries	*Fucus vesiculosus*	1						7200					
Knock Bay	*Porphyra*	8		<0.08		<0.31	<0.18		<0.76	<0.10	<0.26		<0.08
Machrahanish	*Fucus vesiculosus*	1						1400					
Girvan	*Fucus vesiculosus*	1						4200					
Hunterston	*Fucus vesiculosus*	1						1800					
Cape Wrath	*Fucus vesiculosus*	1		<0.05		<0.10	<0.08	320	<0.42	<0.09	<0.11		<0.05
Thurso	*Fucus vesiculosus*	1						570					
Wick	*Fucus vesiculosus*	1		<0.05		<0.16	<0.19		<0.38	<0.08	<0.09		<0.05
Tondra, Shetland	*Fucus vesiculosus*	1						120					
Laxfirth, Shetland	*Fucus vesiculosus*	1						140					
S. Ronaldsay, Orkney	*Fucus vesiculosus*	1						410					
Stornoway, Isle of Lewis	*Fucus vesiculosus*	1						360					
Northern Ireland													
Ardglass	*Fucus vesiculosus*	3		<0.10		<0.34	<0.46	400	<0.94	<0.18	<0.22		<0.10
Portrush	*Fucus vesiculosus*	1		<0.05		<0.14	<0.14	-	<0.44	<0.09	<0.11		<0.05
Portrush	*Fucus serratus*	2		0.06		<0.08	<0.09	-	<0.28	<0.06	<0.07		<0.03
Strangford Lough	*Rhodymenia spp.*	3		<0.07		<0.23	<0.27	48	<0.74	<0.13	<0.18		<0.07
Carlingford Lough	*Fucus spp.*	3		<0.07		<0.21	<0.26	760	<0.64	<0.12	<0.16		<0.07
Isles of Scilly	*Fucus vesiculosus*	1		<0.05		<0.09	<0.06	1.3	<0.38	<0.08	<0.10		<0.05

Table 4.13. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{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*	4	5.3	<0.23	<0.12	1.2	5.7		2.7	0.0039	0.0037	
St Bees	*Porphyra*	4	1.7	<0.30	<0.13	0.34	1.7	19	3.4	*	0.0063	150
St Bees	*Rhodymenia spp.*	2	5.5	<0.83	<0.15	1.7	7.9		7.3	*	0.020	
Braystones south	*Porphyra*	4	1.6	<0.43	<0.22	0.32	1.5	18	2.9	*	0.0043	
Sellafield	*Fucus vesiculosus*	4	9.3	<0.75	<0.41	3.1	14		5.7	0.012	0.014	14000
Seascale	*Porphyra*	52[c]	1.8	<1.5	<0.70				3.7			
Rabbit Cat How, Ravenglass	Samphire	1	0.52	<0.20	<0.09				0.57			
Cockerham Marsh	Samphire	1	1.6	<0.16	<0.07				0.71			32
Marshside Sands	Samphire	1	0.76	<0.23	<0.10				<0.19			
Isle of Man	*Fucus vesiculosus*	3	1.3	<0.43	<0.21				<0.24			1300
Wales												
Portmadoc	*Fucus vesiculosus*	1	0.48	<0.18	<0.08				<0.05			
Fishguard	*Fucus vesiculosus*	1	<0.08	<0.36	<0.19				<0.26			220
Lavernock Point	*Fucus vesiculosus*	1	0.45	<0.47	<0.20				<0.25			280
Lavernock Point	*Fucus serratus*	1	0.22	<0.20	<0.10				<0.13			150
South Wales, Manufacturer A	Laverbread	3	<0.16	<0.34	<0.14				<0.19			
Manufacturer C	Laverbread	3	0.24	<0.32	<0.13				<0.18			
Manufacturer D	Laverbread	3	<0.19	<0.28	<0.12				<0.13			89
Scotland												
Port William	*Fucus vesiculosus*	8	2.0	<0.43	<0.32				<0.44			
Garlieston	*Fucus vesiculosus*	8	4.3	<0.44	<0.32				3.9			
Auchencairn	*Fucus vesiculosus*	8	6.3	<0.44	<0.29				2.6			
Dumfries	*Fucus vesiculosus*	1										
Knock Bay	*Porphyra*	8	0.27	<0.34	<0.25				<0.34			
Machrahanish	*Fucus vesiculosus*	1										
Girvan	*Fucus vesiculosus*	1										
Hunterston	*Fucus vesiculosus*	1										
Cape Wrath	*Fucus vesiculosus*	1	1.4	<0.26	<0.14				<0.25			450
Thurso	*Fucus vesiculosus*	1										
Wick	*Fucus vesiculosus*	1	0.31	<0.21	<0.10				<0.14			310
Tondra, Shetland	*Fucus vesiculosus*	1										
Laxfirth, Shetland	*Fucus vesiculosus*	1										
S. Ronaldsay, Orkney	*Fucus vesiculosus*	1										
Stornoway, Isle of Lewis	*Fucus vesiculosus*	1										
Northern Ireland												
Ardglass	*Fucus vesiculosus*	3	0.74	<0.48	<0.21				<0.20			
Portrush	*Fucus vesiculosus*	1	0.13	<0.28	<0.15				<0.24			
Portrush	*Fucus serratus*	2	0.29	<0.17	<0.08				<0.10			
Strangford Lough	*Rhodymenia spp.*	3	0.93	<0.40	<0.18	0.061	0.36		0.64	*	0.00090	
Carlingford Lough	*Fucus spp.*	3	0.99	<0.35	<0.16				<0.15			
Isles of Scilly	*Fucus vesiculosus*	1	0.10	<0.24	<0.13				<0.22			180

* *not detected by the method used*
[a] *Sampling area*
[b] *See section 3 for definition*
[c] *counted wet*

Table 4.14. Radioactivity in vegetables and soil measured to investigate the transfer of radionuclides from sea to land, 1998

Location[b]	Material	No. of sampling observa-vations	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
Sellafield 1676[c]	Rhubarb	1	<0.05	<0.08	<0.05	84	<0.38	<0.04	0.11	<0.14	<0.07	<0.04
Sellafield 1676[c]	Soil	1	1.3	<0.73	<0.58	2000	<4.0	<0.44	71	<2.4	<1.3	35
Sellafield 14[c]	Onions	1	<0.02	<0.06	<0.05	2.4	<0.23	<0.03	0.17	<0.15	<0.07	<0.07
Sellafield 14[c]	Potatoes	1	<0.15	<0.29	<0.24	31	<1.4	<0.15	0.35	<0.58	<0.28	<0.36
Sellafield 14[c]	Runner beans	1	<0.04	<0.12	<0.12	31	<0.41	<0.04	0.16	<0.15	<0.06	<0.03
Sellafield 14[c]	Soil	2	21	<1.1	<1.1	1900	<4.4	1.0	120	<2.8	<1.9	44
Sellafield 1674[c]	Beetroot	1	<0.11	<0.23	<0.20	220	<0.95	<0.11	<0.10	<0.39	<0.19	<0.23
Sellafield 1674[c]	Cabbage	1	<0.07	<0.11	<0.08	44	<0.56	<0.06	0.25	<0.22	<0.12	<0.14
Sellafield 1674[c]	Onions	1	<0.08	<0.18	<0.16	15	<0.79	<0.08	<0.07	<0.28	<0.11	<0.06
Sellafield 1674[c]	Potatoes	1	<0.05	<0.08	<0.05	47	<0.40	<0.05	0.34	<0.25	<0.14	<0.23
Sellafield 1674[c]	Runner beans	1	<0.07	<0.14	<0.12	2.4	<0.58	<0.06	0.10	<0.20	<0.09	<0.05
Sellafield 1674[c]	Soil	1	0.93	<0.81	<0.68	1500	<3.6	<0.50	71	<2.2	<1.1	2.5

[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, 1998[h]

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{14}C	^{60}Co	^{125}Sb	^{137}Cs	^{154}Eu	^{226}Ra	^{228}Th	^{230}Th	^{232}Th
Aquatic samples											
Flounder	Ribble Estuary	1		<0.09	<0.24	9.2	<0.29				
Salmon	Ribble Estuary	1		<0.09	<0.26	0.43	<0.28				
Sea trout	Ribble Estuary	1		<0.11	<0.29	6.0	<0.35				
Grey mullet	Ribble Estuary	1		<0.19	<0.46	4.7	<0.62				
Shrimps[j]	Ribble Estuary	2	56	<0.05	<0.15	4.4	<0.15	0.033	0.0078	0.010	0.0041
Cockles	Ribble Estuary	1		0.67	<0.25	4.3	<0.24	0.069	0.44	0.63	0.24
Samphire	Marshside Sands	1		<0.05	<0.12	0.76	<0.15				
Turf	Hesketh Bank	4		2.2	<4.5	580	<3.0	27			
Mud	Savick Brook	4		<2.4	<9.9	450	<4.9	33			
Mud & sand	Pipeline	4		<0.87	<3.9	140	<2.3	17	16	150	13
Mud & sand	Ribble Estuary	1		0.96	<1.4	52	<1.1	24	20	18	16

Material	Location[b] or selection[c]	No. of sampling observa-tions[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{234}Th	^{234}U	^{235}U+ ^{236}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples											
Flounder	Ribble Estuary	1	*							<0.29	
Salmon	Ribble Estuary	1	*							<0.24	
Sea trout	Ribble Estuary	1	*							<0.23	
Grey mullet	Ribble Estuary	1	*							<0.85	
Shrimps[j]	Ribble Estuary	2	3.8				0.0034	0.017		0.028	0.000072
Cockles	Ribble Estuary	1	33				0.38	2.0		5.1	0.011
Samphire	Marshside Sands	1	*							0.19	
Turf	Hesketh Bank	4	760							250	
Mud	Savick Brook	4	710000				25	140	1500	210	0.49
Mud & sand	Pipeline	4	63000	31	1.2	23					
Mud & sand	Ribble Estuary	1	790							37	

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	^{60}Co	^{90}Sr	Total Cs	^{230}Th	^{232}Th
Terrestrial samples									
Milk	Near farms	5							
Milk	max								
Apples[e]		1	<3.0	15	<0.40	0.19	0.14	0.0052	<0.0010
Cabbage		1	<3.0	5.0	<0.50	0.28	0.087	0.020	0.019
Duck		1	<3.0	35	<0.40	0.28	3.1	0.014	0.010
Elderberrries[f]		1	<3.0	21	<0.40	0.062	0.059	0.013	0.0052
Leeks		1	2.0	3.0	<0.40	0.28	0.18	0.083	0.068
Potatoes[g]		1	<3.0	15	<0.50	0.077	<0.034	0.0056	0.0032
Runner beans		1	<3.0	9.0	<0.30	0.068	0.058	0.0096	<0.0057
Spinach		1	<3.0	<2.0	<0.40			0.057	0.025

Material	Location[b] or selection[c]	No. of sampling observa-tions[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				<0.0062				
Milk	max					<0.0063				
Apples[e]		1					<0.00030	0.00020	<0.087	0.00040
Cabbage		1					0.00010	0.00030	<0.097	0.00090
Duck		1					0.00090	0.0073	<0.061	0.012
Elderberries[f]		1					<0.00030	0.0011	<0.16	0.0029
Leeks		1					<0.00050	0.0016	<0.34	0.0012
Potatoes[g]		1					<0.00020	<0.00020	<0.25	0.00040
Runner beans		1					<0.00030	<0.00040	<0.22	0.00040
Spinach		1					0.00090	<0.00030	<0.15	0.0018
Bovine faeces		6				3.8				
Bovine faeces	max					14				
Ovine faeces		4				19				
Ovine faeces	max					29				
Grass		8	0.67	0.042	0.52	1.8				
Grass	max		0.75	0.048	0.56	5.1				
Silage		4				0.89				
Silage	max					1.4				
Soil		4	72	3.0	68	81				
Soil	max					150				

* *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 ^{129}I was <0.067 Bq kg^{-1}*

[f] *The concentration of ^{129}I was <0.050 Bq kg^{-1}*

[g] *The concentration of ^{129}I was <0.039 Bq kg^{-1}*

[h] *140 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.86, 3.5 and 0.82 Bq per cloth respectively*

[i] *The concentration of ^{99}Tc was 2.7 Bq kg^{-1}*

[j] *The concentration of ^{237}Np was 0.00060 Bq kg^{-1}*

Table 4.15(b). Monitoring of radiation dose rates near Springfields, 1998

Location	Material or ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Warton Marsh	Mud	4	0.14
Warton Marsh	Mud[c]	4	0.15
Warton Marsh	Saltmarsh	4	0.12
Banks marsh	Mud	4	0.15
Banks marsh	Mud[c]	4	0.16
Banks marsh	Saltmarsh	4	0.18
Hesketh Bank	Mud	4	0.13
Hesketh Bank	Mud[c]	4	0.14
Hesketh Bank	Saltmarsh	4	0.13
Becconsall (boat 5)	Cabin[b]	2	0.086
Beta dose rates			µSv h^{-1}
Lytham - Granny's Bay	Mud and sand	1	1.3
Warton Marsh	Mud	4	4.8
Warton Marsh	Saltmarsh	4	0.71
Banks Marsh	Mud	4	5.8
Hesketh Bank	Mud	4	4.5
Hesketh Bank	Saltmarsh	4	1.3
Ribble estuary	Gill net	2	0.38
Ribble estuary	Shrimp net	2	0.35

[a] *See section 3 for definition*
[b] *In the cabin of a houseboat*
[c] *15 cm above substrate*

Table 4.16. Radioactivity in food and the environment near Capenhurst, 1998[d]

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{233}Pa	^{234}Th	^{234}U	$^{235+236}$U	^{238}U	^{237}Np	^{241}Am
Aquatic samples													
Shrimps	Hoylake	2		<0.06	1.0	3.3	*	*					<0.06
Cockles[e]	Dee estuary	4		0.17	36	1.1	*	<5.7					1.5
Elodea canadensis[f]	Rivacre Brook	2		<0.06	7.2	<0.31	1.2	2.1	5.4	0.30	5.3	0.24	<0.09
Mud	Rivacre Brook	2		<0.41	2000	18	440	990	200	12	160	46	<2.6
Freshwater	Rivacre Brook	2	11	<0.12	0.033	<0.12	*	*	0.031	<0.0012	0.022	0.00064	<0.28

Material	Location or selection[c]	No. of sampling observations[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	6		<0.0050			<0.0018	<0.0063
Milk	max							<0.0069
Milk	Far farms	6	<2.3					
Milk	max			<2.4				
Lettuce		1		<0.028				0.019
Potatoes		1		<0.025				0.034
Strawberries		1		0.12				0.013
Bovine faeces		8		<0.021	0.87	0.034	0.86	2.2
Bovine faeces	max			<0.022				3.2
Grass		8			0.61	0.13	0.60	<0.23
Grass	max							1.1
Silage		4		<0.022				0.16
Silage	max							0.28
Soil		4			7.9	0.30	7.4	44
Soil	max							58
Rain water		81	<2.3					
Rain water	max		4.0					

* *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] *119 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.10, 1.1 and 0.65 Bq kg^{-1} respectively*

[e] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.099, 0.55 and 0.0027 Bq kg^{-1} respectively*

[f] *The concentration of beta activity was 110 Bq kg^{-1}*

Table 4.17(a). Radioactivity in food and the environment near Chapelcross nuclear power station, 1998

Material	Location[b]	No. of sampling observations[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[e]	Inner Solway	1		64	<0.10	0.10	3.2	<1.0	<0.10	<0.50
Sea trout	Inner Solway	1			<0.10			<1.0	<0.10	<0.50
Salmon	Inner Solway	1			<0.10			<1.0	<0.10	<0.50
Shrimps	Inner Solway	4			<0.11	<0.10	5.0	<0.87	<0.10	<0.41
Winkles	Southerness	4			0.83	1.6	440	3.4	<0.48	<0.35
Fucus vesiculosus	Pipeline	4			0.40		1600	<0.89	<0.10	<0.37
Mud and sand	Pipeline	4			1.0			6.1	<0.12	<0.54
Sea water	Pipeline	4	11							
Sea water	Southerness	4	29							

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Aquatic samples										
Flounder[e]	Inner Solway	1	<0.10	1.1	<0.50	<0.50	<0.012	0.014		0.034
Sea trout	Inner Solway	1	<0.10	7.1	<0.50	<0.50	0.00058	0.0010		0.0013
Salmon	Inner Solway	1	<0.10	0.31	<0.50	<0.50				<0.50
Shrimps	Inner Solway	4	<0.10	8.8	<0.40	<0.41	0.0042	0.017		0.0023
Winkles	Southerness	4	<0.10	3.2	<0.40	<0.40	0.52	2.5	17	4.3
Fucus vesiculosus	Pipeline	4	<0.10	13	<0.40	<0.33	0.38	2.0		2.6
Mud and sand	Pipeline	4	<0.13	210	0.84	<0.73	33	170		58
Sea water	Pipeline	4		<0.076						
Sea water	Southerness	4		<0.17			0.00035	0.0020		0.0012

Material	Location[b] or selection[d]	No. of sampling observations[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	120	12	<5.0	<0.10	<0.063	
Milk	Near farms max		180				<0.10	
Milk	Far farms	4	48	15	<5.0	<0.10	<0.055	
Milk	Far farms max		57				<0.070	
Grass		6		26	<5.0	0.51	<0.46	<5.0
Grass	Far farms max			47		1.0	1.5	18

[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] *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 ^{58}Co was 0.10 Bq kg^{-1}*

Table 4.17(b). Monitoring of radiation dose rates near Chapelcross, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Seafield	Mud and sand	4	0.089
Seafield	Saltmarsh	4	0.089
Battle Hill	Mud and sand	4	0.079
Browhouses	Mud, sand and stones	4	0.077
Dornoch Brow	Mud and sand	4	0.078
Dornoch Brow	Saltmarsh	4	0.085
Powfoot	Saltmarsh	4	0.077
Powfoot[b]	Saltmarsh	4	0.085
Priestside Bank	Saltmarsh	4	0.070
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*

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) which is operated by the Ministry of Defence (Procurement Executive) and the activities of AEA Technology at two of their 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 UKAEA establishment are made under authorisation by SEPA. The quantities discharged from Dounreay in 1998 were generally lower than those in 1997 reflecting 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. The establishment is also authorised to dispose of solid low level waste on site. Monitoring in 1998 continued to include sampling of ovine liver and thyroid, grass and soil to detect the effects of gaseous releases. There are no dairy herds in the Dounreay area. Routine marine monitoring involved sampling of fish and shellfish from the area of the Dounreay outfall in the Pentland Firth and other materials further afield, in combination with associated 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 (prohibiting the harvesting of seafoods around the pipeline). The results of SEPA's monitoring are presented in Tables 5.1(a), (b) and (c).

SEPA required UKAEA to send five fragments of irradiated nuclear fuel recovered from the local Dounreay environment, for independent analysis. The results of the analysis are given in Table 5.1 (c). The results did not in all cases accord with UKAEA's declared activity of the fragments and SEPA required UKAEA to comprehensively review the activities of all of the fragments found by UKAEA. This was satisfactorily carried out. The notices erected at Sandside bay to inform the public of the discovery of fragments of irradiated nuclear fuel on the public beach were at the request of Highland Council and the Highland Health Board made multi lingual. 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 and published the findings in 1998 (SEPA, 1998). SEPA's advice to the Scottish Office was that the 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. At the request of SEPA, UKAEA published a summary report into the radioactivity levels outside the UKAEA Dounreay site (UKAEA, 1999) and have agreed to undertake some remediation of certain areas.

In response to the report of contaminated feral pigeons near the Sellafield site, UKAEA undertook a review on the ability of plant at Dounreay to withstand the ingress of vermin which, coupled with the results of a programme of analysis of rabbit and seabird droppings showing no elevated levels of radioactivity, indicates to SEPA that the transfer of contamination to wildlife at Dounreay is not significant.

5. United Kingdom Atomic Energy Authority (UKAEA)

The Prohibition Notice placed on the treatment of radioactive waste sodium at an AEA Technology facility remains in force. The Enforcement Notice issued to UKAEA to control mobile radioactive particulate matter in the duct leading to the main fuel cycle discharge stack was reissued to allow time for the provision of a new duct to modern standards. UKAEA have in the mean time proposed to SEPA that temporary HEPA filtration be provided in order to mitigate any release of the particulate matter in the duct.

Following a round of second consultation, in November 1998 SEPA forwarded draft new authorisations for Dounreay to the Secretary of State for Scotland, as required by law. SEPA published its decision document in February 1999 (SEPA, 1999). Scottish Ministers indicated to SEPA that they are content to leave it to SEPA to issue the proposed authorisations.

Habits surveys have confirmed the existence of four potentially critical exposure pathways for marine radioactivity at Dounreay, three of which involve external irradiation. The first of these is due to radioactivity adsorbed mainly on fine particulate matter becoming entrained on fishing gear which is regularly handled. This results in skin dose, mainly from beta particles, to the hands and forearms of fishermen. The most exposed group is represented by a small number of people who operate a fishery close to Dounreay. Dose rates on their fishing gear were below the limit of detection in 1998.

The second potentially critical pathway arises also from the uptake of radioactivity by particulate material which accumulates in rocky areas of the foreshore and presents a potential source of exposure, mainly to gamma radiation, of those who visit these areas. In 1998, monitoring of sludge at Oigin's Geo showed generally decreased concentrations of radionuclides compared with 1997 reflecting the decrease in the discharge. However, there is known to be significant variability in these concentrations with differing sea and weather conditions. The more important measurements of gamma dose rates above areas of the foreshore remained similar to, or less than, those for 1997. Public radiation dose via this pathway remained low, at 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The third potentially critical pathway involves internal exposure of consumers of locally-collected fish and shellfish; fish, crabs, lobsters and winkles from the outfall area are sampled to enable this pathway to be kept under review. Additionally, sea water and seaweed were sampled as indicator materials. Concentrations of radionuclides in 1998 were generally similar to those for 1997. Technetium-99, due to disposals from Sellafield, remained at its high levels typical of recent years. Despite these, doses from consumption of fish and shellfish continued to be low; for high-rate consumers the radiation dose was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The fourth potential critical pathway is due to consumption of molluscs and external exposure during collection. Gamma dose rates were measured over collecting areas and winkles were analysed for their radioactivity content. Gamma dose rates over the main collecting areas were similar in 1998 to those measured previously. The radiation dose due to a combination of consumption of molluscs and external exposure during collection remained low at 0.008 mSv or less than 1% of the dose limit of 1 mSv. This pathway was the critical marine pathway at Dounreay in 1998.

The results for terrestrial samples, Table 5.1(a), generally showed low levels of radioactivity. There was no evidence for enhanced levels of caesium-137 in ovine liver as was found in 1996. Plutonium-239+240/238 ratios in grass and soil suggested an effect due to 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 0.030 mSv or 3% of the dose limit of 1 mSv.

5.2 Harwell, Oxfordshire

Disposals of radioactive wastes from Harwell continued in 1998 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 points. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels remote from nuclear establishments. Analysis of tritium in aquatic samples was added to that in milk and vegetables.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 5.2(a) and (b). Tritium was detected in fruit and vegetables collected near the site but at lower levels to those observed in local foodstuffs in previous years. Discharges of this radionuclide were about one third of those in 1996. The dose to the most exposed group of terrestrial food consumers was estimated to be less than 0.005 mSv or 0.5% of the dose limit 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 could have been due to site discharges though it was close to the limit of detection. Its effect was trivial since tritium has a very low toxicity. The concentration of caesium-137 in pike increased in 1998 to 26 Bq kg^{-1} (1997: 3.6 Bq kg^{-1}). Based on a single measurement it is difficult to conclude whether the observation is representative. A similar level was found in a sample in 1991.

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 equivalent to a hypothetical consumption of fish at a rate of 1 kg $year^{-1}$. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 1998 was 0.017 mSv, or about 2% of the dose limit of 1 mSv.

5.3 Winfrith, Dorset

Disposals of radioactive wastes from this site continued in 1998 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 and measurements of gamma dose rates on the foreshore.

Data are presented in Tables 5.3(a) and (b). 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 or 0.5% of the dose limit 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 1998 at less than 0.005 mSv or 0.5% of the dose limit.

Table 5.1(a). Radioactivity in food and the environment near Dounreay, 1998

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Aquatic samples											
Cod	Pipeline	1		24	<0.10	<0.50	<0.10		<1.0	<0.10	<0.50
Crabs	Pipeline	5			<0.19	<0.42	<0.24	9.2	<0.84	2.4	<0.36
Lobsters	Pipeline	1			<0.10	<0.50	<0.10	32	<1.0	<0.10	<0.50
Winkles	Brims Ness	4			<0.22	<0.68	<0.84		<1.4	2.0	<0.46
Winkles	Sandside Bay	4			0.43	<0.63	<0.73		<1.4	4.2	<0.44
Sludge[e]	Oigins Geo	4			<17	<0.70	<3.1		<100	<9.2	13
Sand	Sandside Bay	4			<0.19	<0.41	<0.11		<0.87	<0.10	<0.41
Fucus vesiculosus	Sandside Bay	4			0.47	<0.35	<0.19	250	<0.74	<0.10	<0.31
Fucus vesiculosus	Brims Ness	4			<0.23	<0.43	<0.12		<0.83	<0.10	<0.40
Sea water	Sandside Bay	4	2.4								

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm
Aquatic samples											
Cod	Pipeline	1	<0.10	0.70	<0.50	<0.50	<0.50	0.00041	0.0012	0.0021	*
Crabs	Pipeline	5	<0.10	<0.25	<0.44	<0.34	<0.35	0.013	0.047	0.041	*
Lobsters	Pipeline	1	<0.10	<0.10	<0.50	<0.50	<0.50	0.0014	0.0033	0.0070	*
Winkles	Brims Ness	4	<0.13	<0.17	<0.72	<0.35	<0.43	0.060	0.19	0.19	*
Winkles	Sandside Bay	4	<0.12	<0.18	<0.71	<0.35	<0.40	0.056	0.21	0.15	*
Sludge[e]	Oigins Geo	4	<0.37	32	<2.5	<1.7	<1.4	15	40	22	*
Sand	Sandside Bay	4	<0.10	3.6	<0.46	1.1	0.99	4.9	20	14	*
Fucus vesiculosus	Sandside Bay	4	<0.10	0.44	<0.39	<0.30	<0.31			<0.34	
Fucus vesiculosus	Brims Ness	4	<0.10	0.29	<0.42	<0.40	<0.40			<0.40	
Sea water	Sandside Bay	4		<0.05							

Material	Location or selection[d]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{90}Sr	^{129}I	^{131}I	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am
Terrestrial samples									
Ovine liver		2			<0.31	<0.42	<0.0035	<0.0035	<0.0011
Ovine liver	max					0.58			<0.0019
Ovine thyroid		2		<0.034	<0.046				
Ovine thyroid	max			<0.050	<0.070				
Grass		7	0.92	<0.044	<0.56	1.9	<0.062	<0.13	<0.094
Grass	max		1.6	<0.060	<1.7	7.1	0.13	0.64	0.36
Soil		6	1.6	<0.058	<0.44	15	<0.050	0.31	0.13
Soil	max		2.9	<0.090	<0.78	26		0.42	0.27

* *not detected by the method used*

[a] *Except for 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*

[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, 1998

Location	Ground type observations[a]	No. of sampling	µGy h^{-1}
Gamma dose rates at 1 m over substrate			
Oigins Geo	Stones	1	0.14
Oigins Geo	Intertidal sediment	4	0.12
Sandside Bay	Sand	1	0.040
Sandside Bay	Winkle bed	4	0.082
Sandside Bay	Gill nets	1	0.070
Castletown Harbour	Mud	1	0.078
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). Radioactivity in hot particles at Dounreay, 1998

Location	Reference number	No. of sampling observations[a]	Mean radioactivity concentration, Bq per particle									
			^{90}Sr	^{94}Nb	^{134}Cs	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Sandside Bay	971921	1	3800			4000				6.0	2.7	
Sandside Bay	974151	1	97000			120000				310	69	
Offshore	972727	1	36000	<10	<10	39000	8.9		<1.0	120	32	24
Offshore	972941	1	1100000		<800	1400000	280	21	<10	1300	770	650
Offshore	972951	1	14000		<50	14000	3.1	<1.0	<1.0	130	59	46

[a] *See section 3 for definition*

Table 5.2(a). Radioactivity in food and the environment near Harwell, 1998

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{57}Co	^{60}Co	^{65}Zn	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples										
Pike	Outfall (Sutton Courtenay)	1	270	<0.04	<0.04	<0.10	0.28	26	<0.14	<0.13
Pike[g]	Newbridge	1	<120	<0.03	<0.05	<0.15	<0.05	<0.05	<0.12	0.0049
Pike	Staines	1		<0.02	<0.04	<0.04	<0.04	0.26	<0.06	<0.04
Nuphar lutea	Outfall (Sutton Courtenay)	1	<120	<0.04	<0.06	<0.13	<0.06	1.4	<0.14	<0.19
Nuphar lutea	Newbridge	1	<120	<0.03	<0.05	<0.13	<0.05	0.08	<0.12	<0.11
Nuphar lutea	Staines	1	<120	0.06	<0.06	0.33	<0.05	0.14	<0.08	<0.04
Mud	Position 'E'[e]	2		<0.86	5.9	<1.1	<0.62	2000	<2.9	5.4
Mud & Sand[h]	Outfall (Sutton Courtenay)	2		<0.44	3.4	<1.2	<0.65	270	<1.9	1.8

Material	Location or selection[c]		No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
				^{3}H	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples									
Milk[d]	Near farms		4	<3.8	<0.41	<0.40			
Milk[d]	Near farms	max		<4.0	<0.43				
Apples[f]			1	<3.0	<0.30	<0.40			
Asparagus[f]			1	3.0	<0.40	<0.40			
Cabbage[f]			1	<3.0	<0.40	<0.40			
Honey			1	<4.0	<0.30	<0.30			
Marrow[f]			1	3.0	<0.40	<0.50			
Raspberries[f]			1	3.0	<0.30	<0.50			
Dry cloths			96				0.09	1.0	0.57

[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 <3.9 Bq l^{-1}*
[e] *Near the outfall*
[f] *The concentration of ^{3}H (organic) was <3.0 Bq l^{-1}*
[g] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.00053, 0.0026 and 0.000010 Bq kg^{-1} respectively*
[h] *The concentration beta activity was 810 Bq kg^{-1}*

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over river bank			
Outfall (Sutton Courtenay)	Mud and sand	1	0.10
Outfall (Sutton Courtenay)	Soil	1	0.080
Position 'E'[b]	Mud	1	0.10
Position 'E'[b]	Soil	1	0.087

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

Table 5.3(a). Radioactivity in food and the environment near Winfrith, 1998

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{60}Co	^{65}Zn	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Aquatic samples									
Cod	Weymouth Bay	2	<0.07	<0.18	0.31			<0.10	
Plaice	Weymouth Bay	2	<0.05	<0.14	<0.19			<0.06	
Crabs	Chapman's Pool	1	0.85	<0.31	<0.13	0.000071	0.00041	0.00077	0.000046
Crabs	Lulworth Banks	1	0.76	<0.15	<0.05	0.00024	0.0011	0.0018	0.000021
Pacific Oysters	Poole	1	0.12	<0.11	<0.04			<0.19	
Cockles	Poole	1	1.9	<0.13	<0.05			<0.16	
Whelks	Weymouth Bay	1	0.56	<0.14	<0.05			<0.24	
Whelks	Poole	1	0.56	<0.11	<0.04	0.00049	0.0027	0.0027	0.000062
Fucus serratus[g]	Kimmeridge	2	0.95	<0.15	0.06			<0.09	
Fucus serratus	Bognor Rock	2	0.93	<0.13	<0.05			<0.10	
Mud	Parkstone Bay	2	1.4	<0.55	1.2	0.066	0.34	0.30	0.0046

Material	Location or selection[d]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples								
Milk	Near farms[e]	4	<2.7	<0.41	<0.38			
Milk	Near farms[e] max		<2.8	<0.43	<0.40			
Apples[e]		1	<3.0	<0.50	<0.40			
Cabbage[e]		1	<3.0	<0.40	<0.40			
Carrots[e]		1	<3.0	<0.60	<0.60			
Honey		1	<4.0	<0.30	1.2			
Raspberries[e]		1	<3.0	<0.40	<0.40			
Grass[f]		4	<3.5					
Grass[f]	max		5.0					
Dry cloths		60				0.06	0.66	0.37

[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 concentration of ^{3}H (organic) was <3.0 Bq l^{-1}*
[f] *The concentration of ^{3}H (organic) was <3.5 Bq l^{-1}*
[g] *The concentration of beta activity was 150 Bq kg^{-1}*

Table 5.3(b). Monitoring of radiation dose rates near Winfrith, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Parkstone Bay	Mud, sand and stones	1	0.058
Parkstone Bay	Sand	1	0.049

[a] *See section 3 for definition*

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 1998. For consistency with previous reports in this series, they are grouped here under the general description 'electricity companies'. Two of the companies, Nuclear Electric Ltd and Scottish Nuclear Ltd, became British Energy Generation Ltd. and British Energy Generation (UK) Ltd. respectively with effect from 31 December 1998. With effect from 1 April 1998, power stations within Magnox Electric plc became part of Magnox Generation Business Group, BNFL plc. This Group includes other sites which are considered in Section 4.

6.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley Power Station ceased electricity generation in March 1989, but small amounts of 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 Technology 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 1998 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. Most of the artificial radioactivity detected was due to tritium, carbon-14, radiocaesium and sulphur-35. Concentrations of radiocaesium represent the combined effect of disposals from the sites, other nuclear establishments discharging into the Bristol Channel, weapon test and Chernobyl fallout, and possibly a small Sellafield-derived component. Most of the tritium and carbon-14 in seafood is due to disposals from the Nycomed Amersham site at Cardiff. 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 low, at 0.009 mSv or less than 1% of the dose limit of 1 mSv.

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 potatoes. Carbon-14 was detected in local fruit, at levels slightly above background values. The most exposed group dose continued to be low and was estimated to be 0.005 mSv or 0.5% of the 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. 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 external exposure of people who live on houseboats in muddy areas of the estuary and consumption of locally-caught fish and shellfish. 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 1998 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 disposals from the station, Sellafield disposals, and weapon test and Chernobyl fallout. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were similar to those for 1997 (MAFF and SEPA, 1998). A calculation based on concentrations of radionuclides in sediments has been used to estimate the external exposure of the houseboat dwellers who were the most exposed group in 1998. Their dose, including the effects of consumption pathways, was small, amounting to 0.011 mSv or 1% of the dose limit of 1 mSv.

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 or 0.5% of the dose limit 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 1998 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 in 1998 continued to be represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.014 mSv or 1% of the dose limit 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 in fruit, honey and legumes. 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 be due to other sources, e.g. weapon test and Chernobyl fallout. The maximum dose due to gaseous disposals was received by adults. Their dose in 1998 was estimated to be less than 0.005 mSv or 0.5% of the dose limit.

6.4 Hartlepool, Cleveland

This station is powered by twin AGRs. A habits survey was undertaken in 1998 to examine 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

sampling and measurement programmes at Hartlepool were similar to those for other power station sites. However technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield.

Results of the monitoring programme carried out in 1998 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 1998 was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

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 seawater concentrations 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 1998. An increase in the level of technetium-99 in *Fucus vesiculosus* was apparent this year (110 Bq kg^{-1}: 1998; 98 Bq kg^{-1}: 1997). While disposals of technetium-99 from Sellafield decreased in 1998, the increase 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. Gamma and beta dose rates were difficult to distinguish from natural background with the exception of measurements at Paddy's Hole and Redcar. In these locations, waste slag from a steel works can be found containing enhanced levels of gamma-emitting natural radionuclides. The radiation dose to the most exposed group of local fish and shellfish consumers was low, at 0.005 mSv or 0.5% of the dose limit 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 1998 are given in Tables 6.5(a) and (b). In general, similar levels to those for 1997 were observed and the effect of liquid disposals from Heysham was not detectable above the Sellafield background. There were decreases in concentrations of technetium-99 in marine samples reflecting the lower discharges of this radionuclide from Sellafield. Tritium analysis in fish was introduced in 1998. None was detected. The radiation dose in 1998 to the most exposed group of fishermen including a component due to external radiation was 0.074 mSv which is well within the dose limit of 1 mSv. There was little change from the estimate for 1997 of 0.073 mSv (MAFF and SEPA, 1998). 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 difficult to detect in 1998. Small enhancements of concentrations of carbon-14 were apparent in some samples. The most exposed group dose was estimated to be 0.005 mSv or 0.5% of the dose limit 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. 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 made to establish the local effects of discharges from Cardiff.

The results for 1998, 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 and crops 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 0.011 mSv or 1% of the dose limit of 1 mSv.

During a routine test of a filter on one of Hinkley Point A's reactors, a small quantity of test gas containing iodine-131 was released. The release was estimated to be 1.5 MBq. Three grass and one milk sample were taken from the area over which the activity was predicted to have travelled. Levels were similar to those expected under normal operation and no iodine-131 could be detected. The assessed radiation dose was low and confirmed there was no significant or additional risk to consumers of locally produced food.

The concentrations observed in the Bristol Channel were generally similar to those in 1997. The concentration of tritium in seawater decreased in 1998 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 1998 was represented by local fishermen who were estimated to receive an dose of 0.013 mSv or 1% of the dose limit 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 'A' and 'B' nuclear power stations; the 'A' station was powered by twin Magnox reactors and the 'B' station is powered by a pair of AGRs. The 'A' station ceased power production at the end of March 1990. Liquid radioactive waste disposals are made to the Firth of Clyde at a common point under authorisations granted by SEPA. Gaseous disposals are made separately from 'A' and '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 fish and shellfish and measurement of gamma dose rate on the foreshore. Samples of sand are also analysed in support of the gamma dose rate measurements and sea water and *Fucus* seaweed are analysed as indicator materials. Quarterly samples of milk, comprised of bulked samples, and grass are taken for the terrestrial programme.

The results of monitoring in 1998 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 activation products such as manganese-54 were probably due to disposals from the site; however, these were of negligible radiological significance. In 1998, the dose, including external radiation, to members of the most exposed group of fish and shellfish consumers near Hunterston was low, at 0.025 mSv or less than 3% of the dose limit of 1 mSv.

The concentrations of radionuclides in milk and grass were generally low and similar to previous years' results. The radiation dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon test and Chernobyl fallout, was 0.020 mSv or 2% of the dose limit 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). Station 'B' 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 1998 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 weapon test and Chernobyl fallout. Tritium levels in seafood were below the limit of detection. Trace levels of activation products were likely to have been due to disposals from the power stations though there was no conclusive evidence of the effects of the new 'B' station. In 1998, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv or 0.5% of the dose limit 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 and sulphur-35 in milk, crops and fruit showed very low levels of artificial radioactivity near the power stations in 1998. Trace quantities of sulphur-35 were detected in some samples. The estimated dose to the most exposed group of consumers eating such foods was 0.009 mSv or less than 1% of the dose limit of 1 mSv. There has been no significant increase in levels of radioactivity in foodstuffs due to the operation of the PWR.

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.

Results of this monitoring in 1998 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 test and Chernobyl fallout, though trace levels of activation products were likely to have been due to disposals from the station. The group of fish and shellfish consumers received a low dose, 0.006 mSv, or less than 1% of the dose limit of 1 mSv. The beta radiation from fishermen's nets and pots was typical of that due to natural radiation and the most exposed group of terrestrial food consumers would have received a dose, including a contribution due to weapon test and Chernobyl fallout, of 0.016 mSv, or less than 2% of the dose limit of 1 mSv.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned. Low level disposals continued during 1998 under authorisations granted by the Environment Agency. Disposals of liquid radioactive waste were made to a freshwater lake making the power station unique in UK terms. Monitoring is carried out on behalf of the Welsh Office. 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 caesium 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 which they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than those of indigenous fish. However, larger and older rainbow trout are now being observed.

The results of the terrestrial programme, including those for local milk, crops and indicator materials, are shown in Tables 6.10 (a) and (b). Concentrations of activity in all terrestrial foods were low, the most significant being that of 17 Bq kg^{-1} of radiocaesium in hazelnuts. The most likely source of radiocaesium in this and other samples 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. In all cases, 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 1998.

The most exposed group for terrestrial foods at Trawsfynydd in 1998 received doses of 0.006 mSv or 0.6% of the dose limit of 1 mSv. This assessed dose includes a contribution from the caesium activity detailed above.

In the lake itself, there remains clear evidence for the effects of disposals from the power station. Concentrations of caesium considerably exceed 1000 Bq kg^{-1} in the mud from the bed of the lake. 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 1997.

The concentrations of caesium-137 in lake water remained above those for water coming into the lake via the Afon Prysor but were less than those in 1997. There were also small decreases in concentrations of radiocaesium in fish in 1998. For instance brown trout from the lake averaged 120 Bq kg^{-1} in 1998 compared to 150 Bq kg^{-1} in 1997. Taking this and the results of measurements of gamma dose rates into account, the dose to the most exposed group of anglers was 0.023 mSv in 1998, or about 2% of the dose limit of 1 mSv.

6.11 Wylfa, Isle of Anglesey

Gaseous and liquid wastes from this station were discharged in 1998 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 Welsh Office. Such disposals and effects are very low.

The results of the programme in 1998 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 or less than those for 1997, 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 0.010 mSv or 1% of the dose limit of 1 mSv. Gamma dose rates, measured using portable instruments, continued to be difficult to distinguish from the natural background, but a small contribution due to external exposure of the most exposed group has been included in the total above.

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. However, the dose received by high-rate food consumers remained low at less than 0.005 mSv or 0.5% of the dose limit.

Table 6.1(a). Radioactivity in food and the environment near Berkeley and Oldbury nuclear power stations, 1998

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	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples											
Salmon	Beachley	1	<130	37	<0.09	0.28	<0.22			<0.21	
Elvers	Littleton Warth	1			<0.06	0.07	<0.16			<0.24	
Shrimps	Guscar	1	4800	160	<0.08	0.37	<0.22	0.00015	0.00077	0.00090	0.000018
Fucus vesiculosus[f]	Pipeline[d]	2			<0.05	0.38	<0.10			<0.09	
Mud	Hills Flats	2			<0.78	29	2.4			0.65	
Mud	1km south of Oldbury	2			0.97	29	1.6			<1.1	

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	8	<3.8	18	<0.59	<0.34	<0.39			
Milk	Near farms max		<4.3	22	<0.90	<0.40	<0.43			
Milk	Far farms	1	<4.0	15	<0.57	<0.33	<0.43			
Apples		1	<3.0	14	<0.40	<0.30	<0.40			
Blackberries		1	<3.0	38	0.50	<0.30	<0.40			
Cabbage[e]		1	<3.0	6.0	<0.40	<0.40	<0.40			
Carrots		1	<3.0	13	<0.30	<0.30	<0.50			
Goats milk		1	<3.0	14	<1.0	<0.20	<0.40			
Potatoes		1	<3.0	23	1.3	<0.30	<0.50			
Runner Beans		1	<3.0	11	<0.40	<0.40	<0.40			
Wheat		1	<4.0	94	<0.40	<0.30	<0.50			
Dry cloths		151						0.08	0.93	0.48

[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 5 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 5*
[d] *Berkeley*
[e] *The concentration of ^{55}Fe was <0.40 Bq kg^{-1}*
[f] *The concentration of beta activity was 120 Bq kg^{-1}*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 1998

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	0.071
Sharpness	Mud	2	0.072
Hills Flats	Mud	2	0.075

[a] *See section 3 for definition*

Table 6.2(a). Radioactivity in food and the environment near Bradwell nuclear power station, 1998

Material	Location	No. of sampling observations[b]	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	1		<0.07	<0.25		<0.09	0.64	<0.23	<0.34
Herring	Bradwell	1		<0.09	<0.22		<0.09	0.39	<0.15	<0.09
Bass	Pipeline	1		<0.04	<0.11		0.43	2.6	<0.11	<0.10
Mullet	Pipeline	1		<0.06	<0.19		0.17	0.85	<0.19	<0.19
Native oysters[e]	Tollesbury N Channel	2	21	<0.05	0.39		<0.08	0.26	<0.07	0.0044
Pacific oysters	Goldhanger Creek	1		<0.11	0.87		<0.10	0.37	<0.19	<0.23
Winkles	Pipeline	2		<0.32	<0.48		<0.23	0.72	<0.32	<0.22
Fucus vesiculosus[f]	Waterside	2		0.39	<0.18	13	0.59	3.0	<0.15	<0.13
Mud	West Mersea	2		<0.69	<1.0		2.2	17	<1.3	<1.8
Mud	Maldon	2		<1.2	<1.3		6.9	62	<1.5	<2.0

Material	Location or selection[c]	No. of sampling observations[b]	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	<2.6	15	<0.41	<0.43	<0.34	<0.39			
Milk	Near farms max		<3.0	18	<0.43	<0.50	<0.40	<0.43			
Milk	Far farms	3	<2.0	16	<0.41	<0.43	<0.33	<0.41			
Milk	Far farms max			18	<0.45	<0.48	<0.35	<0.43			
Apples		1	<2.0	5.0	0.50	<0.50	<0.40	<0.40			
Blackberries		1	<3.0	15	0.90	<0.40	<0.30	<0.40			
Cabbage[d]		1	5.0	14	0.60	<0.50	<0.30	<0.40			
Carrots		1	<3.0	13	<0.50	<0.40	<0.30	<0.40			
Potatoes		1	<3.0	19	0.70	<0.40	<0.20	<0.40			
Rabbit		1	<3.0	26	<0.80	<0.40	<0.30	<0.40			
Wheat		1	<4.0	92	2.6	<0.30	<0.20	<0.30			
Lucerne		1	<3.0	16	4.4	<0.60	<0.50	<0.50			
Dry cloths		115							0.09	1.2	0.83

[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] *The concentration of ^{55}Fe was <0.40 Bq kg^{-1}*
[e] *The concentrations of ^{238}Pu, $^{239+240}$Pu, ^{242}Cm and $^{243+244}$Cm were 0.00043, 0.0019, 0.000046 and 0.00020 Bq kg^{-1} respectively*
[f] *The concentration of beta activity was 200 Bq kg^{-1}*

Table 6.2(b). Monitoring of radiation dose rates near Bradwell nuclear power station, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
West Mersea	Mud	2	0.070
Maldon	Mud	2	0.064

[a] *See section 3 for definition*

Table 6.3(a). Radioactivity in food and the environment near Dungeness nuclear power stations, 1998

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Aquatic samples												
Plaice	Pipeline	2	<120	<0.07	<0.07	0.18	<0.13			<0.11		
Cod	Pipeline	2	<120	<0.06	<0.06	0.37	<0.14			<0.16		
Bass	Pipeline	1	<130	<0.05	<0.05	0.76	<0.12			<0.12		
Spiny spider crabs	Hastings	1		0.45	<0.19	<0.17	<0.36			<0.42		
Shrimps[f]	Pipeline	2		<0.08	<0.14	0.45	<0.13			<0.08		
Whelks[g]	Pipeline	2		0.34	<0.06	<0.05	<0.14	0.0011	0.0039	0.0053	0.00021	0.00045
Fucus vesiculosus[h]	Copt Point	2		0.43	<0.07	0.17	<0.15			<0.22		
Mud	Rye Harbour	1		1.9	<0.38	1.1	1.9	0.16	0.29	0.25	0.0034	0.014
Mud & sand	Rye Harbour	1		2.2	<0.40	1.8	<0.85			<1.0		
Sea water	Pipeline	2	<1.7									

Material	Location or selection[c]	No. of sampling observations[b]	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[d]	Far farms	2	<2.8	15	<0.36	<0.45	<0.34	<0.40			
Milk[d]	Far farms max			16	<0.38	<0.48	<0.35	<0.43			
Beans		1	3.0	13	<0.30	<0.50	<0.30	<0.50			
Blackberries		1	<3.0	19	<0.30	<0.40	<0.30	<0.40			
Honey		1	5.0	93	<0.70	<0.30	<0.10	<0.30			
Peas		1	<4.0	77	2.1	<0.40	<0.30	<0.50			
Potatoes		1	<3.0	16	<0.40	<0.40	<0.40	<0.40			
Sea kale[e]		1	<3.0	7.0	<3.0	<0.40	<0.40	0.50			
Dry cloths		95							0.13	1.5	0.98

[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] *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] *There are no farms producing milk near this site*
[e] *The concentration of ^{55}Fe was <0.40 Bq kg^{-1}*
[f] *The concentration of ^{14}C was 49 Bq kg^{-1}*
[g] *The concentration of ^{90}Sr was <0.017 Bq kg^{-1}*
[h] *The concentration of beta activity was 170 Bq kg^{-1}*

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose at 1m over intertidal areas			
Rye Harbour	Mud	1	0.076
Rye Harbour	Mud and sand	1	0.064
Beta dose rates			µSv h^{-1}
Rye Harbour	Mud	1	*
Rye Harbour	Mud and sand	1	*

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

Table 6.4(a). Radioactivity in food and the environment near Hartlepool nuclear power station, 1998

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	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples												
Plaice	Pipeline	2		46	<0.05		0.41			<0.11		
Cod	Pipeline	2			<0.05		0.65			<0.13		
Crabs	Pipeline	2		57	<0.07		0.19	0.0017	0.0087	0.015	0.0024	
Winkles	Paddy's Hole	2			<0.07		0.54	0.0090	0.052	0.026	*	
Fucus vesiculosus	Pilot Station	2			<0.04	110	0.23			<0.09		280
Mud	Paddy's Hole	2			<0.36		16		<1.0			
Coal & sand	Little Scar	2			<0.18		1.1			<1.0		
Sea water	Pipeline	2	24									

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	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Far farms	6	<2.0	16	<0.60	<0.38	<0.35			
Milk	Far farms max			21	<0.75	<0.45	<0.38			
Apples		1	<3.0	16	<0.30	<0.30	<0.50			
Cabbage[e]		2	<2.5	7.5	<0.45	<0.50	<0.40			
Cabbage[e]	max		<3.0	8.0	0.50					
Elderberries		1	<3.0	34	<0.40	<0.50	<0.40			
Honey		1	3.0	83	<0.60	<0.30	<0.40			
Potatoes		1	<3.0	29	0.70	<0.50	<0.40			
Swede		1	<3.0	6.0	1.2	<0.50	<0.40			
Wheat		1	<4.0	67	<0.70	<0.60	<0.50			
Dry cloths		116						0.21	1.7	1.1

* *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' 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 <0.40 Bq kg^{-1}*

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 1998

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Middleton Harbour	Mud and sand	1	0.067
Paddy's Hole	Mud	2	0.088
Paddy's Hole	Winkle bed	2	0.21
Bran Sands	Sand	1	0.053
Redcar	Mussel bed	1	0.090

[a] *See section 3 for definition*

Table 6.5(a). Radioactivity in food and the environment near Heysham nuclear power stations, 1998[f]

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{154}Eu
Aquatic samples															
Flounder	Flookburgh	4		98		<0.15			<1.6	<0.25	<0.43	*	<0.15	17	<0.46
Plaice	Morecambe	4	<120			<0.11	0.039	1.6	<0.98	<0.18	<0.25	*	<0.10	6.6	<0.31
Bass	Morecambe	2				<0.15			<1.5	<0.31	<0.42	*	<0.16	18	<0.46
Whitebait	Sunderland Point	1				<0.08	0.20		<0.67	<0.12	<0.20	*	<0.08	5.8	<0.20
Shrimps	Flookburgh	4		77		<0.09		11	<0.83	<0.16	<0.22	*	<0.09	6.8	<0.24
Cockles	Middleton Sands	2				1.7			<1.2	<0.13	<0.17	*	<0.07	4.0	<0.19
Cockles	Flookburgh	4		84		1.4	0.44	25	1.5	<0.11	<0.16	*	<0.06	5.7	<0.16
Winkles	Red Nab Point	4				0.91			2.0	0.52	<0.25	<0.18	<0.08	5.3	<0.23
Mussels	Morecambe	4		87		0.66		250	1.6	<0.10	<0.16	*	<0.06	3.3	<0.14
Fucus vesiculosus	Half Moon Bay	4				0.91		3600	<0.77	<0.16	<0.21	<0.55	<0.10	5.9	<0.27
Samphire	Cockerham Marsh	1				<0.04			<0.34	<0.07	<0.08	*	<0.04	1.6	<0.10
Mud & sand	Flookburgh	4				<0.47			<4.5	<0.81	<1.4	*	<0.53	83	<1.3
Mud & sand	Half Moon Bay	4				8.5			13	<1.1	<2.4	<2.8	<0.76	190	<2.2
Mud & sand	Morecambe Central Pier	4				4.0			<8.7	<0.76	<1.6	*	<0.58	150	<1.3
Turf	Conder Green	4				3.4			<10	<1.3	<3.6	<2.5	<1.0	360	<2.8
Turf	Sand Gate Marsh	4				<1.1			<9.7	<1.4	<3.3	<2.9	<1.0	260	<2.6
Sea water	Pipeline	2	37												
Sea water	Half Moon Bay	1											0.0031	0.23	
Terrestrial samples															
Milk	Near farms	6	<3.9	18	<0.55	<0.41			<3.1	<0.48			<0.33	<0.41	
Milk	Near farms max		<4.5	21	<0.63	<0.45			<3.4	<0.53			<0.35	<0.43	
Apples		1	<3.0	13	0.40	<0.60			<3.2	<0.70			<0.40	<0.50	
Barley		1	<4.0	64	1.5	<0.60			<2.9	<0.70			<0.40	<0.60	
Beetroot		1	3.0	13	0.90	<0.50			<2.8	<0.50			<0.40	<0.50	
Cabbage[e]		1	7.0	5.0	0.80	<0.50			<3.1	<0.60			<0.40	<0.50	
Mushrooms		1	<3.0	9.0	<0.40	<0.30			<1.9	<0.30			<0.20	<0.30	
Potatoes		2	<2.5	20	<0.45	<0.45			<3.0	<0.50			<0.35	<0.45	
Potatoes	max		<3.0		0.60	<0.60			<3.6	<0.60			<0.40	<0.50	
Sprouts		1	<3.0	10	1.3	<0.50			<4.0	<0.30			<0.40	<0.50	
Sprout tops		1	<2.0	18	1.4	<0.40			<3.4	<0.30			<0.40	<0.50	
Grass		1				<0.60			<3.6	<0.70			<0.40	0.60	

Table 6.5(a). continued

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Aquatic samples								
Flounder	Flookburgh	4	0.00031	0.0019		0.0034	0.000041	*
Plaice	Morecambe	4				<0.29		
Bass	Morecambe	2				<0.25		
Whitebait	Sunderland Point	1	0.048	0.26	2.8	0.41	*	0.00067
Shrimps	Flookburgh	4	0.0057	0.031	0.37	0.052	*	0.00019
Cockles	Middleton Sands	2	0.35	1.9		4.9	*	0.0065
Cockles	Flookburgh	4	0.43	2.4	25	6.0	*	0.0094
Winkles	Red Nab Point	4	0.30	1.6		3.0	*	0.0038
Mussels	Morecambe	4	0.33	1.8		3.1	*	0.0042
Fucus vesiculosus[g]	Half Moon Bay	4				0.81		
Samphire[h]	Cockerham Marsh	1				0.71		
Mud & sand	Flookburgh	4				39		
Mud & sand	Half Moon Bay	4	11	63		100	0.093	0.12
Mud & sand	Morecambe Central Pier	4				87		
Turf	Conder Green	4				180		
Turf	Sand Gate Marsh	4				100		
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} and for sediment 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*
[d] *See section 3 for definition*
[e] *The concentration of ^{55}Fe was 0.40 Bq kg^{-1}*
[f] *84 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.06, 0.71 and 0.42 Bq per cloth respectively*
[g] *The concentration of beta activity was 2900 Bq kg^{-1}*
[h] *The concentration of beta activity was 32 Bq kg^{-1}*

Table 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Sand Gate marsh	Saltmarsh	4	0.10
Flookburgh	Mud and sand	4	0.077
High Foulshaw	Saltmarsh	4	0.094
Arnside	Saltmarsh	4	0.11
Morecambe Central Pier	Mussel bed	4	0.081
Morecambe Central Pier	Mud and sand	4	0.081
Half Moon Bay	Mud	1	0.083
Half Moon Bay	Mud and sand	3	0.083
Colloway Marsh	Saltmarsh	4	0.16
Aldcliffe Marsh	Saltmarsh	4	0.12
Conder Green	Mud and sand	4	0.11
Conder Green	Saltmarsh	4	0.12
Cockerham Marsh	Saltmarsh	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, 1998

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	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Aquatic samples														
Flounder	Stolford	1	3200	110	<0.03	<0.03	0.06	0.54	<0.09			<0.10		
Sole	Stolford	1	900		<0.09	<0.08	<0.09	0.46	<0.24			<0.33		
Shrimps	Stolford	2	1900	110	<0.07	<0.06	<0.09	0.55	<0.19	0.00025	0.00078	0.0012	0.000078	0.000042
Fucus vesiculosus[f]	Pipeline	2			0.54	1.1	3.9	14	<0.19			<0.25		
Mud	1.6km east of pipeline	2			<0.59	<0.53	5.2	29	<1.8			<1.5		
Mud	River Parrett	1			<0.52	<0.49	1.2	34	<1.5			<1.7		
Mud and sand	River Parrett	1			<0.84	<0.81	2.6	36	<2.4			<3.6		
Sea water	Pipeline	2	31											

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	^{60}Co	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples												
Milk	Near farms	5	<3.1	20	<0.68	<0.41		<0.34	<0.38			
Milk	Near farms max		<3.8	27	1.2	<0.48		<0.35	<0.40			
Milk	Far farms	1	<2.0	13	<0.43	<0.38		<0.28	<0.38			
Apples		1	<3.0	12	<0.50	<0.50		<0.40	<0.50			
Blackberries		1	5.0	23	<0.40	<0.30		<0.30	<0.40			
Cabbage[e]		1	<3.0	5.0	2.8	<0.50		<0.40	<0.40			
Honey		1	<4.0	87	<0.50	<0.30		<0.20	1.4			
Potatoes		1	4.0	52	1.5	<0.50		<0.40	<0.40			
Runner beans		1	6.0	13	4.4	<0.50		<0.30	<0.40			
Wheat		1	<4.0	92	1.0	<0.60		<0.40	<0.50			
Fodder Beet		1	<2.0	17	<0.30	<0.40		<0.30	<0.40			
Grass		3					<1.4					
Grass	max						<1.8					
Dry cloths		105								0.09	1.1	0.86

[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 <0.40 Bq kg^{-1}*
[f] *The concentration of beta activity was 230 Bq kg^{-1}*

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 1998

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
1.6 km east of pipeline	Mud	2	0.066
River Parrett	Mud	2	0.077

[a] *See section 3 for definition*

Table 6.7(a). Radioactivity in food and the environment near Hunterston nuclear power station, 1998

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{54}Mn	^{60}Co	^{65}Zn	^{106}Ru	^{110m}Ag	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples													
Cod	Millport	2	<0.10	<0.10	<0.20	<0.67	<0.10	2.7	<0.35	<0.30			<0.30
Hake	Millport	2	<0.10	<0.10	0.17	<0.71	<0.10	2.8	<0.35	<0.30			<0.37
Crabs	Millport	1	<0.10	<0.10	<0.20	<1.0	<0.10	<0.50	<0.50	<0.50	0.0062	0.016	0.025
Nephrops	Millport	2	<0.12	<0.12	<0.20	<1.1	<0.12	5.7	<0.54	<0.39			<0.53
Lobsters	Largs	1	<0.10	<0.10	<0.20	<0.10	<0.10	1.6	<0.32	<0.11			0.22
Squat lobsters[g]	Largs	4	<0.10	<0.10	<0.20	<0.68	<0.10	0.47	<0.43	<0.33	0.0059	0.032	0.018
Oysters	Fairlie	1	0.12	<0.10	<0.20	<0.10	<0.10	0.28	<0.26	<0.10			<0.10
Winkles	Pipeline	2	3.3	0.89	<0.20	<1.2	<0.46	1.0	<0.55	<0.40	0.036	0.13	0.046
Scallops	Largs	4	<0.10	<0.10	<0.20	<0.66	<0.10	0.70	<0.41	<0.31	0.0052	0.024	0.0041
Fucus vesiculosus[e]	Pipeline	2	8.2	<0.85	0.14	1.5	<0.10	2.0	<0.40	<0.30			<0.11
Sand	Pipeline	2	0.71	<0.10	<0.20	<0.85	<0.10	11	<0.45	<0.49			<0.34
Sea water[f]	Pipeline	9						<0.072					

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	<26	20	<5.0	<0.10	0.21	
Milk	max		28	24			0.41	
Grass		4		13	<5.0	0.52	0.31	<0.98
Grass	max			16		0.69	0.56	1.4

[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 concentrations of ^{46}Sc and ^{51}Cr were 0.18 and 8.6 Bq kg^{-1} respectively*
[f] *The concentration of ^{3}H was 6.6 Bq l^{-1}*
[g] *The concentration of ^{99}Tc was 2.8 Bq kg^{-1}*

Table 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 1998

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	0.057
0.5 km south of pipeline	Sand and stones	2	<0.059

[a] *See section 3 for definition*

Table 6.8(a). Radioactivity in food and the environment near Sizewell nuclear power stations, 1998[f]

Material	Location[b]	No. of sampling observations[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	<120		<0.04	0.63	<0.11			<0.11		
Sole	Sizewell	1	<130		<0.15	0.40	<0.22			<0.11		
Crabs	Sizewell	2	<120	46	<0.15	<0.20	<0.34	0.00096	0.0053	0.0094	0.000049	
Pacific oysters	Blyth estuary	1			<0.03	0.08	<0.07			<0.10		
Whelks	Dunwich	1			<0.17	<0.14	<0.23			<0.11		
Mud	Southwold	2			2.3	13	<1.4			<1.3		830
Sand	Aldeburgh	2			<0.14	0.20	<0.46			<0.58		
Sea water	Aldeburgh	2	3.2									

Material	Location[b] or selection[c]	No. of sampling observations[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	<2.9	15	<0.55	<0.42		<0.41				
Milk	Near farms max		<3.3	16		<0.45		<0.43				
Milk	Far farms	3	<2.0	24	<0.53	<0.41		<0.43				
Milk	Far farms max			27	<0.55	<0.45		<0.45				
Apples		1	3.0	13	0.90	<0.30		<0.40				
Blackberries		1	2.0	23	<0.30	<0.40		<0.40				
Cabbage[e]		1	<3.0	<3.0	4.1	<0.50		<0.40				
Carrots		1	<3.0	9.0	0.40	<0.30		<0.40				
Honey		1	<4.0	76	<1.1	<0.50		<0.50				
Ovine muscle		1	<3.0	42	<1.8	<0.50	0.11		0.41	<0.00080	<0.00050	0.00050
Ovine offal		1	<5.0	39	2.7	<0.40	<0.020		0.17	<0.00030	0.00020	0.00050
Porcine muscle		1	3.0	30	3.7	<0.50	<0.044		0.77	<0.00020	<0.00020	0.00070
Porcine kidney		1	<3.0	21	<1.4	<0.40	0.036		0.24	0.00030	<0.00030	0.00050
Potatoes		1	<3.0	20	0.90	<0.30		<0.40				
Runner Beans		1	<3.0	8.0	<0.40	<0.50		<0.40				
Wheat		1	<4.0	110	0.70	<0.40		<0.40				

[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] *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 5 for definition.*
[d] *See section 3 for definition*
[e] *The concentration of ^{55}Fe was <0.50 Bq kg^{-1}*
[f] *113 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.10, 1.2 and 0.79 Bq per cloth respectively*

Table 6.8(b). Monitoring of radiation dose rates near Sizewell nuclear power stations, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Aldeburgh	Sand and gravel	2	0.048
Southwold Harbour	Mud	2	0.064
Beta dose rates			µSv h^{-1}
Southwold Harbour	Mud	2	*

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

Table 6.9(a). Radioactivity in food and the environment near Torness nuclear power station, 1998

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	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu +^{240}Pu	^{241}Am
Aquatic samples											
Cod	Pipeline	2		<0.10	<0.10		0.92	<0.31			<0.31
Crabs	Cove	2		<0.10	<0.10		<0.11	<0.30			<0.30
Lobsters	Cove	1		<0.10	<0.31	26	<0.28	<0.50			<0.50
Nephrops	Dunbar	4		<0.11	<0.11		0.62	<0.34	0.0019	0.0067	0.0062
Winkles[e]	Pipeline	2		0.22	<0.18		0.31	<0.39			<0.35
Fucus vesiculosus	Pipeline	2		0.60	0.29		0.80	<0.33			<0.15
Mud	Eyemouth Harbour	1		<0.10	<0.10		3.0	<0.50			<0.50
Mud and sand	Dunbar inner harbour	2		<0.10	<0.10		3.6	<0.74			<0.58
Mud and sand	Barns Ness	1		<0.10	<0.10		3.8	<0.50			<0.50
Sand	Thornton Loch Beach	2		<0.10	<0.10		1.7	<0.36			<0.42
Seawater	Pipeline	12	<4.7				<0.06				

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	^{90}Sr	^{137}Cs	Total alpha
Terrestrial samples								
Milk		3	<25	18	<5.0	<0.10	<0.08	
Milk	max			20			0.10	
Grass		6		27	<5.0	0.24	<0.20	2.2
Grass	max			57		0.39	0.27	3.1

[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 beta activity was 53 Bq kg^{-1}*

Table 6.9(b). Monitoring of radiation dose rates near Torness nuclear power station, 1998

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	0.055
Skateraw Harbour	Sand	2	0.046
Thornton Loch Beach	Sand	2	0.046
Eyemouth Harbour	Mud	1	0.055
Dunbar Inner Harbour	Mud and sand	2	0.074
St Abbs	Sand	2	0.081
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, 1998[e]

Material	Location or selection[c]	No. of sampling observations[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		50		<0.21	3.1	<1.0	2.1	120	Brown
Rainbow trout	Lake	6				<0.13		<0.31	<0.14	2.9	
Perch	Lake	4				<0.15	1.8	<1.2	3.9	180	
Rudd	Lake	1				<0.12		<1.0	4.5	200	
Fontinalis	Afon Prysor	2				<0.21		<0.60	<0.41	7.9	
Fontinalis	Gwylan Stream	2				3.4		<1.7	<0.69	32	
Mud	Barrier wall	2				70		230	50	3500	
Water	Bailey bridge	2	<2.3						<0.00076	0.033	
Water	Cold lagoon	2							<0.00073	0.031	
Water	Afon Prysor	2							*	0.0036	
Terrestrial samples											
Milk	Near farms	1	<2.8	16		<0.45	0.082	<0.93			0.14
Milk	Far farms	1	<2.8	16		<0.38	0.12	<0.85			0.16
Blackberries		1	<3.0	15	<0.40	<0.40		<0.70	<0.30	<0.50	
Cabbage[d]		1	3.0	8.0	0.70	<0.50		<1.3	<0.30	<0.50	
Carrots		1	<3.0	16	<0.30	<0.30		<0.90	<0.30	<0.40	
Chicken		1	<3.0	33	0.80	<0.50		<1.6	<0.30	<0.50	
Hazelnuts		1	<4.0	23	<2.2	<1.0		<1.7	<0.60	17	
Ovine muscle		2	<3.0	37		<0.50	<0.025	<1.1			1.5
Ovine muscle	Max			44			0.034				2.1
Ovine offal		2	<5.0	37		<0.45	0.69	<0.85			0.90
Ovine offal	Max		5.0	38		<0.50	0.76	<1.0			0.93
Potatoes		1	<3.0	24	<0.40	<0.50		<0.80	<0.30	<0.50	

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Am	$^{243+244}$Cm
Freshwater samples									
Brown trout	Lake	6	<1.6	<0.61	<0.74	0.00023	0.00094	0.0016	0.000013
Rainbow trout	Lake	6	<0.70	<0.40	<0.33			<0.41	
Perch	Lake	4	<2.0	<0.46	<0.88	0.00030	0.00012	0.0024	0.000014
Rudd	Lake	1	<1.5	<0.39	<0.58			<0.30	
Fontinalis	Afon Prysor	2	<1.5	<0.60	2.5			<0.76	
Fontinalis	Gwylan Stream	2	<2.3	<1.2	1.9			<1.6	
Mud	Barrier wall	2	<20	30	20			130	
Water	Bailey bridge	2							
Water	Cold lagoon	2							
Water	Afon Prysor	2							
Terrestrial samples									
Milk	Near farms	1	<2.0	<0.50	<0.63				
Milk	Far farms	1	<1.9	<0.43	<0.58				
Blackberries		1	<1.7	<0.40	<0.50	<0.00030	0.00020	0.0024	
Cabbage[d]		1	<3.0	<0.70	<0.90				
Carrots		1	<1.9	<0.40	<0.50	<0.00020	0.00050	<0.00030	
Chicken		1	<3.9	<0.90	<2.4	<0.00010	<0.00010	<0.00040	
Hazelnuts		1	<3.9	<0.70	<1.0				
Ovine muscle		2	<1.9	<0.55	<0.60	<0.00010	<0.00020	<0.00045	
Ovine muscle	Max		<2.0	<0.60	<0.70		0.00020	<0.00050	
Ovine offal		2	<1.7	<0.45	<0.65	<0.00025	<0.00040	<0.00060	
Ovine offal	Max		<2.3	<0.50	<0.70	<0.00030	0.00060	<0.00090	
Potatoes		1	<2.1	<0.50	<0.70	0.00020	0.00040	0.00030	

* *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 <0.40 Bq kg^{-1}*

[e] *120 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.08, 1.2 and 0.53 Bq per cloth respectively*

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over areas near lake shoreline			
Bailey Bridge	Mud and stones	1	0.083
Bailey Bridge	Grass	1	0.072
South end of lake	Peat	1	0.063
South end of lake	Grass	1	0.055
Cae Adda boat mooring	Peat	2	0.065
Footbridge	Rock	2	0.089
Nant Islyn Bay	Mud and stones	1	0.097
Nant Islyn Bay	Grass	1	0.075
West of footbridge	Stones	1	0.096
West of footbridge	Grass	1	0.081

[a] *See section 3 for definition*

Table 6.11(a). Radioactivity in food and the environment near Wylfa nuclear power station, 1998

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples													
Plaice	Pipeline	2	52	<0.14		1.3	<0.29			<0.31			
Lobster	Pipeline	2		<0.11	59	0.34	<0.23	0.0015	0.0082	0.0079	*	0.00011	100
Winkles[e]	Cemaes Bay	2		<0.08		0.64	<0.12	0.025	0.14	0.19	0.00053	0.00035	
Fucus vesiculosus	Cemaes Bay	2		<0.06		1.0	<0.13			<0.17			640
Mud	Cemlyn Bay	2		<0.51		160	<2.0	3.9	22	31	*	0.052	
Seawater	Cemaes Bay	1				0.02							

Material	Location or selection[c]	No. of sampling observations[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	<3.0	16	<0.60	<0.40	<0.40			
Milk	Near farms max		<3.8	22	<0.78	<0.43	<0.45			
Apples		1	3.0	14	0.40	<0.50	<0.40			
Barley		1	4.0	150	35	<0.60	<0.40			
Blackberries		1	<3.0	24	8.0	<0.30	<0.40			
Broad beans		1	<5.0	31	2.2	<0.40	<0.50			
Cabbage[d]		1	<3.0	6.0	0.90	<0.50	<0.50			
Carrots		1	<3.0	13	0.50	<0.30	<0.40			
Goats milk		2	<3.0	12	0.90	<0.50	<0.50			
Goats milk	max				1.3					
Honey		1	<4.0	68	<0.70	<0.40	<0.40			
Marrow		1	<3.0	6.0	<0.60	<0.40	<0.50			
Potatoes		1	<3.0	22	<0.30	<0.50	<0.40			
Dry cloths		87						0.11	1.1	0.53

* *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] *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] *The concentration of ^{55}Fe was <0.40 Bq kg^{-1}*
[e] *The concentration of ^{241} Pu was 1.4 Bq kg^{-1}*

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Cemaes Bay	Sand	4	0.051
Cemlyn Bay	Mud	4	0.073

[a] *See section 3 for definition*

7. DEFENCE ESTABLISHMENTS

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

7.1 Aldermaston, Berkshire

The Atomic Weapons Establishment at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. 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. Habits 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 or 0.5% of the dose limit 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 1997. The most likely source of the radionuclides detected was natural background or weapon test fallout. The maximum dose was assessed to be for adults. The dose in 1998, including contributions from the natural and fallout sources, was 0.005 mSv or 0.5% of the dose limit of 1 mSv.

7.2 Barrow, Cumbria

Whilst the site operated by Vickers Shipbuilding and Engineering Ltd (Marconi Marine (VSEL) Ltd. with effect from 16 October 1998) 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. No discharges were made in 1998. However the monitoring programme continued to provide baseline levels. 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 dose limit 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 and the Ministry of Defence under authorisation into the Tamar Estuary. The monitoring programme in 1998 consisted of measurements of gamma dose rates and analysis of seafood and indicator materials. The results given in Tables 7.2(a) and (b) were similar to those in 1997. No 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 0.019 mSv or 2% of the dose limit of 1 mSv. The radiological significance of this, in common with other defence establishments, continued to be low.

7.4 Faslane, Argyll and Bute

Disposals of liquid radioactive waste into Gare Loch are made under letter of agreement by the Ministry of Defence. The monitoring programme in 1998 was undertaken primarily to investigate external radiation pathways. Levels of cobalt-60 in sediments shown in Table 7.2(a) could be attributed to local disposals but the concentrations were very low. Caesium-137 concentrations were consistent with the distant effects of disposals from Sellafield and weapon test and Chernobyl fallout. Gamma dose rates were difficult to distinguish from natural background (Table 7.2(b)). The dose to the most exposed group was 0.011 mSv in 1998 or 1% of the dose limit 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 at Greenwich, grass is sampled and analysed by gamma spectrometry. In 1998, 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 1998.

The reactor at this site is being decommissioned.

7.6 Holy Loch, Argyll and Bute

A small programme of monitoring Holy Loch continued in surveillance of 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. However, measurements of gamma dose rates in intertidal areas were difficult to distinguish from natural background (Tables 7.2(a) and (b)). The external dose to the most exposed group was 0.006 mSv in 1998 or 0.6% of the dose limit of 1 mSv.

7.7 Rosyth, Fife

Activities at the Rosyth Royal Dockyard continued to give rise to disposals of low levels of liquid radioactive waste into the Firth of Forth. Controlled discharges of gaseous radioactive waste on four occasions were reported during the year. All disposals were within the authorised discharge activity limits.

Rosyth Royal Dockyard Limited reported the discharge of liquid radioactive waste into the River Forth outside the permitted times of the tide on two occasions in March 1998. Given the long record of compliance with this condition, it was unusual to have two incidents so close together. Although the radiological consequences were insignificant since the waste arose from the laundry and no radioactivity was detected, the failure to follow procedures was considered to warrant action by SEPA. An Enforcement Notice was served on the Company in May 1998. The Notice required a review of procedures, a change to the format of the tide tables, retraining of operational staff and an evaluation of alternative methods for restricting the times when discharges take place. All aspects of the Notice were complied with in accordance with the specified time scale. There have been no similar events since the Notice was issued.

The monitoring programme comprised sampling and analysis of crabs and indicator materials and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 7.2(a) and 7.2(b). As was the case at other defence establishments, the radioactivity levels detected were low, and in most part due to other sources. Gamma dose rates were difficult to distinguish from natural background. The dose to the most exposed group in 1998 was estimated to be 0.008 mSv or less than 1% of the dose limit 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, 1998

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{57}Co	^{65}Zn	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am	$^{243+244}$Cm
Aquatic samples										
Pike	Newbridge	1	<120	<0.03	<0.15	<0.05	0.00053	0.0026	0.0049	0.000010
Pike	Outfall (Pangbourne)	1	<120	<0.03	<0.11	0.61	0.000010	0.000025	0.00010	*
Pike	Staines	1		<0.02	<0.10	0.26			<0.04	
Nuphar lutea	Newbridge	1	<120	<0.03	<0.13	<0.08			<0.11	
Nuphar lutea	Staines	1	<120	0.06	0.33	0.14			<0.04	
Clay[f]	Outfall (Pangbourne)	1		<0.27	<0.59	0.77			<0.93	

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{137}Cs	Total U	^{238}Pu	$^{239+240}$Pu	^{241}Am	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk[d]	Near farms	4	<2.9	<0.42	<0.0067	<0.00016	<0.00018	<0.00034			
Milk[d]	max		<3.3	<0.43	<0.0076	<0.00018	<0.00025	<0.00043			
Apples		1	<3.0	<0.30	0.75	<0.00020	0.00020	<0.00020			
Carrots		1	<3.0	<0.50	0.041	<0.00020	0.00010	<0.00040			
Honey		1	<4.0	<0.30	<0.011	<0.00030	<0.00030	0.00040			
Lettuce		1	<3.0	<0.50	1.0	0.00020	0.0040	0.0023			
Potatoes		1	4.0	<0.40	<0.023	<0.00020	0.00030	0.00050			
Raspberries		1	<3.0	<0.40	<0.023	<0.00030	0.00010	0.00080			
Runner beans		1	2.0	<0.40	0.0059	<0.00030	0.00010	0.00040			
Wheat		1	4.0	<0.50	0.025	0.00030	0.00010	0.00060			
Soil[e]		4			46						
Soil[e]	max				57						
Dry cloths		84							0.06	0.61	0.38

* *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] *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 ^{238}U was <0.0021 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 10, 0.37 and 9.7 Bq kg^{-1} respectively*

[f] *The concentration of beta activity was 450 Bq kg^{-1}*

Table 7.2(a). Radioactivity in food and the environment near naval establishments, 1998

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{106}Ru	^{125}Sb	^{131}I	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Barrow														
Mud and sand	Walney Channel (Vickerstown church)	4			<0.63	13	59	<3.1	*	190	<7.5	<3.1	<2.7	240
Grass	Barrow	2	<3.0											
Grass	max		3.0											
Devonport														
Dogfish	Plymouth Sound	1			<0.18	<0.17	<1.8	<0.40	*	<0.16	<0.95	<0.51	<0.43	<0.62
Crabs	Plymouth Sound	1		38	<0.07	<0.07	<0.64	<0.16	*	<0.06	<0.43	<0.19	<0.20	<0.28
Fucus vesiculosus	Kinterbury	2			<0.05	<0.05	<0.40	<0.10	<0.85	0.07	<0.26	<0.15	<0.13	<0.21
Mud[e]	Kinterbury	2			<0.27	<0.24	<2.2	<0.59	<2.0	3.5	<1.5	<0.76	2.2	0.15
Grass	Devonport	4	<3.0			<0.45	<2.6			<0.40	<2.2			
Grass	max					<0.50	<3.5			<0.50	<2.9			
Faslane														
Mud and sand	Carnban boatyard	2			<0.10	<0.10	<0.84	<0.35		7.9	<0.53	<0.32	<0.34	<0.46
Holyloch														
Sand	Mid-Loch	1			<0.10	<0.10	<1.0	<0.50		7.0	<0.50	<0.50	0.70	<0.50
Rosyth														
Crabs	East of dockyard	2			<0.10	<0.10	<0.68	<0.30		<0.19	<0.36	<0.30	<0.30	<0.30
Fucus vesiculosus	"	2			<0.10	<0.11	<0.65	<0.30		5.3	<0.33	<0.30	<0.30	<0.34
Mud	Port Edgar	2			<0.10	<0.12	<0.84	<0.35		5.2	<0.53	<0.32	<0.76	<0.44
Mud and sand	West of dockyard	2			<0.11	<0.14	<1.0	<0.39		4.3	<0.30	<0.35	<0.51	<0.54
Mud and sand	Blackness Castle	2			<0.12	<0.12	<1.1	<0.40		4.7	<0.67	<0.35	<0.44	<0.57
Sand	Burntisland Bay	2			<0.17	<0.12	<0.69	<0.31		0.88	<0.40	<0.30	<0.33	<0.32
Sand	East of Dockyard	2			<0.10	<0.10	<0.86	<0.36		0.59	<0.53	<0.33	<0.39	<0.46

* *not detected by the method used*
[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 for definition*
[d] *See section 3 for definition*
[e] *The concentrations of ^{238}Pu and $^{239+240}$Pu were 0.018 and 0.38 Bq kg^{-1} respectively*

Table 7.2(b). Monitoring of radiation dose rates near naval establishments, 1998

Establishment	Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas				
Barrow	Walney Channel (Vickerstown church)	Mud and sand	4	0.089
Devonport	Kinterbury	Mud	1	0.079
Faslane	Gareloch Head	Mud, sand and stones	2	0.056
Faslane	Gulley Bridge Pier	Sand and stones	2	0.059
Faslane	Rhu	Gravel	2	0.052
Faslane	Rosneath	Sand and gravel	2	0.059
Faslane	Carnban boatyard	Mud and sand	2	0.071
Holy Loch	North Sandbank	Mud and sand	1	0.069
Holy Loch	Kilmun Pier	Sand and stones	1	0.065
Holy Loch	Mid-Loch	Sand	1	0.050
Rosyth	Blackness Castle	Mud and sand	2	0.065
Rosyth	Burntisland Bay	Sand	2	0.053
Rosyth	East of Dockyard	Sand	2	0.059
Rosyth	Port Edgar	Mud	2	0.074
Rosyth	West of Dockyard	Mud and sand	2	0.063

[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 below the limit of detection.

The activity concentrations in milk and crops were generally lower than the limits of detection. However, low levels of 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 and a hypothetical consumption of fish at a rate of 1 kg year^{-1} was assumed. The anglers' dose in 1998 was much less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The dose to the most exposed group of terrestrial food consumers was assessed as being 0.007 mSv or 0.7% of the dose limit.

8.2 Cardiff, South Glamorgan

A second laboratory, situated near Cardiff, produces labelled 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 Welsh Office, 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, silage and dry cloths provide additional information.

The results of monitoring in 1998 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 1998. Additional samples of shellfish on the Welsh coast were obtained to establish the extent of the signal from Cardiff. These data suggest that the extent of contamination of the Welsh coast is limited. Further information on tritium levels in seawater and at other nuclear sites in the

8. Nycomed Amersham plc

Bristol Channel can be found in Sections 6 and 11. Research and further sampling are underway in 1999 to examine the mechanisms by which tritium becomes incorporated into biota in the marine environment.

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 0.057 mSv or 6% of the dose limit of 1 mSv. The increase over the value for 1997, 0.032 mSv (MAFF and SEPA, 1998), is largely due to the increases in the observed concentration of tritium and carbon-14 in fish. As this is only the second year of tritium in fish measurements this is not indicative of any upward trend These results are based on new consumption and occupancy data from a local habits survey undertaken in 1998.

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 including grass. Sulphur-35 and calcium-45 were also detected, the former showing a significant increase compared to 1997 levels. The source of sulphur-35 is unknown and is under investigation. All these measurements were of low radiological significance.

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

Table 8.1. Radioactivity in food and the environment near Amersham, 1998

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{57}Co	^{65}Zn	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples												
Pike	Newbridge	1	<120		<0.03	<0.15	<0.05	<0.12	0.00053	0.0026	0.0049	0.000010
Pike	Outfall (Grand Union Canal)	1	<130	26	<0.05	0.21	0.27	<0.11			<0.11	
Pike	Staines	1			<0.02	<0.10	0.26	<0.06			<0.04	
Nuphar lutea	Newbridge	1	<120		<0.03	<0.13	0.08	<0.12			<0.11	
Nuphar lutea	Outfall (Grand Union Canal)	1	<120		<0.04	<0.21	<0.07	<0.14			<0.16	
Nuphar lutea	Staines	1	<120		0.06	0.33	0.14	<0.08			<0.04	
Mud[d]	Outfall (Grand Union Canal)	1			2.0	3.0	13	1.5			<0.38	

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{35}S	^{75}Se	^{125}I	^{131}I	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk	Near farms	3	<2.8	<0.40	<0.50	<0.031	<0.026	<0.38			
Milk	Near farms max		<3.0	<0.45	<0.60	<0.037	<0.042	<0.40			
Beetroot		1	<3.0	<0.50	<0.70	<0.21		<0.50			
Cabbage		1	<3.0	1.1	<0.60	<0.12		<0.40			
Carrots		1	<3.0	<0.30	<0.30	<0.21		<0.50			
Elderberries		1	<3.0	0.80	<0.50	0.13		<0.50			
Goats milk		1	<2.0	<0.50	<0.70	0.31		<0.40			
Runner beans		1	<3.0	0.40	<0.30	<0.18		<0.40			
Strawberries		1	<3.0	1.2	<0.40	<0.091		<0.30			
Wheat		1	<4.0	0.40	<0.30	<0.16		<0.50			
Dry cloths		71							0.07	0.86	0.39

[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 beta activity was 410 Bq kg^{-1}*

8. Nycomed Amersham plc

Table 8.2(a). Radioactivity in food and the environment near Cardiff, 1998[d]

Material	Location[b]	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	Total beta
Aquatic samples								
Flounder	East of new pipeline	6	31000	640	<0.07	0.33	<0.14	
Sole	East of new pipeline	1	25000	720	<0.05	0.29	<0.15	
Cockles	Swansea Bay	1	<120	24	<0.20	<0.16	<0.33	
Cockles	Burry Inlet	1	<120	19	<0.16	<0.14	<0.36	
Cockles	Ferryside	1	<120	27	<0.07	0.07	<0.19	
Mussels	Orchard Ledges	2	41000	580	<0.11	0.38	<0.24	
Mussels	Swansea Bay	1	<120	25	<0.16	<0.14	<0.22	
Mussels	Burry Inlet	1	<120	19	<0.12	<0.11	<0.29	
Mussels	Tenby	1	<120	22	<0.17	<0.14	<0.23	
Mussels	St Ishmael	1	<120	21	<0.03	<0.03	<0.10	
Fucus vesiculosus	Orchard Ledges	2		25	<0.05	0.33	<0.11	
Fucus vesiculosus	East of new pipeline	1			0.05	0.36	<0.12	160
Fucus spiralis	East of new pipeline	1		13	<0.04	0.13	<0.10	81
Mud	East of new pipeline	2		33	<0.63	25	<1.5	
Mud	West of new pipeline	1		42	<0.56	16	<1.1	
Mud and sand	West of new pipeline	1			<0.31	14	2.1	
Sea water	Orchard Ledges East	2	28					

Material	Location[b] or selection[c]	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H (organic)	^{3}H	^{14}C	^{32}P	^{35}S	^{45}Ca	^{57}Co	^{125}I	^{134}Cs	^{137}Cs
Terrestrial samples												
Milk	Near farms	4	<24	<46	23	<0.45	<0.44	<0.38	<0.31	<0.035	<0.30	<0.38
Milk	Near farms max		41	85	28		<0.48		<0.33	<0.037	<0.35	<0.40
Milk	Far farms	2	<3.9	<6.5	19		<0.49	<0.49	<0.33	<0.035	<0.33	<0.41
Milk	Far farms max		<4.7	<8.3			<0.55	<0.60		<0.036	<0.35	<0.43
Apples		2	<4.5	12	12		1.1	0.30	<0.35	<0.082	<0.40	<0.40
Apples	max		6.0	17	14		1.2	0.40	<0.40	<0.088		
Barley		1		180	85		1.2	5.4	<0.30	<0.13	<0.40	<0.40
Bovine muscle		1	56	100	53		2.4	<0.30	<0.20	<0.073	<0.40	<0.50
Bovine offal		1	73	120	66		5.5	6.6	<0.50	<0.070	<0.20	<0.40
Cabbage		1	<3.0	<3.0	5.0		0.40	1.1	<0.20	0.11	<0.30	<0.40
Honey		1		92	73		<0.50	1.0	<0.40	<0.12	<0.30	<0.30
Ovine muscle		2	130	190	95		3.2	<0.30	<0.30	<0.053	<0.35	<0.50
Ovine muscle	max		150	200	97		3.3		<0.40	<0.058	<0.50	
Ovine offal		2	65	120	69		5.0	2.5	<0.35	<0.071	<0.30	<0.40
Ovine offal	max		91	160	79		6.0	2.8	<0.40	<0.074	<0.40	
Potatoes		1	<3.0	3.0	19		0.70	<0.40	<0.30	<0.19	<0.30	<0.50
Rape		1		5.0	110		1.7	2.7	<0.30	<0.12	<0.50	<0.50
Grass		4	<30	44	27		4.1	3.4	<0.30	<0.12	<0.30	<0.40
Grass	max		91	120	41			4.6		<0.13		
Silage		2	82	120	47							
Silage	max		150	230	62							

***** *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 0.10, 0.67 and 0.39 Bq kg^{-1} respectively*

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 1998

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
East of pipeline	Mud	2	0.077
West of pipeline	Mud	2	0.066
New Gout	Mud	1	0.071
Beta dose rates			µSv h^{-1}
East of pipeline	Mud	1	0.16
West of pipeline	Mud	1	0.14

[a] *See section 3 for definition*

9. MINOR SITES

Three 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 1998 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 1998 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 1998 were less than the limits of detection.

9.3 Rolls Royce plc, Derby, Derbyshire

Results of monitoring at Derby are presented in Table 9. 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 1997. 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 reactor at this site has now ceased operation. The reactor has been defuelled and the fuel removed for storage. Decommissioning plans are well advanced. Disposals of small amounts of radioactive wastes to sewer still take place. The only monitoring carried out is that performed by the operator.

Table 9.1. Radioactivity in the environment near Derby, 1998

Material	No. of samples	Mean radioactivity concentration, Bq kg[1]			
		Total U	^{234}U	^{235}U	^{238}U
Grass[a]	4	0.12	0.053	0.0040	0.047
Grass[a] max		0.21			
Soil[b]	4	68	31	0.93	26
Soil[b] max		110			

[a] *fresh weight*
[b] *dry weight*

10. INDUSTRIAL AND LANDFILL SITES

10.1 Albright and Wilson 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 UK marine environment has continued. Previous surveys (Rollo *et al.*, 1992) have established that an important man-made source was the 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 1998 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 1998 are shown in Table 10.1.

Analytical effort has focused on lead-210 and polonium-210 which 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. It also demonstrates the seasonal variations in concentrations which have been previously observed (Rollo *et al.*, 1992). Concentrations of lead-210 and polonium-210 were generally similar to those in 1997, however an increase in the polonium-210 content of mussels was observed. Concentrations of other natural radionuclides are difficult to distinguish from natural levels.

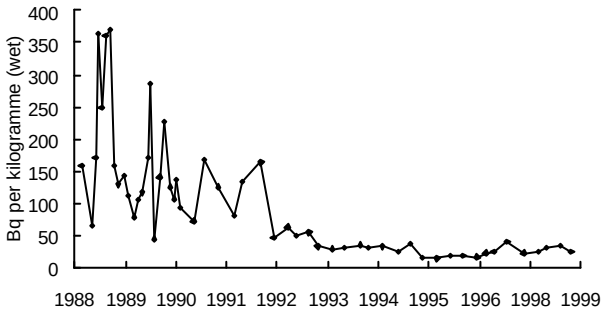

Figure 10.1 Polonium-210 in Parton winkles

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 1998 but no changes to fish and shellfish data were made. The dose to the most exposed group in 1998 was 0.31 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.

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 increased from 0.40 mSv

in 1997 (MAFF and SEPA, 1998) to 0.49 mSv in 1998, the increase being due to higher levels of polonium-210 in mussels. 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 polonium-210 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.

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 1998 these exposures added a further 0.074 mSv to the doses above resulting in a total dose to this group of up to 0.56 mSv. The estimated doses in 1998 are therefore well within the dose limit for members of the public of 1 mSv.

10.2 Scotoil, Aberdeen

Another possible source of enhancement of natural radionuclides in the marine environment can be found at Aberdeen. Prior to the setting up of the decontamination facility for equipment from the oil and gas industry that is contaminated with enhanced levels of radionuclides of natural origin, a phosphogypsum process was operated on the site with discharges to sea. Scotoil as the operator of the facility has an authorisation granted by SEPA to discharge small amounts of radioactive waste to sea near the Harbour. The authorisation includes conditions requiring environmental monitoring. Contractors carry this out on behalf of Scotoil. The primary discharge is of radium-226 and radium-228 (a few GBq/y) though approximately 0.1 GBq quantities of lead-210 and polonium-210 are also discharged each year.

In 1998 SEPA initiated independent sampling of mussels and marine sediments from Aberdeen Bay and had them analysed. The results are given in Table 4.1. SEPA intends to continue taking independent samples on an annual basis. Of main radiological interest is the relatively high value for polonium-210 in mussels (180 Bq kg^{-1}). Other concentrations in mussels are low. There is no known harvesting of mussels for consumption from the Harbour, but if 1 kg were consumed, the radiation exposure, excluding background, would lie between 0.18 and 0.28 mSv depending on the gut uptake factor chosen. This assumes that the background concentration for polonium-210 in mussels is 33 Bq kg^{-1}.

As stated in Section 10.1, there is considerable uncertainty in the natural variation in background levels of polonium-210 and other nuclides in mussels and other seafood. There is evidence that riverine inputs, of the sort present at Aberdeen, may give rise to ‘background’ levels of polonium-210 well in excess of 33 Bq kg^{-1} (Reed, G, 1991). In addition, when comparing the level of discharge from Scotoil with the higher historic discharges that have been made from Whitehaven, no significant change to concentrations of polonium-210 in mussels would be expected at Aberdeen. Taken together, these indications suggest that it is unlikely that, should consumption of local mussels occur, the dose from normal levels of natural radiation would be enhanced due to Scotoil operations.

10.3 Other industrial sites

Levels of natural radionuclides in gaseous discharges from some large-scale industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and metal or phosphate ore processing. Since 1991, a small rolling programme to examine the effects of these activities has been carried out. In 1998 four sites were chosen for study:

- Port Talbot, West Glamorgan (steel works)
- Scunthorpe, Humberside (steel works)
- Pontypool, Gwent (industrial waste incinerator)
- Sidcup, Kent (hospital waste incinerator)

The results of the sampling of grass, soil and animals in 1998 are given in Table 10.2. The analyses performed included ones for man-made radionuclides to rule out the possibility that these nuclides were enhanced by an unforeseen mechanism.

There is considerable variability in the concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the effects of man-made sources of natural radionuclides. With this proviso, we conclude that in 1998 the concentrations of natural radionuclides in grass and soil were within the ranges expected for natural sources. However, the existence of unsupported polonium-210 has been observed before when monitoring industrial sites (MAFF, 1995) and may be attributed to gaseous disposals of this radionuclide. Monitoring of such sites will therefore continue in 1999.

The concentrations of man-made radionuclides in all samples were all low and of negligible radiological significance. Tritium concentrations in grass at Pontypool and Sidcup may have been affected by site discharges. However, there was suspected contamination of the samples during analysis, and the results should therefore be treated with caution. Estimated doses from consumption of rabbit sampled near the sites were all less than 0.005 mSv.

10.4 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 landfill waste disposal sites. In addition items with a small radioactive content can be disposed of in general refuse in accordance with RSA 93. Specific exemption orders apply in certain cases. There is potential for the radioactivity in wastes disposed of in this way to migrate in groundwater and in leachates to surrounding farmland. Monitoring of leachates in England and Wales is carried out by the Environment Agency (Environment Agency, 1999). In Scotland, this function is undertaken by SEPA whose results are presented in Table 10.3. These show very low levels of carbon-14 and caesium-137 but, in common with data for sites in England and Wales, there is evidence for migration of tritium from the disposal sites. Inadvertent ingestion of such leachate (2.5 l y^{-1}), even at the highest concentration of tritium observed, would only result in a dose of 0.0001 mSv.

Once covered over, landfill sites may also be converted back to agricultural use. In recognition of this, the programme in England and Wales includes monitoring of indicator materials (grass) collected near such sites. In 1998 the sites chosen were:

- Northwich, Cheshire
- Stallingborough, Lincolnshire
- Strumpshaw, Norfolk
- Ware, Hertfordshire

Grass samples were collected at each site. Mean concentrations of tritium were of the order of 100 Bq kg^{-1} in 1998, being an order of magnitude lower than those which can be detected in grass in the vicinity of some nuclear sites. They are of negligible radiological significance. Nevertheless they do provide some evidence for migration of tritium at landfill sites. The results for other nuclides were typical of those expected due to natural background, weapon tests or Chernobyl fallout with the exception of the carbon-14 result for Stallingborough (98 Bq kg^{-1}) which is higher than expected. The results are summarised in Table 10.4.

The landfill programme in England and Wales will not be continued in 1999 as it has been demonstrated that this is a pathway of low radiological significance. There will be a corresponding increase in the industrial site sampling element of the programme.

Table 10.1. Natural radioactivity in fish, shellfish and sediment, 1998

Material	Location[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Albright and Wilson Ltd, Whitehaven												
Winkles	Saltom Bay	4	24	1.6								
Winkles	Parton	4	28	4.6	0.082		1.0	2.0	0.76	2.0	0.079	1.9
Winkles	North Harrington	1	22									
Winkles	Fleswick Bay	4	18									
Winkles	Nethertown	4	19	4.0								
Winkles	Drigg	4					0.84	1.1	0.66			
Winkles	Tarn Bay	1	16									
Mussels	Parton	2	69	5.7								
Mussels	Nethertown	4	52	4.7								
Cockles	Southern North Sea	2					0.44	0.23	0.33			
Cockles	Ribble Estuary	1			0.069		0.44	0.63	0.24			
Crabs	Parton	4	26	0.017			0.087	0.031	0.013	0.049	0.0016	0.044
Crabs	St Bees	4	19	0.075								
Crabs	Sellafield coastal area	4	13	0.083								
Lobsters	Parton	4	8.8	0.017			0.032	0.010	0.0055	0.022	0.0011	0.020
Lobsters	St Bees	4	17	<0.011								
Shrimps	Ribble Estuary	2			0.033		0.0078	0.010	0.0041			
Cod	Parton	2	0.89	0.014			0.025	0.0019	0.00080	0.0041	<0.00010	0.0035
Flounder	Whitehaven	1	2.1									
Scotoil, Aberdeen												
Mussels	Aberdeen Harbour	1	180		<2.0	<0.50						
Shoreline sediment	Aberdeen Harbour	3	6.8		23	10						
Sub-tidal sediment	Aberdeen Harbour	4	8.6		<25	13						

[a] *landing point or sampling area*
[b] *except for sediment where dry concentrations apply*

Table 10.2 Radioactivity in food and the environment near industrial sites, 1998

Site	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	$^{239+240}$Pu
Pontypool, Gwent	Grass[b]	4	<0.23	<0.26	2.3	0.87	0.20	0.033	<0.00037	0.0025
	Soil	4	<0.67	18	36	33	20	17	<0.033	0.37
	Rabbit	2	<0.13	<0.13	<0.023	0.036	0.020	<0.0021	0.00028	0.0054
Port Talbot, West Glamorgan	Grass	4	<0.20	<0.22	4.4	2.2	0.14	0.056	<0.00012	0.0012
	Soil	4	<0.56	23	48	42	23	15	0.038	0.50
	Rabbit	1	<0.14	0.22	0.050	0.036	0.015	<0.0024	0.00015	0.0011
Scunthorpe, Humberside	Grass	2	<0.26	0.27	3.1	1.7	0.41	0.10	<0.00017	0.0011
	Soil	2	<0.56	8.0	25	24	24	16	<0.035	0.14
Sidcup, Kent	Grass[c]	4	<0.19	<0.21	5.0	2.3	0.092	0.14	<0.00056	0.0017
	Soil	4	<0.46	12	26	24	18	11	<0.019	0.27
	Rabbit	1	<0.15	<0.17	0.0080	0.024	0.015	0.0015	0.00050	0.0051

[a] *except for soil samples where dry concentrations apply*

[b] *Concentrations of 33, 38, <65, <0.020 and <0.93 Bq kg^{-1} (wet) of tritium, carbon-14, iodine-123, iodine-125 and iodine-131 were also detected in this sample. Due to suspected contamination, tritium results should be interpreted with caution.*

[c] *Concentrations of 63, 25, <37, <0.016 and <0.67 Bq kg^{-1} (wet) of tritium, carbon-14, iodine-123, iodine-125 and iodine-131 were also detected in this sample. Due to suspected contamination, tritium results should be interpreted with caution.*

Table 10.3. Radioactivity in surface water leachate from landfill sites in Scotland, 1998

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{40}K	^{137}Cs
Aberdeen City	Ness Tip	1	160	<15	2.5	<0.050
City of Edinburgh	Braehead	1	<25	<15	1.1	<0.050
City of Glasgow	Summerston Tip	1	250	<15	6.7	0.058
Clackmannanshire	Black Devon	1	<25	<15	4.9	<0.050
Dundee City	Riverside	1	<25	<15	5.0	<0.050
East Dunbartonshire	Birdston Tip	1	38	<15	0.38	<0.050
Fife	Balbarton	1	64	<15	4.1	<0.050
Fife	Melville Wood	1	48	<15	5.3	<0.050
Highland	Longman Tip	1	36	<15	1.6	<0.050
North Lanarkshire	Dalmacoulter	1	200	<15	7.5	0.055
North Lanarkshire	Kilgarth	1	<25	<15	<0.40	<0.050
Stirling	Lower Polmaise	1	<25	<15	14	0.24

Table 10.4. Radioactivity in plants near landfill sites, 1998

Sampling location	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H[b]	^{14}C	^{90}Sr	^{125}I	^{134}Cs	^{137}Cs	^{238}Pu	$^{239+240}Pu$
Northwich, Cheshire	Grass	4	110	23	0.41	<0.018	<0.19	<0.19	<0.000060	0.00044
Stallingborough, Lincolnshire	Grass	4	62	98	0.27	<0.018	<0.42	<0.41	<0.00020	0.00054
Strumpshaw, Norfolk	Grass	4	47	24	0.65	<0.0073	<0.18	<0.20	<0.000083	0.0013
Ware, Hertfordshire	Grass	4	110	23	0.39	<0.0090	<0.22	<0.21	<0.000099	<0.0022

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

[b] *Due to suspected contamination, these results should be interpreted with caution*

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 1998 with surveillance of sheep and indigenous freshwater fish. Caesium is detected in sheep grazing certain upland areas in the UK which were subjected to heavy rainfall after the Chernobyl accident in 1986. Restrictions are in place on the movement, sale and slaughter of sheep from these areas 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 EC expert committee in 1986.

In the summer of 1998 intensive monitoring surveys of parts of the post-Chernobyl restricted areas of Cumbria and Scotland were carried out. The results of the surveys enabled restrictions to be lifted on 2 holdings and part of one other. This leaves 389 holdings or parts of holdings 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 holdings 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 1998 was 37 Bq kg^{-1} and the highest result was 420 Bq kg^{-1}. Further information and results have been published by MAFF (MAFF, 1999) and The Scottish Office (Scottish Office, 1999).

In Northern Ireland the remaining thirteen farms in Glenwherry, County Antrim, were removed from restrictions in February 1998. Forty-five farms in the Glenshane and Belraugh areas of County Londonderry remain under restriction following a monitoring survey in the summer of 1998 (Figure 11.4).

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 -137 in fish and water. Artificial radionuclides, other than those of radiocaesium were, in 1998, 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. Perch had the highest concentrations of any of the freshwater species but, as they are not eaten in large quantities, the radiological significance of these concentrations is low. 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 1997 there are likely to be large statistical fluctuations because of the small sampling programme, but concentrations of radiocaesium were generally similar in 1998 to those in 1997.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously (MAFF and SEPA, 1998). 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 1998, estimated doses were less than 0.009 mSv.

The ICRP (ICRP, 1993) provides guidance in the context of emergencies, which includes suggested levels of averted dose above which particular countermeasures would almost certainly be justified. It recommends that intervention should be taken by restricting a single foodstuff if the averted effective dose is in excess of 10 mSv in a year. Given that the dose estimates here are cautious, it is clear that the residual contamination of freshwater fish from fallout from Chernobyl is only of minor radiological importance.

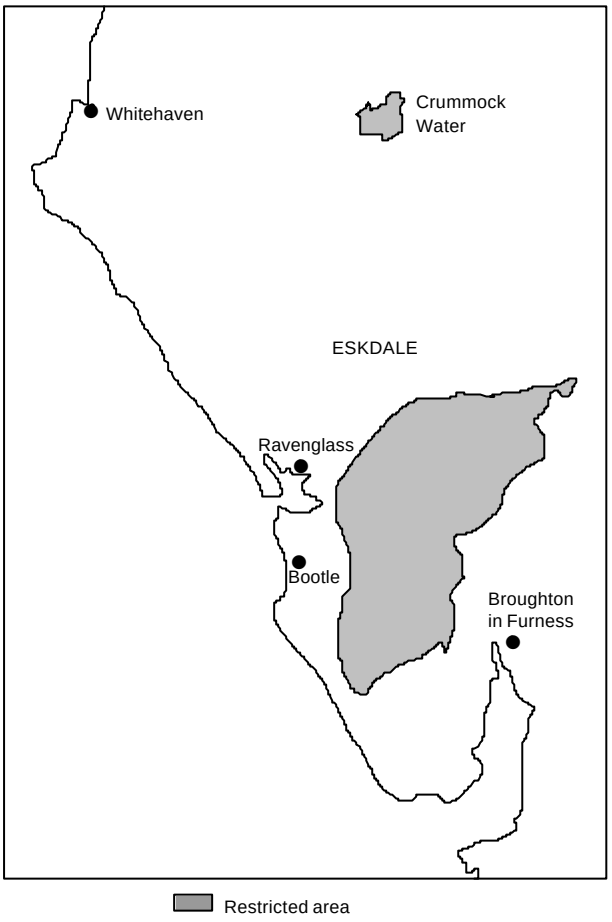

Figure 11.1. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - England***

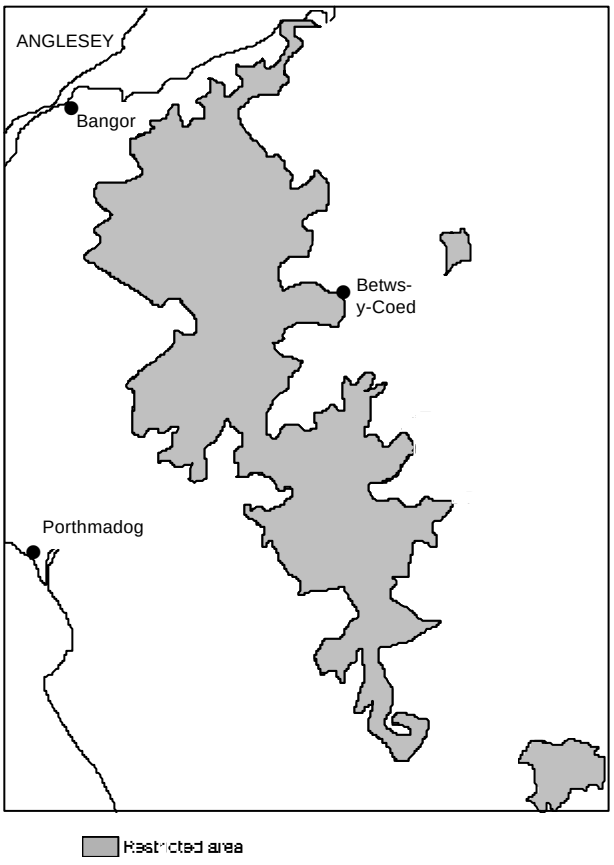

Figure 11.2. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Wales***

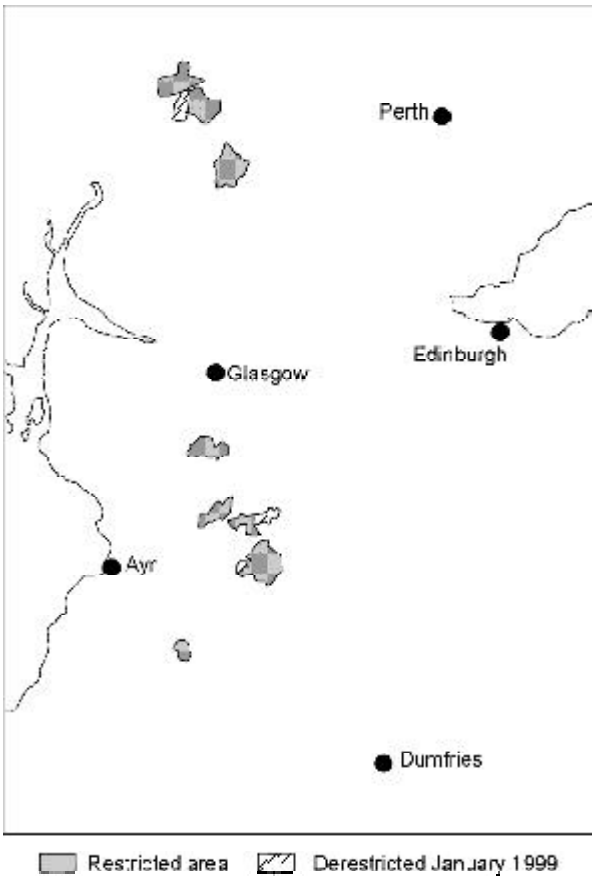

Figure 11.3. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Scotland***

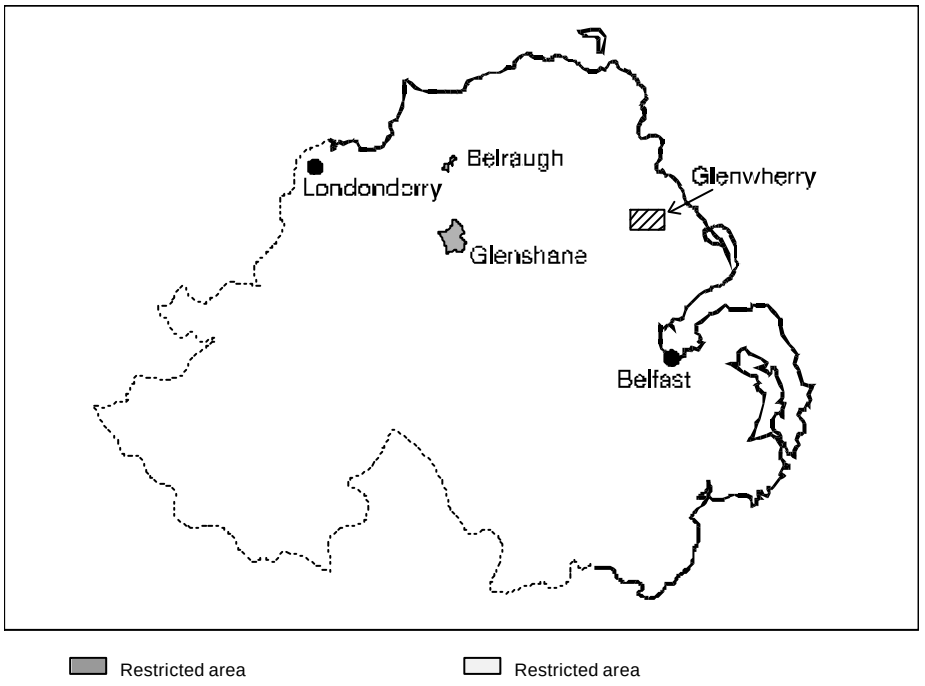

Figure 11.4. ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Northern Ireland***

11.2 Isle of Man

MAFF 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 exposure from the UK 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 1998 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, caesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. Low levels of tritium and sulphur-35 were detected, but taken as a whole, the results demonstrate that there was no significant impact on Manx agriculture from operation of mainland nuclear installations in 1998.

These data are similar to results obtained in previous years. The dose to the most exposed group from consumption of Manx foodstuffs monitored in 1998 was 0.020 mSv or 2% of the dose limit 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 1998 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 based on the results of a recent habits survey gives a dose of 0.007 mSv in 1998 or 0.7% of the dose limit to the most exposed group of high-rate fish and shellfish consumers including 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 MAFF'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 UK 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 1998. 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. Concentrations of sulphur-35 were less than the limits of detection. Strontium-90, caesium-137 and actinide concentrations were below or close to the limit of detection and were similar to levels in previous years. Tritium concentrations, although of little radiological significance, were higher than those for 1997. However, due to suspected contamination during analysis, the results should be interpreted with caution. (NRPB, 1999)

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 radionuclide was strontium-90, derived from weapon test fallout. The nationwide mean dose for all man-made radionuclides was low at 0.005 mSv. Similar doses were estimated for 1997 (MAFF and SEPA, 1998).

The mean concentration of carbon-14 in diet in 1998 was 42 Bq kg^{-1} with a range from 33 to 48 Bq kg^{-1}. In previous years, the mean values have been 33, 38, 43, 54 and 39 Bq kg^{-1} for 1993, 1994, 1995, 1996 and 1997 respectively. The general expectation is for a small reduction from year to year due to the Suess effect (the diluting of carbon-14 by carbon-12 released by the burning of fossil fuels) and dispersion of weapon test fallout (Collins and Otlet., 1995). However, given the variability of results from region to region, it is not surprising that this trend is not evident.

The mean concentration of lead-210 increased from 0.047 Bq kg^{-1} in 1997 to 0.29 Bq kg^{-1} in 1998. This is due to high results in several regions in 1998. Such results have been occasionally observed previously. Concentrations of polonium-210, radium-226 and uranium were similar to those in 1997.

The mean dose due to consumption of natural radionuclides was 0.31 mSv. The most important radionuclide was lead-210. Significant contributions would also have been made by other members of the uranium-238 and thorium-232 decay series which 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 1998. 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 1998 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 7 and 17 Bq l^{-1} were found at Gwynedd and Tyneside respectively. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels.

The concentration of strontium-90 was approximately 0.04 Bq l^{-1}, which is in good agreement with results from other surveillance studies (Welham *et al.,* 1996.).

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 programme 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).

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 doses ranged from 0.023 to 0.054 mSv and were 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 1998 (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 1997.

Sampling of bread and meat continued in Scotland in 1998. The results, presented in Tables 11.9 and 11.10, show the presence of low-levels of man-made and natural radionuclides consistent with natural and weapon test and Chernobyl fallout sources. Similar levels to those in 1997 were observed (MAFF and SEPA, 1998).

11.7 Fresh water and air particulates

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

Air particulates continued to be sampled at Glasgow. The results for beta activity were <2.0 mBq m^{-3} and are largely determined by fallout from weapon test 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). 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 1998 cruises are presented in Figures 11.5 - 11.7. Data from shoreline sampling in the Irish Sea and Scottish waters in 1998 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 1998 data for the North 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 North Sea (Figure 11.6) were at fallout levels and less than those observed in the Irish Sea which are under the influence of discharges from Sellafield (MAFF and SEPA, 1998). In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 11.7).

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 1997 gave results of <160 and <2300 mBq kg^{-1} respectively. These levels are similar to those for 1997.

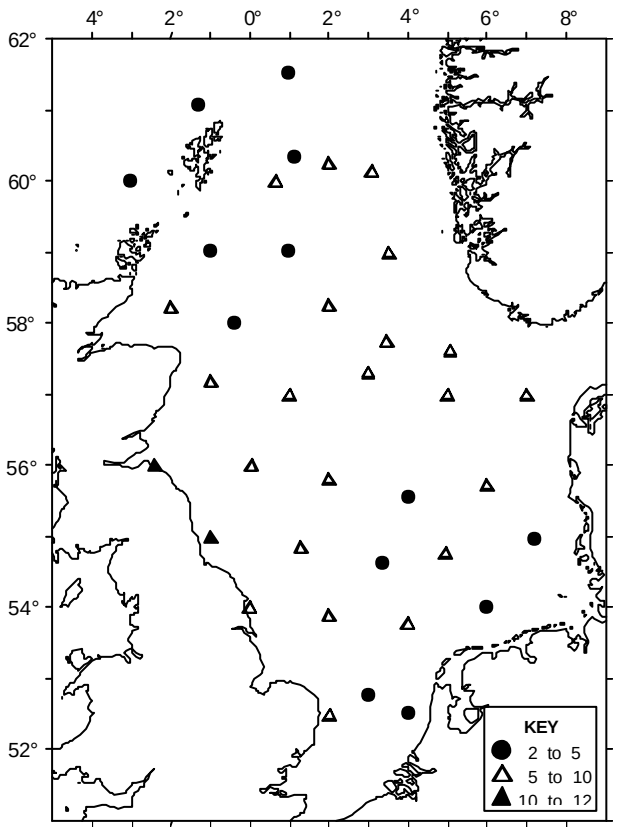

Figure 11.5 Concentrations (mBq kg^{-1}) of caesium-137 in filtered surface water from the North Sea, August-September 1998

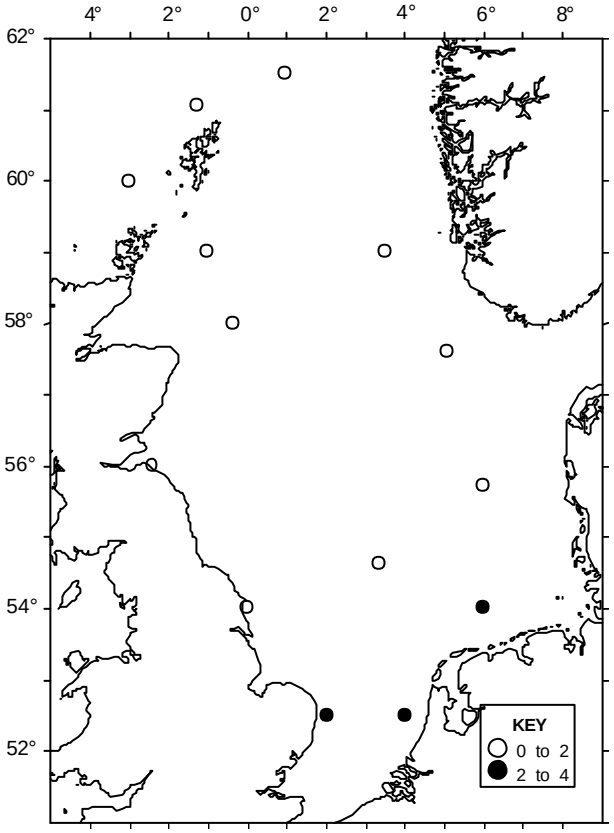

Figure 11.6 Concentrations (Bq kg^{-1}) of tritium in surface water from the North Sea, August-September 1998

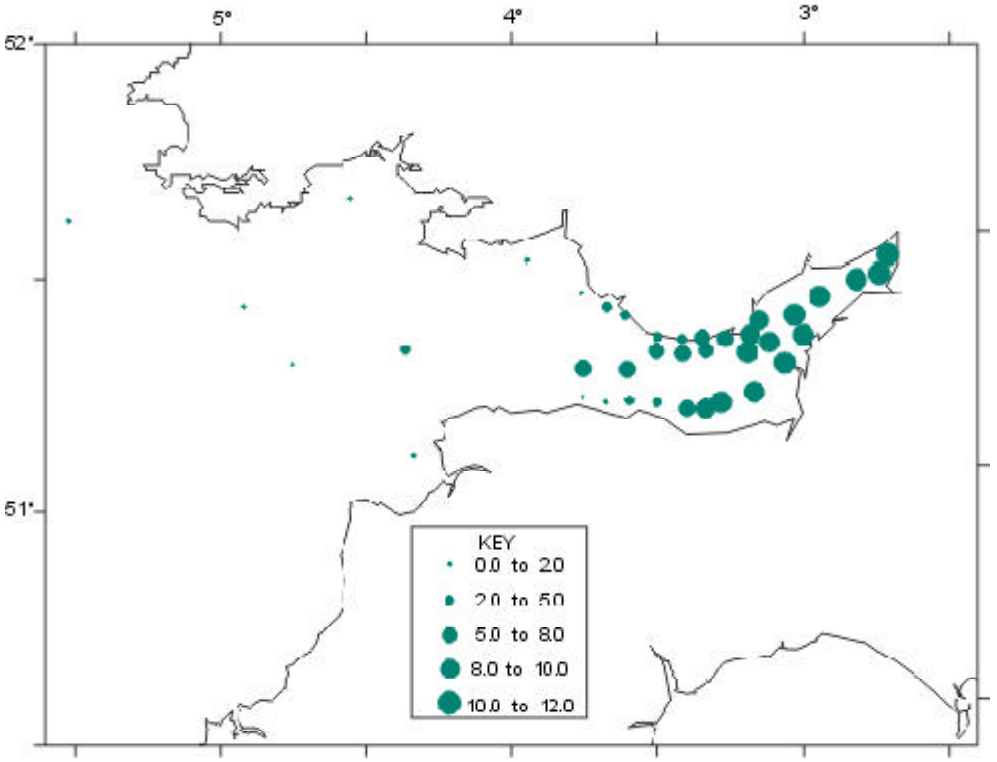

Figure 11.7 Concentrations (Bq kg^{-1}) of tritium in surface water from the Bristol Channel, September 1998

Table 11.1. Caesium radioactivity in the freshwater environment, 1998

Location	Material	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.07	0.33
Narborough[b]	Rainbow trout	1	<0.14	0.42
Ennerdale Water	Water	1	*	*
Devoke Water	Perch	1	2.1	250
Devoke Water	Brown trout	1	0.59	68
Devoke Water	Water	1	*	0.012
Gilcrux	Rainbow trout	1	<0.08	0.24
Scotland				
Loch Dee	Brown trout	1	1.8	190
Loch Dee	Water	3	*	0.018

* *not detected by the method used*
[a] *except for water where units are Bq l^{-1}*
[b] *Concentrations of 47, 0.000052, 0.00032, 0.00049 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, 1998

Material or selection[c]	No. of sampling observations[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	<2.8	14	<0.55	<0.44	0.077	<1.3	<1.6	<0.0040	<3.0	<0.78
Milk max					<0.45	0.094	<1.4	<1.8			
Apples	1	9.0	7.0	<0.40	<0.50	0.047	<0.70	<0.70		<3.1	<1.0
Cabbage	1	<3.0	4.0	2.5	<0.40	0.097	<0.70	<0.70	0.033	<2.6	<0.60
Potatoes	1	4.0	16	0.40	<0.20	0.14	<0.80	<0.50	<0.040	<3.0	<0.80

Material or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{129}I	Total Cs	^{144}Ce	^{147}Pm	^{238}Pu	$^{239+240}$Pu	^{241}Pu	^{241}Am
Milk	2	<0.011	0.15	<1.8	<0.20	<0.00030	0.00010	<0.036	0.00010
Milk max			0.20	<1.9					
Apples	1		<0.030	<1.3					
Cabbage	1	<0.036	0.069	<1.3	<0.50	0.00020	<0.00010	<0.083	0.00020
Potatoes	1	<0.043	0.061	<1.6	<0.20	<0.00050	<0.00050	<0.093	<0.00050

[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, 1998

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	^{129}I	^{137}Cs
Rays	Guernsey	1			<0.05			<0.52	<0.10		0.38
Mackerel	Guernsey	2			<0.11			<1.2	<0.27		0.35
Pollack	Jersey	1			<0.06			<0.63	<0.13		0.25
Edible crabs	Guernsey	1			0.21			<0.63	<0.13		<0.06
Edible crabs	Jersey	1			0.12			<0.49	<0.10		<0.05
Edible crabs	Alderney	2		37	0.22		0.22	<1.3	<0.21		<0.11
Spiny spider crab	Alderney	1			1.1			<1.6	<0.27		<0.13
Lobsters	Guernsey	1			<0.19			<1.8	<0.35		<0.19
Lobsters	Jersey	1			<0.07			<0.54	<0.12		<0.07
Lobsters	Alderney	1			<0.13			<1.2	<0.20		<0.11
Oysters	Jersey	1			<0.06			<0.49	<0.11		<0.05
Limpets	Guernsey	1			<0.06			<0.50	<0.11		<0.05
Limpets	Jersey La Rozel	1			<0.14			<0.84	<0.20		<0.09
Scallops	Guernsey	2			<0.22			<1.2	<0.23		<0.13
Scallops	Jersey	1			0.30			1.3	0.22		0.08
Ormers	Guernsey	1			<0.12			<1.0	<0.20		<0.08
Porphyra	Guernsey Fermain Bay	4			<0.12			<1.3	<0.22		<0.10
Porphyra	Jersey Plemont Bay	4			<0.10			<1.1	<0.10		<0.05
Porphyra	Alderney Quenard Point	3			<0.08			1.4	<0.13		<0.06
Fucus vesiculosus	Alderney Quenard Point	2								1.4	
Fucus vesiculosus	Jersey La Rozel	1			0.48			<0.68	<0.14		0.11
Fucus serratus	Guernsey Fermain Bay	4			<0.29	<0.036	1.4	<0.68	<0.13		<0.12
Fucus serratus	Jersey La Rozel	3			0.59	<0.11	3.5	<0.63	<0.14		0.11
Fucus serratus	Alderney Quenard Point	4			0.50	<0.044	1.8	<0.58	<0.10		<0.06
Laminaria digitata	Jersey Verclut	4			<0.09			<0.83	<0.16		<0.14
Mud	Guernsey St Sampson's Harbour	1			4.7			<1.7	<0.31		20
Mud	Jersey St Helier	1			21			<3.7	<0.67		5.8
Sand	Alderney Lt. Crabbe Harbour	1			0.47			<1.7	<0.32		1.6
Sea water	Guernsey	4									0.002
Sea water	Jersey	1									0.004
Sea water	Alderney	4	<2.9								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	<0.16	0.0024	0.0076	0.0039	*	*	110
Mackerel	Guernsey	2	<0.26	0.00010	0.00055	0.00054	*	0.000012	120
Pollack	Jersey	1	<0.11			<0.07			120
Edible crabs	Guernsey	1	<0.12			0.0018	0.000030	0.00030	69
Edible crabs	Jersey	1	<0.10	0.00023	0.00052	0.0028	*	0.00054	99
Edible crabs	Alderney	2	<0.29	0.0013	0.0048	0.0093	0.000038	0.00062	64
Spiny spider crab	Alderney	1	<0.21	0.00099	0.0030	0.0044	0.00016	0.00084	79
Lobsters	Guernsey	1	<0.36			<0.37			71
Lobsters	Jersey	1	<0.14	0.00025	0.00047	0.0029	0.000040	0.00069	100
Lobsters	Alderney	1	<0.27	0.00037	0.0014	0.0074	0.000041	0.0014	56
Oysters	Jersey	1	<0.09	0.0020	0.0048	0.0052	*	0.00093	78
Limpets	Guernsey	1	<0.10			<0.06			100
Limpets	Jersey La Rozel	1	<0.23	0.0037	0.0081	0.012	*	0.0018	80
Scallops	Guernsey	2	<0.21	0.0018	0.0051	0.0048	*	0.00054	100
Scallops	Jersey	1	<0.17	0.032	0.063	0.049	0.00014	0.0070	190
Ormers	Guernsey	1	<0.22			<0.28			80
Porphyra	Guernsey Fermain Bay	4	<0.24	0.0022	0.0078	0.018	<0.00014	0.0025	120
Porphyra	Jersey Plemont Bay	4	<0.11			<0.12			200
Porphyra	Alderney Quenard Point	3	<0.16			<0.22			73
Fucus vesiculosus	Alderney Quenard Point	2							
Fucus vesiculosus	Jersey La Rozel	1	<0.18			<0.23			230
Fucus serratus	Guernsey Fermain Bay	4	<0.15	0.0065	0.020	0.0087	0.00012	0.0015	170
Fucus serratus	Jersey La Rozel	3	<0.14	0.021	0.054	0.036	0.00021	0.0031	310
Fucus serratus	Alderney Quenard Point	4	<0.13	0.011	0.030	0.010	*	0.0015	160
Laminaria digitata	Jersey Verclut	4	<0.15			<0.13			380
Mud	Guernsey St Sampson's Harbour	1	<0.50	0.26	0.75	1.0	*	0.15	500
Mud	Jersey St Helier	1	1.5	1.1	2.5	4.1	*	0.59	670
Sand	Alderney Lt. Crabbe Harbour	1	<0.67			<1.2			340
Sea water	Guernsey	4							
Sea water	Jersey	1							
Sea water	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 and Wales, 1998

Region	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{3}H[c]	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Wales	1	7.2	39	<0.53	78	0.54	0.05	<1.0	0.041
East Midlands	1	16	47	<0.13	83	0.15	0.04	0.60	0.040
South West	1	24	48	<0.17	69	0.19	0.06	0.27	0.038
North East	1	16	41	<0.39	83	0.22	<0.05	0.042	0.041
South East	1	9.8	41	<0.40	71	0.16	<0.05	<0.010	0.039
West Midlands	1	74	45	<0.22	67	0.14	<0.05	<0.020	0.041
East	1	12	39	<0.41	72	0.20	<0.07	0.15	0.050
South	1	4.9	33	<0.70	81	0.14	<0.07	0.50	0.059
North West	1	49	47	<0.14	81	0.25	0.04	<0.010	0.090

Region	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		^{226}Ra	^{232}Th	Total U	^{238}Pu	$^{239+240}$Pu	^{241}Am
Wales	1	0.032	0.0019	0.027	<0.00040	0.00088	0.0024
East Midlands	1	0.037	0.0037	0.021	<0.000090	0.00019	0.00029
South West	1	0.045	<0.00055	0.024	0.00011	0.00051	0.0059
North East	1	0.039	<0.0015	0.030	0.00015	0.00083	<0.0026
South East	1	0.036	<0.0020	0.020	<0.00026	0.00013	0.00047
West Midlands	1	0.044	0.0012	0.024	0.00033	0.0014	0.00079
East	1	0.033	<0.00080	0.016	<0.00021	0.00048	<0.0023
South	1	0.038	<0.0020	0.025	<0.00046	0.0014	0.00072
North West	1	0.037	<0.0016	0.022	0.00016	0.00075	0.0019

[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*

[c] *Due to suspected contamination, these results should be interpreted with caution*

Table 11.5. Radioactivity in regional diet in Scotland, 1998

Area	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}			
		^{3}H	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	12	<25	89	<0.10	<0.084
East Lothian (North Berwick)	12	<25	85	<0.10	<0.073
Highland (Dingwall)	12	<25	94	<0.10	<0.094
Renfrewshire (Paisley)	12	<25	78	<0.10	<0.10

Table 11.6. Estimates of radiation exposure from radionuclides in regional diet, 1998

Nuclide[a]	Exposure, mSv[b]	
	Mean	Range
Man-made radionuclides		
Tritium	0.0006	0.0001-0.002
Sulphur-35	0.0004	0.0001-0.0007
Strontium-90	0.003	0.002-0.01
Caesium-137	0.0001	0.00009-0.0002
Plutonium-238	0.00002	0.000007-0.00004
Plutonium-239+240	0.00006	0.00001-0.0001
Americium-241	0.0001	0.00002-0.0004
Sub-total	0.005	
Natural radionuclides		
Carbon-14	0.01	0.01-0.015
Lead-210	0.2	0.007-0.7
Polonium-210	0.08	0.06-0.2
Radium-226	0.007	0.006-0.008
Uranium	0.0006	0.0004-0.0008
Thorium-232	0.0001	0.00005-0.0003
Sub-total	0.31	
Total	0.31	

[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, 1998

Location	Selection[a]	No. of sampling observations[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		12	<2.8	15		0.030		0.26	<0.031	0.0050	<0.0063	<0.00020	<0.00010	
	max		<3.0	25		0.038		0.33						
Co. Armagh		12	<2.8	16		0.030		0.085	<0.030	0.0080	<0.0062	<0.00020	<0.00020	
	max		<3.0	20		0.041		0.13						
Cambridgeshire[c]		12	<2.2			0.024		0.054	<0.032	0.0060	<0.0062	<0.00010	<0.00010	
	max		3.0			0.032		0.083						
Clwyd		12	<2.8	16		0.038		0.043	<0.032	0.0070	<0.0061	<0.00020	<0.00010	
	max		<3.0	28		0.059		0.062						
Cornwall		11	<2.7	19		0.043		0.056	<0.039	0.011	<0.0062	<0.00020	<0.00020	
	max		<3.0	28		0.052		0.10						
Devon		11	<2.7	17		0.039		0.056	<0.040	0.0070	<0.0060	<0.00020	0.00010	
	max		3.0	24		0.051		0.082						
Co. Down		12	<2.8	15		0.044		0.097	<0.031	0.0070	<0.0062	<0.00010	<0.00010	
	max		4.0	20		0.062		0.14						
Dumfries and Galloway			12	<25	15	<5.0	<0.10	<0.021	<0.071[d]					<0.38
	max			20			<0.030	0.19[d]						<0.40
Co. Fermanagh		12	<2.8	17		0.039		0.21	<0.039	0.010	<0.0061	<0.00010	<0.00010	
	max		3.0	21		0.051		0.30						
Gloucestershire		12	<2.8	18		0.033		<0.043	<0.030	0.010	<0.0061	0.00010	<0.00010	
	max		3.0	29		0.084		0.10						
Gwent[c]		11	<1.9			0.037		0.059	0.037	0.0050	<0.0061	<0.00020	<0.00010	
	max		<2.0			0.047		0.10						
Gwynedd		10	<3.3	17		0.042		0.055	<0.031	0.0040	0.014	<0.00020	<0.00010	
	max		7.0	26		0.056		0.073						
Hampshire		12	<2.9	15		0.025		0.044	<0.034	0.0040	<0.0062	<0.00020	<0.00010	
	max		4.0	19		0.037		0.079						
Highland		12	<25	13	<5.0	<0.10	<0.023	<0.076[d]						<0.35
	max			14			<0.030	0.14[d]						<0.40
Humberside		11	<2.9	16		0.022		<0.036	<0.050	0.0050	<0.0061	<0.00010	<0.00010	
	max		4.0	24		0.036		0.054						
Lancashire		12	<2.9	15		0.029		0.064	<0.031	0.0080	<0.0061	<0.00010	<0.00010	
	max		4.0	21		0.046		0.16						
Lincolnshire		12	<3.1	16		0.019		<0.039	<0.038	0.0070	<0.0062	<0.00010	<0.00010	
	max		5.0	28		0.038		0.076						

Table 11.7. continued

Location	Selection[a]	No. of sampling observations[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. Londonderry		12	<2.8	16		0.033		0.15	<0.033	0.0070	<0.0062	<0.00010	<0.00010	
	max		4.0	22		0.044		0.32						
Middlesex		10	<2.8	16		0.027		0.053	<0.043	0.0060	<0.0062	<0.00020	<0.00010	
	max		<3.0	24		0.039		0.11						
Midlothian		12	<25	12	<5.0	<0.10	<0.024	<0.057[d]						<0.35
	max			16			<0.060	0.10[d]						<0.39
Norfolk		12	<2.9	14		0.025		0.043	<0.031	0.0040	<0.0062	<0.00020	<0.00010	
	max		<3.0	20		0.035		0.092						
North Yorkshire		12	<3.1	13		0.027		0.040	<0.027	0.0070	<0.0062	0.00010	<0.00020	
	max		6.0	21		0.035		0.070						
Oxfordshire		12	<2.8	16		0.034		0.046	<0.031	0.0070	<0.0061	<0.00020	0.00010	
	max		3.0	22		0.053		0.082						
Renfrewshire		12	<25	13	<5.0	<0.10	<0.022	0.16[d]						<0.30
	max			15			<0.030	0.41[d]						<0.32
Shropshire		12	<2.8	15		0.030		0.040	<0.037	0.010	<0.0062	<0.00010	<0.00010	
	max		<3.0	23		0.037		0.066						
Somerset		12	<2.8	15		0.042		0.062	0.086	0.0060	<0.0061	<0.00010	<0.00010	
	max		<3.0	24		0.066		0.18						
Suffolk		12	<2.8	16		0.013		0.033	<0.030	0.0020	<0.0062	<0.00010	<0.00010	
	max		<3.0	29		0.018		0.062						
Tyneside		12	<6.4	16		0.040		0.062	<0.032	0.0050	<0.0062	<0.00020	<0.00010	
	max		17	25		0.055		0.14						
Co. Tyrone[c]		12	<2.0			0.032		0.14	<0.029	0.010	<0.0061	<0.00020	<0.00020	
	max					0.039		0.19						
West Midlands		12	<2.7	18		0.027		0.034	<0.030	0.010	<0.0061	<0.00020	<0.00010	
	max		<3.0	26		0.052		0.057						
Mean values														
England			<3.0	16		0.029		<0.047	<0.038	0.0068	<0.0062	<0.00015	<0.00011	
Northern Ireland			<2.7	16		0.035		0.16	<0.032	0.0078	<0.0062	<0.00015	<0.00013	
Wales			<2.7	17		0.039		0.052	<0.033	0.0053	<0.0086	<0.00020	<0.00010	
Scotland			<25	13	<5.0	<0.10	<0.023	<0.091[d]						<0.35
United Kingdom			<8.3	15	<5.0	<0.051	<0.023	<0.087	<0.034	0.0066	<0.0070	<0.00017	<0.00012	<0.35

[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, 1998[b]

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
Buckinghamshire Bicester	Apples	1	<2.0	16		0.059	0.14						<0.00020	<0.00020	<0.00040	
	Cabbage	1	<3.0	13		0.078	0.14	0.10	0.34	<0.0030	<0.0086	0.12	<0.00030	0.00080	<0.00070	
	Carrots	1	<2.0	8.0		0.36	<0.032	0.21	0.012	0.012	<0.0022	<0.020	<0.00020	<0.00030	<0.0070	
Camarthenshire Llandeilo	Apples	1	<3.0	15		0.11	0.084						0.00040	<0.00020	0.00080	
	Cabbage	1	<3.0	<2.0		0.18	<0.033						<0.00030	<0.00020	<0.00060	
	Potatoes	1	<3.0	19		0.026	0.073						<0.00020	<0.00020	<0.00040	
Cheshire Northwich	Cabbage	1	<3.0	5.0		0.25	<0.034						<0.00020	<0.00030	<0.00050	
	Carrots	1	<3.0	7.0		0.068	0.081						<0.00020	<0.00030	<0.00040	
	Pumpkin	1	<3.0	<3.0		0.073	0.061						<0.00040	<0.00030	<0.00050	
Cornwall Wadebridge	Kale	1	<3.0	10		1.8	0.14	0.70	0.27	<0.0030	<0.0021	<0.035	0.00080	<0.00030	<0.00060	
	Strawberries	1	<3.0	10		0.32	0.038						<0.00030	0.00030	0.00060	
	Fodder Beet	1	<3.0	11		0.20	0.061	<0.038	0.027	0.028	0.028	0.034	0.00020	0.00030	<0.00040	
Cumbria Appleby	Turnips	2	<2.0	8.5		0.025	<0.030						<0.00040	<0.00030	<0.00070	
	Barley	1	<4.0	89		0.34	0.20						<0.00020	<0.00020	<0.00030	
Devon Tiverton	Apples	1	<3.0	15		0.30	0.044						<0.00030	<0.00020	<0.00040	
	Cabbage	1	<3.0	9.0		0.22	0.10						<0.00020	<0.00020	<0.00040	
	Swede	1	<3.0	7.0		0.071	<0.028						<0.00030	0.00010	0.00050	
Dumfries and Galloway Dumfries	Leafy Green Veg.	4	<25	4.7	<5.0	<0.10	<0.068[c]									<0.22
East Lothian North Berwick	Leafy Green Veg.	4	<25	4.3	<5.0	<0.10	<0.058[c]									<0.23
Hampshire Petersfield	Blackberries	1	<3.0	13		0.26	0.064						<0.00010	<0.00010	<0.00040	
	Cabbage	1	<3.0	4.0		0.11	<0.034						0.00030	<0.00010	<0.00050	
	Carrots	1	<3.0	8.0		0.18	0.096						<0.00030	0.00050	0.0010	
Herefordshire Leominster	Cabbage	1	<3.0	6.0		0.090	0.047	0.034	0.016	0.015	<0.00090	<0.016	<0.00020	0.00010	<0.00070	
	Carrots	1	<3.0	7.0		0.20	0.042	0.068	0.013	0.075	0.0012	<0.019	<0.00040	<0.00020	0.00090	
	Raspberries	1	8.0	34		0.094	0.042						<0.00040	0.00010	<0.00050	
Hertfordshire Stevenage	Blackberries/ Raspberries	1	<3.0	14		0.058	<0.025						<0.00010	<0.00020	0.00060	
	Cabbage	1	<3.0	14		0.30	<0.031						<0.00050	<0.00030	<0.0010	
	Potatoes	1	<3.0	26		0.034	0.041						<0.00030	0.00030	<0.00050	

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
Highlands																
Dingwall	Leafy Green Veg.	4	<25	3.7	<5.0	<0.10	<0.063[c]									<0.23
Lincolnshire																
Gainsborough	Cabbage	1	<3.0	<3.0		0.093	0.061						<0.00010	0.00010	<0.00030	
	Potatoes	1	<3.0	12		<0.010	0.033						<0.00020	<0.00020	0.00090	
	Soft fruit	1	<3.0	13		0.086	0.029						<0.00030	<0.00020	0.00050	
Northamptonshire																
Wellingborough	Cabbage	1	3.0	12		0.088	0.089	1.1	0.010	0.029	<0.0014	<0.011	<0.00030	<0.00020	<0.00080	
	Potatoes	1	<3.0	14		0.027	<0.026	<0.033	0.012	0.024	0.010	<0.029	<0.00040	<0.00020	0.00050	
	Strawberries	1	<3.0	18		0.093	<0.027						<0.00020	<0.00010	<0.0010	
Northumbria																
Morpeth	Cabbage	1	<3.0	9.0		0.17	0.048	0.24	0.096	<0.0010	<0.0021	<0.022	<0.00020	<0.00040	<0.0010	
	Strawberries	1	<3.0	8.0		0.062	0.050						<0.00030	<0.00010	<0.00040	
	Swede	1	<3.0	13		0.22	0.088	0.11	0.023	0.033	0.0046	0.040	<0.00030	<0.00030	<0.00060	
NorthYorkshire																
Ripon	Raspberries	1	<3.0	10		0.12	0.037						<0.00020	0.00030	0.00070	
	Sugar Beet	1	<3.0	14		0.10	0.11	0.11	0.057	0.066	0.028	0.083	<0.00030	<0.00030	0.00050	
	Sugar Beet Tops	1	<3.0	8.0		0.31	0.14	1.3	0.65	0.039	0.0092	0.057	<0.00030	<0.00030	<0.00040	
Selby	Cabbage	1	<3.0	9.0		0.70	0.13						<0.00030	<0.00050	<0.00060	
	Elderberries	1	6.0	28		0.24	0.10						<0.00020	0.00010	<0.00050	
	Turnips	1	<2.0	10		0.11	0.11						<0.00020	<0.00020	<0.00030	
Powys																
Rhayader	Cabbage	1	<3.0	5.0		0.085	<0.028	<0.033	0.027	<0.0040	<0.0029	<0.022	<0.00030	<0.00030	0.00080	
	Swede	1	<3.0	5.0		0.17	0.12	0.14	0.066	0.038	0.031	0.092	<0.00040	<0.00030	0.00040	
	CrabApples	1	<2.0	13		0.19	0.14						<0.00040	<0.00040	<0.00050	
Renfrewshire																
Paisley	Leafy Green Veg.	4	<25	4.5	<5.0	<0.10	<0.058[c]									<0.25
Somerset																
Frome	Blackberries	1	<3.0	34		0.43	0.087						<0.00020	<0.00020	<0.00030	
	Leafy Green Veg.	1	<3.0	8.0		0.53	0.091	1.0	0.45	<0.0030	0.0038	<0.057	<0.00040	0.00020	0.00040	
	Potatoes	1	<3.0	20		0.053	0.062	<0.031	0.038	0.026	0.027	0.064	0.00030	<0.00040	0.00030	
Glastonbury	Apples	1	<3.0	10		0.028	0.073						<0.00030	<0.00030	<0.00060	
	Cabbage	1	<3.0	<2.0		0.25	0.096						<0.00030	<0.00030	0.00040	
	Fodder Beet	1	<4.0	11		0.077	0.12						<0.00030	<0.00030	0.00070	

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
Suffolk																
Sudbury	Cabbage/Sprouts	1	<3.0	9.0		0.27	0.066	0.43	0.16	0.0030	<0.0025	<0.044	0.00040	<0.00050	<0.0012	
	Pears	1	<2.0	15		<0.013	<0.035						<0.00030	<0.00020	<0.00080	
	Potatoes	1	<3.0	17		0.043	<0.033	<0.034	0.0090	0.017	0.012	0.042	<0.00030	<0.00020	<0.00080	
Shropshire																
Whitchurch	Cabbage	1	<3.0	4.0		0.11	<0.036						<0.00040	0.00010	0.00040	
	Potatoes	1	<3.0	6.0		0.18	0.13	0.067	0.093	<0.0030	<0.0025	<0.0076	<0.00020	0.00030	<0.00040	
	Pumpkin	1	<3.0	19		0.12	0.031	<0.030	0.021	0.018	0.0065	0.026	<0.00040	<0.00030	<0.00060	
Worcestershire																
Evesham	Cabbage	1	3.0	7.0		0.061	0.041						<0.00020	0.00010	0.00020	
	Carrots	1	<3.0	11		0.35	0.15						<0.00010	<0.00010	<0.00040	
	Raspberries	1	<3.0	12		0.077	0.048						0.00070	0.00020	0.00070	
Mean values																
England			<3.1	<13		<0.20	0.069	0.31	0.13	<0.022	<0.0085	<0.040	<0.00029	<0.00025	<0.00058	
Wales			<2.8	<9.8		0.13	<0.079	<0.087	0.047	<0.021	<0.017	<0.057	<0.00033	<0.00027	<0.00058	
Scotland			<25	4.3	<5.0	<0.10	<0.061[c]									<0.23
Great Britain			<10	<9.1	<5.0	<0.14	<0.070	<0.20	<0.089	<0.022	<0.013	<0.048	<0.00031	<0.00026	<0.00058	

[a] *see section 3 for definition*

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

[c] ^{137}*Cs only*

Table 11.9. Radioactivity in bread in Scotland, 1998

Area	No. of sampling observations	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	59	<5.0	<0.10	<0.16	<0.74
East Lothian (North Berwick)	4	<25	65	<5.0	<0.10	<0.14	<0.92
Highland (Dingwall)	4	<25	55	<5.0	<0.10	<0.14	<0.82
Renfrewshire (Paisley)	4	<25	59	<5.0	<0.10	<0.17	<0.86

Table 11.10. Radioactivity in meat in Scotland, 1998

Area	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	3	<25	37	<5.0	<0.10	<0.08	<0.44
East Lothian (North Berwick)	4	<25	32	<5.0	<0.10	<0.10	<0.44
Highland (Dingwall)	4	<25	30	<5.0	<0.10	0.29	<0.41
Renfrewshire (Paisley)	4	<25	34	<5.0	<0.10	<1.1	<0.39

Table 11.11. Radioactivity in freshwater in Scotland, 1998

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	10	<1.0	<0.0046	<0.014		
Argyll and Bute	Auchengaich	1	<1.0	<0.0050		<0.010	0.15
Argyll and Bute	Helensburgh Reservoir	3			<0.0077	<0.012	<0.071
Argyll and Bute	Loch Ascog	3			<0.015	<0.011	<0.071
Argyll and Bute	Loch Eck	1	<1.0	<0.0050		<0.010	0.028
Argyll and Bute	Loch Finlas	3			<0.0083	<0.013	<0.071
Argyll and Bute	Lochan Ghlas	3			<0.0077	<0.011	<0.071
Clackmannanshire	Gartmorn	1	<1.0	<0.0050		<0.010	0.044
Dumfries and Galloway	Black Esk	1	<1.0	<0.0050		<0.010	<0.010
Dumfries and Galloway	Purdomstone	3			<0.0087	<0.011	<0.085
Dumfries and Galloway	Winterhope	1	<1.0	<0.0050		<0.010	0.047
East Lothian	Hopes Reservoir	1	<1.0	<0.0050		<0.010	0.026
East Lothian	Thorters Reservoir	1	<1.3	<0.0050		<0.010	<0.010
East Lothian	Whiteadder	1			<0.010	<0.011	<0.013
Fife	Holl Reservoir	1	<1.0	<0.0050		<0.010	<0.010
Highland	Loch Baligill	1	<1.0	<0.0050		0.051	0.12
Highland	Loch Calder	3			<0.0081	<0.011	<0.071
Highland	Loch Glass	12	<1.0	<0.0054	<0.017		
Highland	Loch Shurrerey	1	<1.0	<0.0050		<0.010	<0.010
North Ayrshire	Camphill	1	<1.0	<0.0050		<0.010	0.027
North Ayrshire	Knockendon Reservoir	3			<0.011	<0.011	<0.042
North Ayrshire	Munnoch Reservoir	1	<1.0	<0.0050		<0.010	0.13
North Ayrshire	Outerwards	1	<1.0	<0.0050		<0.010	0.046
Orkney Islands	Heldale water	1	<1.0	<0.0050		<0.010	0.025
Perth and Kinross	Castlehill	1			<0.010	<0.012	<0.013
Scottish Borders	Knowsdean	12	<1.0	<0.0047	<0.0061		
Stirling	Loch Katrine	12	<1.0	<0.0053	<0.0057		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0	<0.0050		<0.010	0.032
West Lothian	Morton No. 2	1	<1.0	<0.0050		<0.010	0.034

[a] *See section 3 for definition*

Table 11.12. Radioactivity in sea water from the Irish Sea and Scottish waters, 1998

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
		^{3}H	^{99}Tc	^{134}Cs	^{137}Cs
Seascale	4			<0.0031	0.20
St Bees	12	14	0.11	<0.0034	0.17
Whitehaven	1			0.0023	0.18
Maryport	1			0.0023	0.22
Silloth	1			0.0033	0.33
Silecroft	1			0.0039	0.16
Walney-west shore	4	13		0.0022	0.14
Isle of Whithorn	1			*	0.056
Drummore	1			*	0.039
Half Moon Bay	1			0.0031	0.23
Rossal (Fleetwood)	1			0.0013	0.16
Ainsdale	1			0.0020	0.14
New Brighton	1			0.0030	0.11
Ross Bay	1			*	0.091
North of Larne	12		0.028	*	0.028
Seafield	4	11			<0.076
Southerness[a]	4	29			<0.17
Knock Bay	8	<3.0		*	<0.043
Prestatyn	1			*	0.065
Llandudno	1			*	0.046
Cemaes Bay	1			*	0.021
Holyhead	4	<1.6		*	0.019
Cape Wrath	2			*	0.0087
Pentland Firth	4			*	0.012
Fair Isle	3			*	0.0068
Aberdeen	4			*	0.0092

* *not detected by the method used*

[a] *Concentrations of 0.00035, 0.0020 and 0.0012 Bq l^{-1} of ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were determined*

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

MAFF 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 1998 is presented in Table 12.1., and is also available on MAFF's Web site (www.maff.gov.uk). Copies of the final reports for each of those projects funded by MAFF are available from the MAFF library, Nobel House, 17 Smith Square, London, SW1P 3JR. A charge will be made to cover photocopying and postage. Table 12.1 also provides information on projects which are currently underway. The results of these projects will be made available in due course.

Table 12.1. Extramural projects in support of the monitoring programmes

	Further details	Target completion date
Potential variability of naturally occurring radionuclides in foodstuffs	M	Complete
Variability of concentrations between individual crabs and lobsters	M	Complete
Variability of radionuclides in terrestrial foodstuffs	M	Complete
Free foods in the vicinity of nuclear sites	M	Complete
Radioactivity from fish in animal feed	M	Complete
Food production and distribution surveys	M	Complete
Optimisation of MAFF's monitoring programme	M	Complete
Iodine-129 losses during milk storage	M	Complete
Discharges to sewers	S	Complete
Improvements to sheep radiocaesium monitor	M	Aug-98 (delayed)
Samplers for radionuclides in freshwaters	M	Apr-99
Improved analysis of cerium-144	M	Apr-99
Food and non-licensed sites	M	Jun-99
Assessments of contaminated land	S	Aug-99
Impact on Irish Sea coastal communities	S	Oct-99
Methods for censored data sets	M	Dec-99
Quality control for the determination of radionuclides in foodstuffs	M	Mar-00
RIFE Trend studies	M	Mar-00
Impact on non-human species	S	Nov-00
Accumulation of technetium-99 in the Irish Sea	M	Mar-01
Organic tritium in seafood	M	Mar-01
Cs, Am and Pu in Northern Irish waters	S	Dec-01
Dietary studies near nuclear installations	M	Mar-02
Natural radionuclides in seafood	M	Mar-02
Enhanced natural radionuclides	S	

M = MAFF
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, 1998

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Sellafield	Alpha	1	0.174	17
Sea pipelines	Beta	400	85.9	21
	Tritium	$2.5\ 10^{4}$	2310	9.2
	Carbon-14	20.8	3.74	18
	Cobalt-60	13	2.41	19
	Strontium-90	48	17.7	37
	Zirconium-95+Niobium-95	9	0.647	7.2
	Technetium-99	200	52.7	26
	Ruthenium-106	63	5.58	8.9
	Iodine-129	1.6	0.553	35
	Caesium-134	6.6	0.319	4.8
	Caesium-137	75	7.54	10
	Cerium-144	8	0.762	9.5
	Plutonium alpha	0.7	0.140	20
	Plutonium-241	27	3.54	13
	Americium-241	0.3	0.0472	16
	Uranium[d]	2040	554	27
Factory sewer	Alpha	0.0033	$3.2\ 10^{-5}$	<1
	Beta	0.0135	$4.9\ 10^{-4}$	3.6
	Tritium	0.132	0.0174	13
Drigg				
Sea pipeline	Alpha	0.1	$1.20\ 10^{-4}$	<1
	Beta[e]	0.3	0.00172	<1
	Tritium	120	0.530	<1
Stream[f]	Alpha	$9.0\ 10^{4}$	67.5	<1
	Beta[e]	$1.2\ 10^{6}$	847	<1
	Tritium	$6.0\ 10^{8}$	$4.9\ 10^{4}$	<1
Springfields	Alpha	4	0.195	4.9
	Beta	240	150	63
	Technetium-99	0.6	0.0273	4.6
	Thorium-230	2	0.0850	4.3
	Thorium-232	0.2	0.0012	<1
	Neptunium-237	0.04	$2.0\ 10^{-4}$	<1
	Uranium	0.15	0.0467	31
Capenhurst[t]				
Rivacre Brook	Uranium	0.02	$1.2\ 10^{-3}$	6
	Uranium daughters	0.02	<0.0028	<14
	Non-uranic alpha	0.003	$1.5\ 10^{-5}$	<1
	Technetium-99	0.1	0.00134	1
Chapelcross	Alpha	0.1	$4.24\ 10^{-4}$	<1
	Beta[e]	25	0.0404	<1
	Tritium	5.5	0.216	3.9

* *Whilst great care has been taken in the compilation of Appendix 1, MAFF 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 1998	
			TBq[a]	% of limit[b]
United Kingdom Atomic Energy Authority				
Dounreay	Alpha[c]	0.75	0.012	1.6
	Beta[e]	110	0.584	<1
	Tritium	130	0.454	<1
	Cobalt-60	1	0.010	1.0
	Strontium-90	12	0.171	1.4
	Zirconium-95+Niobium-95	6	0.012	<1
	Ruthenium-106	12	0.074	<1
	Silver-110m	0.4	0.0060	1.5
	Caesium-137	50	0.182	<1
	Cerium-144	12	0.006	<1
	Plutonium-241	15	0.096	<1
	Curium-242	1	$5.0\ 10^{-4}$	<1
Harwell (pipeline)	Alpha	0.001	$5.12\ 10^{-5}$	5.1
	Beta[e]	0.02	0.00298	15
	Tritium	4	0.0879	2.2
	Cobalt-60	0.007	$4.57\ 10^{-5}$	<1
	Caesium-137	0.007	$4.90\ 10^{-4}$	7.0
Harwell (Lydebank Brook)	Alpha	$5\ 10^{-4}$	$2.56\ 10^{-5}$	5.1
	Beta[e]	0.002	$2.12\ 10^{-4}$	11
	Tritium	0.1	0.0263	26
Winfrith (inner pipeline)	Alpha	0.3	0.00133	<1
	Tritium	650	3.42	<1
	Cobalt-60	10	$3.11\ 10^{-4}$	<1
	Zinc-65	6	$3.20\ 10^{-4}$	<1
	Other radionuclides	80	0.00814	<1
Winfrith (outer pipeline)	Alpha	0.004	$6.30\ 10^{-5}$	<1.6
	Tritium	1	0.0095	<1
	Other radionuclides	0.01	$1.00\ 10^{-4}$	<1
Magnox Electric plc[r]				
Berkeley	Tritium	8	0.0342	<1
	Caesium-137	0.2	0.0143	7.1
	Other radionuclides	0.4	0.0734	18
Bradwell	Tritium	30	1.793	6.0
	Caesium-137	0.75	0.323	43
	Other radionuclides	1	0.359	36
Dungeness 'A' Station	Tritium	35	0.421	1.2
	Caesium-137	1.2	0.708	59
	Other radionuclides	1.4	0.386	28
Hinkley Point 'A' Station	Tritium	25	0.708	2.8
	Caesium-137	1.5	0.493	33
	Other radionuclides	1	0.284	28
Hunterston 'A' Station	Total activity[e]	2	0.242	12
	Tritium	5	0.00668	<1
Oldbury	Tritium	25	0.173	<1
	Caesium-137	0.7	0.0620	8.9
	Other radionuclides	1.3	0.175	14

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Sizewell				
'A' Station	Tritium	35	2.91	8
	Caesium-137	1.0	0.0706	7
	Other radionuclides	0.7	0.145	20
Trawsfynydd	Total activity[e,i,j]	0.72	0.0177	2.5
	Tritium	12	0.0628	<1
	Strontium-90	0.08	0.0103	13
	Caesium-137	0.05	0.00651	13
Wylfa	Tritium	40	9.64	24
	Other radionuclides	0.15	0.0701	47
Nuclear Electric Ltd[s]				
Dungeness				
'B' Station	Tritium	650	172	26
	Sulphur-35	2	0.202	10
	Cobalt-60	0.03	0.00126	4.3
	Other radionuclides	0.25	0.0165	6.6
Hartlepool	Tritium	1200	329	27
	Sulphur-35	3	0.325	11
	Cobalt-60	0.03	0.00327	11
	Other radionuclides	0.3	0.00255	<1
Heysham				
Station 1	Tritium	1200	396	33
	Sulphur-35	2.8	0.241	8.6
	Cobalt-60	0.03	0.00100	3.3
	Other radionuclides	0.3	0.00917	3.1
Station 2	Tritium	1200	307	26
	Sulphur-35	2.3	0.0339	1.5
	Cobalt-60	0.03	0.00109	3.6
	Other radionuclides	0.3	0.0171	5.7
Hinkley Point				
'B' Station	Tritium	620	387	62
	Sulphur-35	5	0.578	12
	Cobalt-60	0.033	$4.40\ 10^{-4}$	1.3
	Other radionuclides	0.235	0.0193	8.2
Sizewell				
'B' Station	Tritium	80	48.3	60
	Other radionuclides	0.2	0.0178	8.9
Scottish Nuclear Ltd[s]				
Hunterston				
'B' Station	Alpha	0.001	$9.03\ 10^{-5}$	9.0
	Beta[e,g,p]	0.45	0.0102	<1
	Tritium	800	442	55
	Sulphur-35	10	2.36	24
	Cobalt-60	0.03	0.0019	6.3
Torness	Alpha	0.001	$6.88\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	0.00344	<1
	Tritium	800	355	44
	Sulphur-35	10	0.0483	<1
	Cobalt-60	0.03	$4.53\ 10^{-4}$	1.5

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Ministry of Defence				
Aldermaston (pipeline)[k]	Alpha	$1.5\ 10^{-4}$	$1.89\ 10^{-5}$	13
	Tritium	0.05	0.00143	2.9
	Plutonium-241	$6.0\ 10^{-4}$	$7.57\ 10^{-5}$	13
	Other radionuclides	$1.5\ 10^{-4}$	$1.19\ 10^{-5}$	7.9
Aldermaston (Silchester)[k]	Alpha	$1.0\ 10^{-4}$	$5.59\ 10^{-6}$	5.6
	Beta	$3.0\ 10^{-4}$	$2.45\ 10^{-5}$	8.2
Barrow[l]	Tritium	0.02	Nil	
	Manganese-54	$2.5\ 10^{-7}$	"	
	Cobalt-58	$7.0\ 10^{-7}$	"	
	Cobalt-60	$7.0\ 10^{-8}$	"	
	Tin-113	$2.5\ 10^{-7}$	"	
	Antimony-124	$2.0\ 10^{-6}$	"	
	Other radionuclides	$3.5\ 10^{-6}$	"	
Burghfield[k]	Alpha	$2.0\ 10^{-6}$	$5.92\ 10^{-8}$	3.0
	Other radionuclides	$1.2\ 10^{-5}$	$1.18\ 10^{-7}$	<1
Devonport[m,n] (sewer)	Beta		$6.54\ 10^{-6}$	
	Tritium		$5.71\ 10^{-6}$	
	Cobalt-60		$3.03\ 10^{-7}$	
Devonport[m,n] (river)	Beta		Nil	
	Tritium		"	
	Cobalt		"	
Devonport[n,o] (sewer)	Total activity		$4.66\ 10^{-4}$	
	Cobalt-60		$4.31\ 10^{-4}$	
Devonport[o] (pipeline)	Total activity[e,p]	0.001	$2.31\ 10^{-5}$	2.3
	Tritium	0.12	0.113	94
	Cobalt-60	0.006	$1.24\ 10^{-4}$	2.1
Faslane	Alpha activity	$2.0\ 10^{-4}$	$8.05\ 10^{-6}$	4.0
	Beta activity[e,p]	$5.0\ 10^{-4}$	$2.19\ 10^{-5}$	4.4
	Tritium	1	0.0425	4.3
	Cobalt-60	$5.0\ 10^{-4}$	$2.19\ 10^{-5}$	4.4
Greenwich	Alpha and beta	$4.44\ 10^{-3}$	$4.50\ 10^{-6}$	<1
Rosyth[q]	Alpha	10^{-6}	$7.5\ 10^{-8}$	7.5
	Beta[e,p]	$5\ 10^{-4}$	$2.47\ 10^{-4}$	49
	Tritium	0.04	0.0208	52
	Cobalt-60	0.005	$5.66\ 10^{-4}$	11
Nycomed Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$4.20\ 10^{-5}$	14
	Beta >0.4 MeV	0.1	0.00766	7.7
	Tritium	0.2	0.00229	1.2
	Iodine-125	0.2	0.00215	1.1
	Caesium-137	0.005	$3.56\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0563	19
Cardiff	Tritium	900	277	31
	Carbon-14	2	1.15	58
	Phosphorus-32/33	0.01	$4.44\ 10^{-6}$	<1
	Iodine-125	0.05	0.00812	1
	Others	$5.0\ 10^{-4}$	$1.20\ 10^{-5}$	2.4

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Imperial College Reactor Centre				
Ascot	Tritium	$1.0\ 10^{-4}$	$2.01\ 10^{-6}$	2.0
	Other radioactivity	$4.0\ 10^{-5}$	$1.46\ 10^{-6}$	3.7
Imperial Chemical Industries plc				
Billingham	Beta/gamma	0.36	$1.07\ 10^{-7}$	<1
Rolls Royce plc				
Derby	Alpha	0.00666	$2.51\ 10^{-4}$	3.8
Scottish Universities Research and Reactor Centre				
East Kilbride	Total activity	$1.56\ 10^{-3}$	$9.9\ 10^{-6}$	<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] *Data are for January to September. Authorisation was revised 1 October 1998. No discharges were made under the revised authorisation.*
[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] *With effect from 1/4/98, power stations within Magnox Electric plc became part of Magnox Generation Business Group BNFL plc*
[s] *With effect from 31/12/98, Nuclear Electric Ltd and Scottish Nuclear Ltd became British Energy Generation Ltd and British Energy Generation (UK) Ltd respectively*
[t] *Discharge limits depend on operational throughput*

Table A1.2. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 1998

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Sellafield[a,b]	Alpha	0.0017	$1.1\ 10^{-4}$	6.4
	Beta	0.048	0.00154	3.2
	Tritium	1400	250	18
	Carbon-14	8.4	2.62	31
	Sulphur-35	0.21	0.15	71
	Argon-41	3700	2530	68
	Cobalt-60	$9.2\ 10^{-4}$	$5.30\ 10^{-5}$	5.7
	Krypton-85	$3.5\ 10^{5}$	$9.9\ 10^{4}$	28
	Strontium-90	0.0016	$6.0\ 10^{-5}$	3.8
	Ruthenium-106	0.046	$1.1\ 10^{-3}$	2.4
	antimony-125	0.005	$1.90\ 10^{-4}$	3.8
	Iodine-129	0.052	0.0268	52
	Iodine-131	0.055	0.00317	5.8
	Caesium-137	0.0073	$4.41\ 10^{-4}$	6.0
	Plutonium (alpha)	$8.4\ 10^{-4}$	$3.4\ 10^{-5}$	4.0
	Plutonium-241	0.0051	$2.67\ 10^{-4}$	5.2
	Americium-241 and curium-242	$3.6\ 10^{-4}$	$4.98\ 10^{-5}$	14
Springfields	Uranium	0.006	$1.54\ 10^{-3}$	26
Capenhurst[d]	Tritium		5.09	
	Uranium		$6.15\ 10^{-6}$	
Chapelcross	Tritium	5000	1270	25
	Sulphur-35	0.05	0.0217	43
	Argon-41	4500	2800	62
United Kingdom Atomic Energy Authority[h]				
Dounreay (Fuel Cycle Area)	Alpha	0.001	$5.7\ 10^{-5}$	5.7
	Beta	0.045	$3.2\ 10^{-4}$	<1
	Tritium	40	0.025	<1
	Krypton-85	1000	Nil	Nil
	Strontium-90	0.005	$9.9\ 10^{-4}$	20
	Ruthenium-106	0.007	$2.4\ 10^{-5}$	<1
	Iodine-129	0.004	$2.8\ 10^{-5}$	<1
	Iodine-131	0.003	$1.8\ 10^{-5}$	<1
	Caesium-134	0.001	$3.4\ 10^{-6}$	<1
	Caesium-137	0.007	$8.0\ 10^{-5}$	1.1
	Cerium-144	0.007	$1.9\ 10^{-5}$	<1
	Plutonium-241	0.005	$5.6\ 10^{-4}$	11
	Curium-242	0.001	$2.2\ 10^{-7}$	<1
	Curium-244[i]	10^{-4}	$6.9\ 10^{-6}$	6.9
Dounreay (Fast Reactor)	Beta	0.0015	$1.52\ 10^{-7}$	<1
	Tritium	130	0.0105	<1
	Krypton-85	$4.0\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Tritium	18	0.708	3.9
	Argon-41	1.5	Nil	Nil
	Krypton-85m	10	"	"
	Krypton-87	20	"	"
	Krypton-88	20	"	"
	Xenon-133	3750	"	"
	Xenon-133m	75	"	"
	Xenon-135	350	"	"

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Harwell	Alpha	$7.0\ 10^{-6}$	$1.80\ 10^{-7}$	2.6
	Beta	$4.5\ 10^{-4}$	$4.00\ 10^{-6}$	<1
	Tritium	150	2.60	1.7
Windscale	Alpha	$1.2\ 10^{-5}$	$3.09\ 10^{-7}$	2.6
	Beta	0.005	$4.97\ 10^{-6}$	< 1
	Tritium	2.3	0.0043	<1
	Krypton-85	14	0.17	1.2
	Iodine-131	0.0012	$2.45\ 10^{-6}$	<1
Winfrith	Alpha	$2.0\ 10^{-6}$	$2.1\ 10^{-9}$	<1
	Beta	$2.5\ 10^{-5}$	$3.0\ 10^{-9}$	<1
	Tritium	5	0.35	6.9
	Carbon-14	0.3	$6.6\ 10^{-4}$	<1
	Krypton-85	150	Nil	Nil
Magnox Electric plc[e,k]				
Berkeley	Alpha and beta	$2.0\ 10^{-4}$	$1.87\ 10^{-6}$	<1
	Tritium	2	$1.3\ 10^{-2}$	<1
	Carbon-14	0.2	$2.31\ 10^{-4}$	<1
	Sulphur-35	0.006	Nil	Nil
(Technology Centre)	Alpha and beta	$2.0\ 10^{-5}$	$1.53\ 10^{-6}$	8
Bradwell	Beta	0.001	$2.62\ 10^{-4}$	26
	Tritium	1.5	0.839	56
	Sulphur-35	0.2	0.058	29
	Carbon-14	0.6	0.379	63
	Argon-41	1000	724	72
Dungeness 'A' Station	Beta	0.001	$3.6\ 10^{-4}$	36
	Tritium	2	0.57	29
	Carbon-14	5	3.0	61
	Sulphur-35	0.4	0.063	16
	Argon-41	2000	1300	65
Hinkley Point 'A' Station	Beta	0.001	$1.05\ 10^{-4}$	11
	Tritium	25	2.59	10
	Carbon-14	4	1.42	35
	Sulphur-35	0.2	0.058	29
	Argon-41	4500	2700	60
Hunterston 'A' Station	Beta[j]	10^{-4}	$1.3\ 10^{-7}$	<1
	Tritium	1	Nil	Nil
	Carbon-14	0.2	"	"
Oldbury	Beta	0.001	$1.03\ 10^{-4}$	10
	Tritium	5	2.39	48
	Carbon-14	6	3.72	62
	Sulphur-35	0.75	0.311	41
	Argon-41	500	180	36
Sizewell 'A' Station	Beta	0.001	$5.62\ 10^{-5}$	5.6
	Tritium	7	0.515	7.4
	Carbon-14	1.5	0.465	31
	Sulphur-35	0.6	0.019	3.2
	Argon-41	3000	841	28

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Trawsfynydd	Beta	0.002	$1.51\ 10^{-6}$	<1
	Tritium	10	0.137	1.4
	Carbon-14	5	$1.55\ 10^{-3}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta	0.001	$6.35\ 10^{-5}$	6.35
	Tritium	20	8.25	41
	Carbon-14	2.4	1.47	61
	Sulphur-35	0.5	0.30	59
	Argon-41	120	60.6	50
Nuclear Electric Ltd[e,l]				
Dungeness 'B' Station	Beta	0.001	$1.61\ 10^{-5}$	1.6
	Tritium	15	3.32	22
	Carbon-14	5	0.405	8.1
	Sulphur-35	0.45	0.023	5.1
	Argon-41	150	23.1	15
	Iodine-131	0.005	$4.22\ 10^{-6}$	<1
Hartlepool	Beta	0.001	$4.43\ 10^{-6}$	<1
	Tritium	6	1.5	25
	Carbon-14	5	1.91	38
	Sulphur-35	0.16	0.022	14
	Argon-41	60	12.4	21
	Iodine-131	0.005	$8.87\ 10^{-5}$	1.8
Heysham Station 1	Beta	0.001	$3.60\ 10^{-5}$	3.6
	Tritium	6	1.42	24
	Carbon-14	4	1.16	29
	Sulphur-35	0.12	0.014	12
	Argon-41	60	12.6	21
	Iodine-131	0.005	$7.47\ 10^{-4}$	15
Heysham Station 2	Beta	0.001	$1.46\ 10^{-5}$	1.5
	Tritium	15	2.18	15
	Carbon-14	3	1.05	35
	Sulphur-35	0.3	0.0153	5.1
	Argon-41	85	16.3	19
	Iodine-131	0.005	$1.89\ 10^{-4}$	3.8
Hinkley Point 'B' Station	Beta	0.001	$5.16\ 10^{-5}$	5.2
	Tritium	30	1.72	5.7
	Carbon-14	8	1.92	24
	Sulphur-35	0.4	0.101	25
	Argon-41	300	36.6	12
	Iodine-131	0.005	$1.25\ 10^{-5}$	<1
Sizewell 'B' Station (outlets 1-3)	Noble gases	295	15.7	5.3
	Halogens	0.0027	$5.95\ 10^{-5}$	2.2
	Beta	0.01	$1.06\ 10^{-5}$	<1
	Tritium	7.8	1.39	18
	Carbon-14	0.59	0.23	39
" (Approved places)	Noble gases	5	Nil	Nil
	Halogens	$3.0\ 10^{-4}$	"	"
	Tritium	0.2	"	"
	Carbon-14	0.01	"	"

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
Scottish Nuclear Ltd[e,l]				
Hunterston				
'B' Station	Beta[j]	0.002	$4.48\ 10^{-5}$	2.2
	Tritium	20	2.15	11
	Carbon-14	3	1.86	62
	Sulphur-35	0.8	0.0801	10
	Argon-41	220	61.9	28
Torness	Beta[j]	0.002	$1.55\ 10^{-5}$	<1
	Tritium	20	2.08	10
	Carbon-14	3	0.766	26
	Sulphur-35	0.8	0.039	4.9
	Argon-41	220	10.8	4.9
Ministry of Defence				
Aldermaston[a,n]	Alpha	$9.0\ 10^{-7}$	$1.31\ 10^{-7}$	13
	Beta[f]	$4.6\ 10^{-6}$	$1.51\ 10^{-7}$	3.3
	Tritium	340	3.65	1.1
	Krypton-85	0.4	$2.56\ 10^{-3}$	<1
Barrow[g]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.08	"	"
Burghfield[a,n]	Alpha	$2.0\ 10^{-8}$	$7.90\ 10^{-10}$	4.0
	Tritium	0.35	$1.26\ 10^{-4}$	< 1
	Krypton-85	1	Nil	Nil
Dounreay				
(Vulcan)	Noble gases	9.25	Nil	Nil
Iodine	$1.85\ 10^{-3}$	$2.88\ 10^{-5}$	1.6	
Fission products	0.0592	$1.7\ 10^{-6}$	<1	
Greenwich[m]	Argon-41	[d]	Nil	
Alpha	$5.0\ 10^{-10}$	$1.01\ 10^{-10}$	60	
Tritium	$2.9\ 10^{-5}$	Not assessed		
Other activity	$1.0\ 10^{-6}$	$2.0\ 10^{-8}$	6	
Rosyth[c]	Beta	10^{-7}	Nil	Nil
Argon-41	0.4	0.0957	24	
Nycomed Amersham plc				
Amersham	Alpha	$2.0\ 10^{-6}$	$1.70\ 10^{-7}$	8.5
	Other (penetrating)	0.05	$1.30\ 10^{-4}$	<1
	Other (non-penetrating)	0.5	0.013	2.6
	Tritium	40	Nil	Nil
	Selenium-75	0.03	$2.80\ 10^{-4}$	<1
	Iodine-125	0.1	0.014	14
	Iodine-131	0.05	$5.50\ 10^{-4}$	1.1
	Radon-222	10	1.6	16
Cardiff	Soluble tritium	400	153	38
	Insoluble tritium	1000	407	41
	Carbon-14	6	2.63	44
	Phosphorus-32/33	$2.0\ 10^{-4}$	$3.07\ 10^{-6}$	1.5
	Iodine-125	$5.0\ 10^{-4}$	$1.17\ 10^{-4}$	23
	Other activity	0.04	Nil	Nil
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$1.44\ 10^{-4}$	29
	Argon-41	2.5	0.672	27

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1998	
			TBq[a]	% of limit[b]
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	0.00177	12
	Other activity	$5.0\ 10^{-4}$	Nil	Nil
Rolls Royce plc				
Derby	Alpha	[d]	$1.04\ 10^{-6}$	
Scottish Universities Research and Reactor Centre				
East Kilbride	Tritium	19.2	Nil	
	Argon-41	3.33	"	
URENCO				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$6.87\ 10^{-8}$	2.7

[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] *Discharges may also be authorised from incinerators at these sites*
[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] *With effect from 1/4/98, power stations within Magnox Electric plc became part of Magnox Generation Business Group, BNFL plc*
[l] *With effect from 31/12/98, Nuclear Electric Ltd and Scottish Nuclear Ltd became British Energy Generation Ltd and British Energy Generation (UK) Ltd respectively*
[m] *Authorisation was revised with effect from 1 October 1998. The first block of data relates to the period 1 January 1998 to 30 September 1998; the second block of data relates to the period 1 October 1998 to 31 December 1998. '% limit' refers to equivalent limit for 9 and 3 months respectively*
[n] *Discharges are made by Hunting-BRAE Ltd*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 1998

Establishment	Radioactivity TBq	Disposal limit,	Disposals during 1998	
			TBq	% of limit
Drigg	Tritium	10	8.65	87
	Carbon-14	0.05	0.025	50
	Cobalt-60	2	0.551	28
	Iodine-129	0.05	$1.0\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.017	56
	Uranium	0.3	0.10	37
	Other alpha[a]	0.3	0.212	71
	Others[a,b]	15	9.54	69
Dounreay[c]	Alpha	0.0232		
	Beta/gamma	0.502		

[a] *With half-lives greater than three months*
[b] *Other beta emitting radionuclides but including iron-55 and cobalt-60*
[c] *Limits exist for concentrations of activity, activity per unit area and dose rate.*

APPENDIX 2. MODELLING OF RADIOACTIVITY IN FOOD

2.1 Introduction

There are two cases where the results of terrestrial monitoring in 1998 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 mode

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]	$2.33\ 10^{-4}$	[b]	[b]	$3.68\ 10^{-5}$
	Ravenglass	[a]	$3.67\ 10^{-4}$	$4.89\ 10^{-3}$	$2.45\ 10^{-3}$	$1.42\ 10^{-5}$
	Drigg	[a]	$6.50\ 10^{-4}$	[b]	$1.30\ 10^{-3}$	$1.95\ 10^{-5}$
	Isle of Man	[a]	$4.51\ 10^{-4}$	$4.51\ 10^{-3}$	$1.73\ 10^{-3}$	$1.44\ 10^{-5}$
Beef	Sellafield	[a]	$2.33\ 10^{-1}$	[b]	[b]	$3.68\ 10^{-3}$
	Ravenglass	[a]	$3.67\ 10^{-1}$	$2.45\ 10^{-1}$	$6.12\ 10^{-1}$	$1.42\ 10^{-3}$
Lamb	Sellafield	[a]	$2.69\ 10^{-1}$	[b]	[b]	$1.70\ 10^{-3}$
	Ravenglass	[a]	$4.24\ 10^{-1}$	$2.82\ 10^{-1}$	$7.06\ 10^{-1}$	$6.56\ 10^{-4}$
	Drigg	[a]	$7.50\ 10^{-1}$	[b]	$3.75\ 10^{-1}$	$9.00\ 10^{-4}$
Beef offal	Sellafield	[a]	$2.33\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	[a]	$3.67\ 10^{-1}$	[a]	4.89	[a]
Lamb offal	Sellafield	[a]	$2.69\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	$3.11\ 10^{-1}$	$4.24\ 10^{-1}$	[a]	4.24	[a]
	Drigg	[a]	$7.50\ 10^{-1}$	[b]	2.25	[a]

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

APPENDIX 3. ABBREVIATIONS

AEAT	AEA Technology plc
AGR	Advanced Gas-Cooled Reactor
BNFL	British Nuclear Fuels plc
CARE	Centre for Analytical Research in the Environment (Imperial College)
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (MAFF)
DoH	Department of Health
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
FARM	Food and Agriculture Monitoring Programme
FEPA	Food and Environment Protection Act
GDL	Generalised Derived Limit
G-M	Geiger-Muller
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LoD	Limit of Detection
MAFF	Ministry of Agriculture, Fisheries and Food
MRL	Minimum reporting level
ND	Not detected
NEA	Nuclear Energy Agency
NII	Nuclear Installations Inspectorate
NRPB	National Radiological Protection Board
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Commission
PWR	Pressurised Water Reactor
RSA	Radioactive Substances Act
RSND	Radiological Safety and Nutrition Division (MAFF and DoH)
SEPA	Scottish Environment Protection Agency
SGHWR	Steam Generating Heavy Water Reactor
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TRAMP	Terrestrial Radioactivity Monitoring Programme
UKAEA	United Kingdom Atomic Energy Authority
VLA	Veterinary Laboratories Agency

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	A	75 kg y^{-1} fish 5.0 kg y^{-1} crustaceans 2000 h y^{-1} over mud
	B	4.7 kg y^{-1} oysters
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	A	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	1600 h y^{-1} handling pots
	B	54 kg y^{-1} cod
		20 kg y^{-1} crab and lobster
		0.40 kg y^{-1} winkles
	C	5.5 kg y^{-1} winkles
		380 h y^{-1} over winkle beds
	D	100 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		98 kg y^{-1} fish
		9.4 kg y^{-1} shrimps
		14 kg y^{-1} whelks
		2000 h y^{-1} over mud
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	2.7 kg y^{-1} crab
	B	1900 h y^{-1} over mud and sand
Sellafield	A	45 kg y^{-1} cod (50%) and plaice (50%)
		28 kg y^{-1} crab (85%) and lobster (15%)
		15 kg y^{-1} winkles (30%) and other molluscs (70%)
		1100 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 (Whitehaven boat dwelling)	310 h y^{-1} over mud
		1.8 kg y^{-1} cod and plaice
		2.0 kg y^{-1} mussels from north Solway
	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 (seafood by-catches)	8.3 kg y^{-1} sea mice
		19 kg y^{-1} crab
		22 kg y^{-1} whelks
		1.7 kg y^{-1} lobster
		7.5 kg y^{-1} plaice
	O (bait diggers)	950 h y^{-1} handling sand
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 (boat dwelling)	3300 h y^{-1} over mud
	B	530 h y^{-1} handling nets
	C	360 h y^{-1} wildfowling
		16 kg y^{-1} wildfowl
		550 h y^{-1} handling mud
	D	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
	E (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%)

Table A4.2. continued

Site	Group[a]	Rates
Winfrith	A	77 kg y^{-1} cod
		26 kg y^{-1} crab
		39 kg y^{-1} whelks
	B	390 h y^{-1} over mud
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).

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
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

Ministry of Agriculture, Fisheries and Food
Joint Food Safety and Standards Group
Radiological Safety and Nutrition Division
Ergon House
17 Smith Square
London SW1P 3JR

Scottish Environment Protection Agency
Erskine Court
The Castle Business Park
Stirling FK9 4TR

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