FOOD STANDARDS AGENCY
SCOTTISH ENVIRONMENT PROTECTION AGENCY

Radioactivity in Food and the Environment, 2000

RIFE - 6

September 2001

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

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FOREWORD

The safety of food and protection of the environment continue to be important issues. Radioactivity in the environment and its entry into the foodchain is potentially a source of harm to the public and therefore, regular surveys of radioactivity in food and environmental materials are conducted to assess the exposure of the public to radioactivity.

Results of these surveys are made available through publications, such as this report and regular updates on the Food Standards Agency Web site. This report presents the scope and results of the Food Standards Agency and Scottish Environment Protection Agency's radiological surveillance programmes conducted in 2000. In England and Wales the Environment Agency survey non-food pathways, and their publication is complementary to this report.

The Food Standards Agency and Scottish Environment Protection Agency undertake measurements in samples from around nuclear sites and other potential sources of elevated radioactivity throughout the United Kingdom. Measurements of the concentration of radioactivity in the national food supply are also reported.

The results reported here demonstrate that the public exposure to radioactivity via the foodchain is well below dose limits. We remain committed to ensuring that a proper, rigorous and transparent surveillance programme is continued to ensure that this remains the case.

Professor Sir John Krebs
Chairman, Food Standards Agency

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

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EXECUTIVE SUMMARY

Radiation Safety – Food and the Environment at Nuclear Sites

This report combines data from both the Scottish Environment Protection Agency's (SEPA's) and the Food Standards Agency's* monitoring programmes for radioactivity in food and the environment in 2000.

The purpose of the Food Standards Agency's programme is to ensure that any radioactivity present in food does not compromise food safety and that authorised discharges of radioactivity do not result in unacceptable doses to consumers via the diet.

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

Both programmes demonstrate that as a result of consumption of terrestrial foodstuffs and seafood produced in and around the United Kingdom the most exposed consumers receive small radiation doses which are well below all dose limits. In 2000 exposure of consumers to artificially produced radioactivity via the food chain remained well below the statutory United Kingdom principal annual dose limit to members of the public of 1 mSv (millisievert) for all artificial sources of radiation (except medical sources), European Union (EU) limits and Government targets.

The highest doses were received by a group of high-rate consumers of fish and shellfish in Cumbria. The doses contain contributions from liquid discharges from both Sellafield and from the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) plant at Whitehaven. The dose to these high-rate consumers (including external doses) from Sellafield discharges were estimated to be 0.15 mSv in 2000 compared with 0.21 mSv in 1999 (Food Standards Agency and SEPA, 2000). This decrease was largely due to changes in the habits of high-rate consumers of seafood. This critical group also received an estimated dose of 0.38 mSv from enhanced levels of natural radioactivity due to **past** operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. As these doses are for the critical group by definition other groups will have received lower doses.

In Scotland the highest exposures are in the south west. They relate to an actual group of consumers of seafood, spending time over inter-tidal areas, who are estimated to receive annual doses of 0.032mSv, mainly as a result of the distant effect of Sellafield. They are associated with gaseous discharges from Chapelcross, where a hypothetical group of infants, drinking milk, at above average consumption rates, with the highest concentration of activity recorded, could receive an annual dose of 0.034 mSv. However, this dose can not be directly compared with the dose estimated in 1999. There were small increases in activity levels detected, but in the main the apparent increase in dose was due to changes in the scope of the monitoring programme and the method of calculation.

Doses due to gaseous discharges from Sellafield were 0.033 mSv, a small reduction on the dose in 1999. The assessment covered consumption of milk, vegetables, fruit and meat.

Most of the seafood and external exposure that can be attributed to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed around 13% of the dose to the Sellafield seafood consumers.

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

Heysham high-rate seafood consumers were estimated to receive 0.066 mSv but most of this was attributed to Sellafield discharges. Therefore the nuclear site of next importance, with regard to public exposures from site discharges, was Nycomed Amersham in Cardiff where radiochemicals for research, medicine and industry are produced. Doses to high-rate seafood consumers at Cardiff were estimated to be 0.064 mSv in 2000. Most of the dose was due to tritium and carbon-14 in fish from the Bristol Channel. Research is underway to determine the mechanisms whereby tritium from this site accumulates in seafood. Such accumulation has not been observed to the same extent at other sites in the United Kingdom.

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

Radioactivity levels in samples collected around nuclear sites

No significant changes in radioactive contamination of food or external dose rates were observed in 2000. 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 which is a likely consequence of reduced discharges to sea. The assessed dose to the most exposed group of seafood consumers from technetium-99 discharges was less than 2% of the principal dose limit for members of the public of 1 mSv. Sea-to-land transfer of technetium-99 occurred on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser but there was no evidence for significant transfers of technetium-99 through alginate production or animals feeding on seaweed.

Concentrations of tritium associated with organic material in seafood near Cardiff remained at levels in excess of 10000 Bq kg^{-1} (wet). Relatively high concentrations, 30,000 Bq kg^{-1}, were also found in fresh water barbel from a nearby river. Small increases of tritium above background in freshwater and seafood were also found in the Thames catchment and in various coastal locations around the UK, respectively. These findings are the subject of further research.

Site incidents and non-routine sampling

Two incidents occurred at Sizewell 'B' power station, both coincidentally in October 2000. In the first, an abnormal gaseous release of iodine-131 took place. In the second, contaminated water entered the site's drainage system and was discharged to sea. In both cases surveillance was immediately initiated and the results put into the public domain. Restrictions on food harvesting, sale or consumption were not necessary because the increase in radiation above expected levels was very low.

A section of the liquid effluent pipeline which takes waste from the Harwell site to the River Thames failed in September 2000 during routine testing. Sampling of agricultural land in the vicinity was undertaken but very low levels of radioactivity were detected. No unusual levels of radioactivity in food grown in the area were found.

During 2000, further radioactive fragments** were recovered near Dounreay. Six radioactive fragments were recovered from Sandside Bay, five from the site foreshore and 115 from the seabed near to the Dounreay site. The fishing restrictions under the Food and Environment Protection Act 1985 (United Kingdom-Parliament, 1985) are still in force.

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* *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 with that of technetium-99 (tritium and carbon-14) are exempted from these intervention levels. Government policy is explained in Section 3.5.*

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

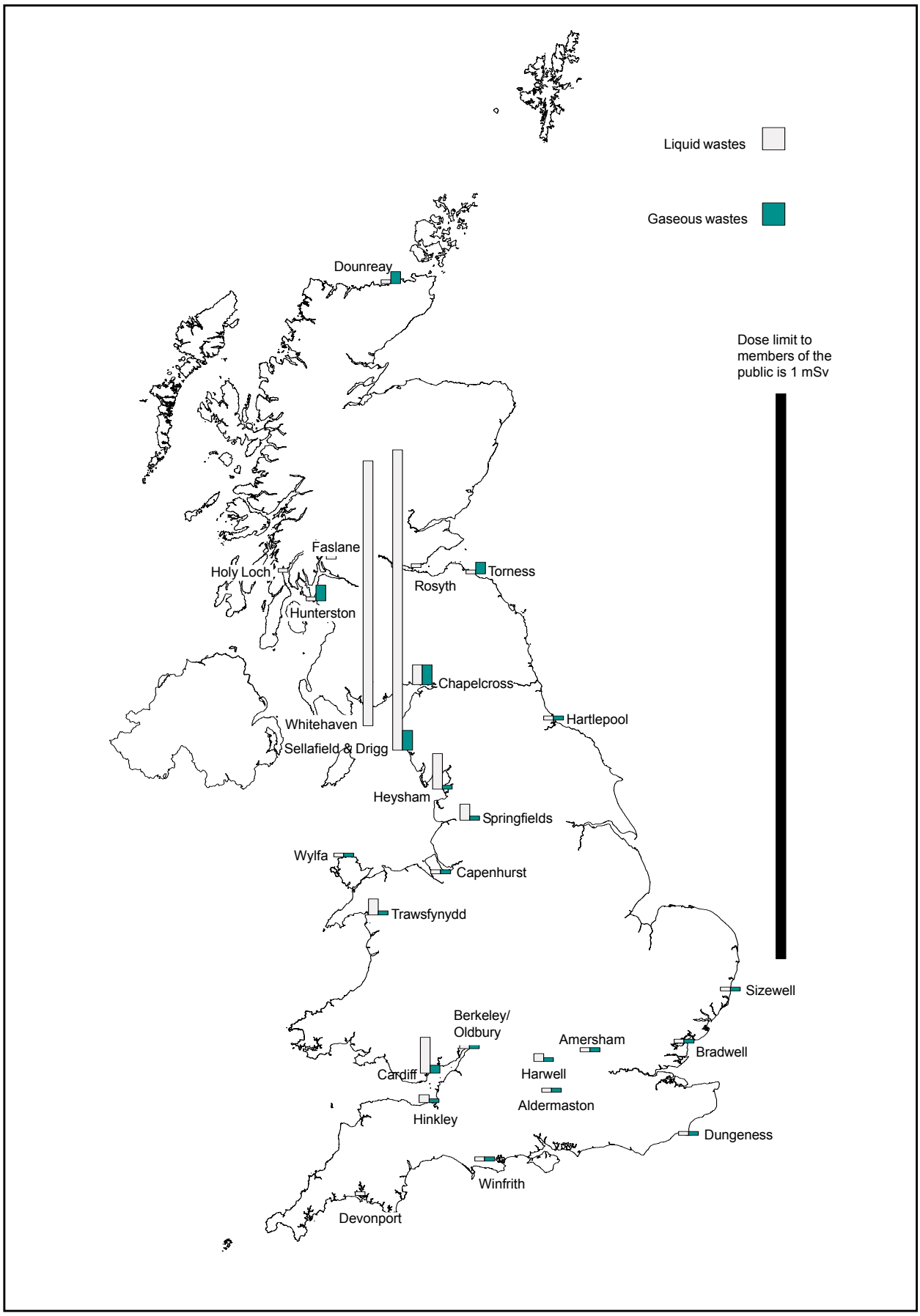

Figure S. Radiation exposures in the UK due to radioactive waste discharges, 2000 - Food Standards Agency and SEPA surveillance

(Exposures at Whitehaven and Sellafield include the effects of artificial and enhanced natural nuclides from nuclear and non-nuclear industries)

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 2000[a]

Establishment	Radiation exposure pathway	Critical group	Exposure, mSv[b]	Contributors[c]
British Nuclear Fuels plc[d]				
Sellafield and Drigg[e]	Fish and shellfish consumption and external	Local fishing community	0.15	$^{239/240}$Pu ^{241}Am
	Terrestrial foods	Local consumers at Sellafield	0.033	^{90}Sr ^{106}Ru
	Terrestrial foods	Local consumers at Drigg	0.015	^{90}Sr ^{106}Ru
	Terrestrial foods	Local consumers at Ravenglass	0.018	^{90}Sr ^{106}Ru
	External (skin)	Anglers	0.16[f]	Beta
	Handling of fishing gear	Local fishing community	0.12[f]	Beta
	Porphyra/laverbread consumption	Consumers in South Wales	<0.005	^{106}Ru ^{241}Am
	Trout consumption[g]	Local consumers at Sellafield	0.035	^{137}Cs ^{241}Am
	Seaweed/crops	Local consumers at Sellafield	0.027	^{99}Tc ^{241}Am
Springfields	External (skin)	Local fishermen	0.80[f]	Beta
	Fish and shellfish consumption and external	Local fishing community	0.025	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers[h]	0.007[i]	^{90}Sr ^{232}Th
Capenhurst	Inadvertent ingestion of water and sediment	Local community	<0.005	U ^{234}Th
	Terrestrial foods	Local consumers[h]	<0.005	^{3}H U
Chapelcross	Fish and shellfish consumption and external	Local fishing community	0.032	Ext ^{241}Am
	Terrestrial foods	Local consumers	0.034	^{3}H ^{35}S
United Kingdom Atomic Energy Authority				
Dounreay	Fish and shellfish consumption	Local fishing community	<0.005	^{14}C ^{99}Tc
	External	Local community	<0.005	Ext
	Terrestrial foods	Local consumers[h]	0.020	^{90}Sr ^{238}Pu
Harwell	Fish consumption and external	Anglers	0.013	Ext ^{137}Cs
	Terrestrial foods	Local consumers	<0.005	^{3}H
Winfrith	Fish and shellfish consumption	Local fishing community	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers[h]	<0.005	^{3}H ^{137}Cs
Electricity Companies[d]				
Berkeley and Oldbury	Fish and shellfish consumption and external	Local fishing community	<0.005	Ext ^{3}H
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption	Local fishing community	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Dungeness	Fish and shellfish consumption and external	Bait diggers	0.005	Ext ^{241}Am
	Terrestrial foods	Local consumers[j]	<0.005	^{14}C ^{137}Cs
Hartlepool	Fish and shellfish consumption	Local fishing community	<0.005	^{14}C ^{241}Am
	Terrestrial foods	Local consumers	0.007	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external	Local fishing community	0.066	Ext ^{241}Am
	Terrestrial foods	Local consumers	0.005	^{14}C ^{35}S
Hinkley Point	Fish and shellfish consumption and external	Local fishing community	0.012[k]	Ext ^{3}H
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption and external	Local fishing community	0.009	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	0.026	^{14}C ^{35}S
Sizewell	Fish and shellfish consumption and external	Local fishing community	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	Local consumers	0.008	^{14}C ^{35}S

Summary Table: continued

Establishment	Radiation exposure pathway	Critical group	Exposure, mSv[a]	Contributors[c]
Electricity Companies *continued*				
Torness	Fish and shellfish consumption	Local fishing community	<0.005	^{99}Tc ^{241}Am
	External	Local community	<0.005	Ext
	Terrestrial foods	Local consumers	0.018	^{35}S ^{90}Sr
Trawsfynydd	Fish consumption and external	Local fishing community	0.028	Ext ^{137}Cs
	Terrestrial foods	Local consumers	<0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external	Local fishing community	0.010	Ext ^{241}Am
	Terrestrial foods	Local consumers	<0.005	^{14}C ^{35}S
Defence Establishments				
Aldermaston	Fish consumption and external	Anglers	<0.005	^{3}H ^{137}Cs
	Terrestrial foods	Local consumers	<0.005[i]	^{3}H U
Devonport	Fish and shellfish consumption and external	Local community	0.009	Ext ^{241}Am
Faslane	Fish and shellfish consumption and external	Local community	<0.005	Ext ^{137}Cs
Holy Loch	External	Local community	<0.005	Ext
Rosyth	External	Local community	<0.005	Ext
Nycomed Amersham plc				
Amersham	Fish consumption and external	Anglers	<0.005	Ext ^{241}Am
	Terrestrial foods	Local consumers	0.005	^{75}Se ^{131}I
Cardiff	Fish and shellfish consumption and external	Local fishing community	0.064	^{3}H ^{14}C
	Terrestrial foods	Local consumers	0.015	^{3}H ^{14}C
Rhodia Consumer Specialties Ltd				
Whitehaven[l]	Fish and shellfish consumption	Local fishing community	0.42	^{210}Po ^{210}Pb

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

[b] *Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv (see section 3). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. All exposures for terrestrial pathways include a component from radionuclides which were found to be below the limits of detection. Unless stated otherwise, the critical group for terrestrial pathways is represented by the 1 year old age group*

[c] *The top two contributors to the dose; either 'ext' to represent the whole body external exposure from beta or gamma radiation, 'beta' for beta radiation of skin or a radionuclide name to represent a contribution from internal exposure. Some contributions from radionuclides to internal exposure are based on concentration data at limits of detection.*

[d] *Power stations are operated by Magnox Electric (a wholly owned subsidiary of BNFL plc), British Energy Generation Ltd or British Energy Generation (UK) Ltd*

[e] *The estimates for marine pathways include the effects of liquid discharges from Drigg, 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 2000 was 0.38 mSv*

[f] *Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see section 3)*

[g] *A hypothetical pathway. Although consumption took place in the past, none occurred in 2000*

[h] *15 y old*

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

[j] *Adults*

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

[l] *These estimates include the effects of enhanced concentrations of natural radionuclides but exclude a small contribution from the effects of artificial radionuclides from other sites. They assume a gut uptake factor of 0.8 for polonium which is based on studies of seafood consumption (see section 3). The exposure due to artificial radionuclides in 2000 was 0.049 mSv*

Radiation doses and levels at other locations in the UK

Analyses of food throughout the United Kingdom in the general diet demonstrated that natural radionuclides were by far the most significant source of exposure from radiation to communities in areas remote from nuclear sites and man-made radionuclides only contributed about 2% of the mean dose.

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 (Rhodia Consumer Specialties Ltd.) continued to be enhanced above normal levels. Making maximising assumptions about the level of enhancement, doses to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, were estimated to be 0.53 mSv for the most exposed group at Whitehaven.

The programme of monitoring the effects of discharging gaseous wastes at other non-nuclear industrial sites continued. Following a small-scale programme in 1999, significant enhancement of tritium and carbon-14 was again found in grass in the Billingham area in 2000. Several sites discharge radioactive waste in this area. The dose to hypothetical high-rate consumers near the site was estimated to be up to 0.26 mSv based on pessimistic assumptions relating the measured activities in grass to expected activities in food. Actual exposures are likely to be an order of magnitude less although again this was a hypothetical dose as the samples with the highest activity were from a playing field. No agriculture was noted in this area.

Tritium was found in leachate from some landfill sites in Scotland at levels that were of no radiological significance.

The surveillance programmes

These surveillance programmes involved the collaboration of four specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised independently of the industries discharging wastes by SEPA, the Food Standards Agency and CEFAS. The programme includes monitoring undertaken on behalf of the Scottish Executive, Channel Island States, the Department for Environment, Food and Rural Affairs* , the Environment and Heritage Service for Northern Ireland, the Manx Government and the National Assembly for Wales. In 2000, 2200 food samples and 3300 other samples were collected to determine levels of radioactivity in the environment. 22000 analyses or dose rate measurements were completed. In Scotland, SEPA increased monitoring of food and the environment as a result of a review of its programme in 1999/2000. Food sampling at such sites is now consistent with that in the rest of the UK.

Results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries on the Internet (www.foodstandards.gov.uk). Further details of all programmes described in this report can be obtained by telephoning the Food Standards Agency on **0207 276 8748** or SEPA on **01786 457 700**.

Research

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

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* *The Department for Environment, Food and Rural Affairs (DEFRA) took over the responsibilities of MAFF in relation to this report in June 2001. For simplicity we have referred to the MAFF studies in 2000 as being those of DEFRA.*

1. INTRODUCTION

1.1 Background

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

The data in this report cover the calendar year of 2000. The results of the programmes have been assessed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of the Food Standards Agency, SEPA, the Department for Environment, Food and Rural Affairs (DEFRA), the National Assembly for Wales, the Environment and Heritage Service (Northern Ireland), the Manx Government and the Channel Island States.

The purpose of the programmes is to ensure that any radioactivity present in foods does not compromise food safety and that public radiation exposure via the diet is within EU accepted limits. In Scotland, SEPA has a broader responsibility (under the Environment Act 1995 (United Kingdom - Parliament, 1995a)) for protecting (and determining general levels of pollution in) the environment and the data reported here are also used to assess the environmental impact of radioactive discharges.

The monitoring undertaken by the Food Standards Agency and SEPA 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 discharges from nuclear sites in the United Kingdom. However, data on the marine environment of the whole of the British Isles and further afield, together with information on the levels of radioactivity in foodstuffs in areas of the United Kingdom remote from nuclear sites, is included. For Scotland, monitoring of both the environment and foodstuffs is included in this report. Where appropriate, the monitoring data for nuclear sites are supplemented by results from other projects related to the behaviour of radioactivity in the environment. The most recent summary of the scope of all radioactivity-monitoring programmes as undertaken by nuclear site operators and local and central government can be found in DETR* (2001).

To place the monitoring results from the programme in context, radioactive waste discharges from nuclear establishments in the United Kingdom for 2000 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 abbreviations is provided in Appendix 3.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

Data on United Kingdom radioactive waste discharges (disposals) are published by the Department for Environment, Food and Rural Affairs (DEFRA) (www.defra.gov.uk/environment/index.htm), the latest available data at the time of writing being for the year 1999. Details of the discharges from individual sites are available from public records held by SEPA and the Environment Agency. These agencies are

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* *The Environment Protection Group of DETR transferred to DEFRA after June 2001*

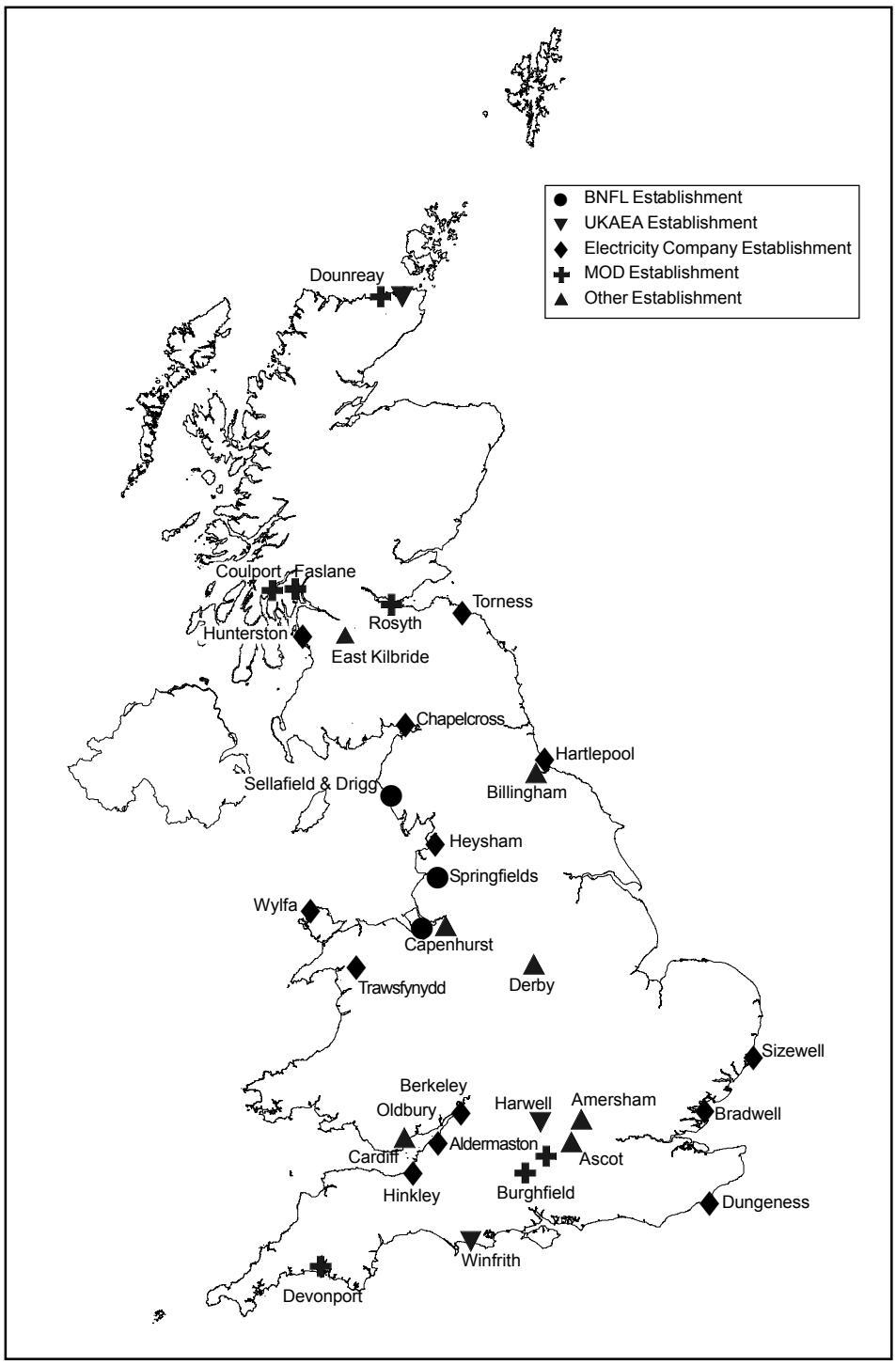

Figure 1.1. Principal sources of radioactive waste disposal in the UK

responsible for authorising discharges in Scotland, and in England and Wales respectively under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). A summary of 2000 discharges is included in Appendix 1 to enable the results of monitoring presented in this report to be considered in the context of the relevant discharges.

The sites that are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. The programmes include monitoring at each of these sites. For completeness, it should be noted that discharges of radioactive waste are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993) from other sites such as hospitals, chemical works and research establishments. Occasionally, the impact of such discharges is detected within this programme. For example, iodine-131 originating from hospitals is detected in some marine samples. Small amounts of very low level solid waste are also disposed of in specified landfill sites. The non-nuclear licensed sites are not subject to the additional controls provided for by the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). As noted in Figure S and the Summary Table there is a significant impact due to the non-nuclear site at Whitehaven although in general discharges from non-nuclear sites are considered insignificant and as such environmental monitoring of their effects is often not required. However, this situation is reviewed from time to time and small surveys are included in the programme where relevant.

Appendix 1 presents the principal discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the United Kingdom during 2000. The tables also list the discharge and disposal limits that are authorised or, in the case of the Ministry of Defence, administratively agreed. In some cases, the authorisations specify limits in greater detail than can be summarised in a single table: in particular, periods shorter than one year are specified at some sites. The authorised limits are usually significantly lower than discharge levels that would result in an exposure equivalent to the dose limits which are recommended by the International Commission on Radiological Protection (ICRP), and embodied in EU and UK law. The percentages of the authorised (or agreed) limits taken up in 2000 are also stated in the tables.

Where changes in the rates of discharge in 2000 have affected the levels of radioactivity in the environment, this is addressed in the relevant part of the subsequent text.

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"

This objective will be achieved through progressive and substantial reductions of discharges, emissions and losses of radioactive substances and the following issues should, among other things, be taken into account:

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

These changes put the UK's commitment to discharge reductions clearly within the Sintra implementation proposals.

The UK Government is working within the OSPAR Convention framework to achieve the objectives of the Sintra Statement. Information on work in progress within the Radioactive Substances Committee of OSPAR can be found on the OSPAR website (www.ospar.org).

During 2000, the UK Government consulted upon the draft UK National Discharge Strategy (NDS) (DETR, 2000b). The NDS discusses the implementation of the requirements for progressive reductions in discharges. The consultation period is now closed and the UK Government and the devolved administrations are taking forward the issues raised. Publication of the finalised NDS is expected by the end of 2001.

1.2.2 Radioactive waste disposal at sea

In the past, disposals of packaged solid waste of low specific activity were mainly made to an area of the deep Atlantic Ocean. The last such disposal was in 1982. The Government announced the permanent cessation of disposal of such material at sea at the OSPAR Ministerial meeting in 1998. At that meeting, Contracting Parties agreed that there would no longer be any exception to a prohibition on the dumping of radioactive substances, including wastes (OSPAR, 1998). The environmental impact of the deep ocean disposals is predicted by detailed mathematical modelling and has been shown to be negligible (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 2000 are presented in Section 11.3. They confirm that the radiological impact of these disposals was insignificant.

In England and Wales, DEFRA issues licences to operators for the disposal of dredge material under the Food and Environment Protection Act, 1985 (United Kingdom – Parliament, 1985). The protection of the marine environment is considered before a licence is issued. Since dredge material may contain radioactivity, assessments are undertaken where appropriate for assurance that there is no significant foodchain or other risk from the disposal. In 2000, a specific assessment of the disposal of spoil from the Tamar Estuary near Devonport was carried out. The Tamar estuary contains low levels of artificial radionuclides due to discharges from the submarine related operations at Devonport and from other widespread sources such as weapon test fallout. Samples of the material were taken and analysed and the results are given in Appendix 7. The assessment showed that the impact of the radioactivity associated with the disposal operation was very low, below 'de minimis'* levels of exposure. Full guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA, 1999).

1.2.3 Other sources of radioactivity

There are several other possible sources of radioactivity that may affect the marine food chain and the environment. These include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas installations and the operation of nuclear powered submarines. Submarine berths in the United Kingdom are monitored by the Ministry of Defence (DRPS, 2000). 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 2000. Small enhancements in environmental levels were detected in the Channel Islands (Section 11.3) and these may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague.

The irradiation of food by intense sources of radioactivity to limit spoilage and microbial contamination is not considered in this report. Information on this practice is available from the Food Standards Agency. The regulations concerning approval, labelling, trade and control of irradiated products in England and Scotland were revised in 2000 (United Kingdom-Parliament, 2000 a and b) following a consultation exercise to reflect new EU legislation (EC Directives 1999/2/EC and 1999/3/EC).

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* *'De minimis' relates to doses of the order of 10 µSv or less (IAEA, 1999)*

2. SAMPLING AND MEASUREMENT

2.1 Sampling programme

The primary purpose of the Food Standards Agency programme is to ensure that any radiation present in food does not compromise food safety. In order to assess the total radiation dose received by a member of the public, for comparison with dose limits, samples of food and materials from the environment are collected. In this context, the term 'sampling' includes the collection of samples for laboratory analysis 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.

In Scotland, SEPA's sampling programme has been designed to monitor both the safety of the food chain together with determining the levels of man-made radionuclides in the environment such that an assessment can be made on the effects on human health as well as that of the environment. The programme also acts as an additional check for compliance with conditions in authorisations and provides a baseline dataset from which to judge the importance of any accidental releases of radioactivity. The programme provides information on radioactivity in the environment and the diet of the general Scottish population and aids calculation of collective radiation exposures to the population as a whole.

Sampling is focused on nuclear sites licensed by the Health and Safety Executive under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965). The programme also serves to provide information to assist SEPA and the Environment Agency to fulfil statutory duties under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). Additional sampling is carried out in areas remote from nuclear sites to establish the general safety of the food chain and the environment. Results from this sampling generate data that can be used as background levels to compare with results from around nuclear sites. Measurements can be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

A review of the scope of the programme in Scotland has now been completed. The main conclusion of the review was that there should be increased surveillance of food in the vicinity of major Scottish nuclear sites and appropriate changes were introduced to the programme in 2000. The revised programme includes the sampling of a greater number of food types and increases in the number of environmental measurements taken to further ensure that the effects of radioactivity in the environment and foodstuffs are fully assessed.

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 the programmes in each sector is summarised in Table 2.1 and described in the following Section.

2.1.1 Nuclear sites

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

The frequency and type of measurement and the materials sampled vary from site to site. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring when necessary, for example, in relation to incidents or reports of unusual or high levels of radioactivity with the potential to get into the food chain. The results of both routine and additional monitoring are included in this report.

The main aim of the programme is to monitor the diet of consumers who live or work near nuclear sites in order to estimate exposures for those small groups of people who are most at risk from disposals of radioactive waste. In the aquatic environment, the pathways that are the most relevant are the ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. In the terrestrial environment they are the ingestion of terrestrial foods, inhalation of airborne activity and external exposure from material in the air and deposited on land. The drinking water pathway is of interest for inland nuclear sites, which are found in England and Wales. This pathway is considered as part of the Environment Agency programme (Environment Agency, 2000). 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, in order that levels 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 gaseous disposals to the atmosphere.

In England and Wales, the responsibility for the bulk of surveillance of external exposure from radioactive waste disposals rests with the Environment Agency which publishes its results in a separate report (e.g. Environment Agency, 2000). In Scotland, SEPA's programme provides external exposure information for Scotland which is included in RIFE. Where appropriate, this report also contains external exposure data for England and Wales as part of a holistic approach to high-rate consumers' protection and to give assurance for the farming and fishing communities.

The aquatic programme

The general scope of the aquatic programme in 2000 is summarised in Table 2.2. A wide range of seafood and indicator materials (see below) and selected direct measurements of external dose rates were taken in areas of known or suspected contamination and where public occupation occurs or is likely to occur. In both cases, the frequency of measurement depends on the level of environmental impact from the source under scrutiny, with the intervals between measurements vary 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 from year to year, according to local circumstances.

Indicator materials, such as soil, tide-washed pasture, sediments and seaweeds are sampled to provide information on trends in contamination levels in the environment. These materials can concentrate particular radionuclides and offer a cost-effective means of determining levels of activity in the environment. In the case of sediments, there is an immediate use for the concentration levels in dose assessments. They are used to help distinguish contributions to the overall dose rates from artificial and natural radionuclides.

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

The terrestrial programme

The general scope of the terrestrial programme in 2000 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of foodstuffs that may be affected by disposals to atmosphere, although in some cases where food availability is limited, environmental indicator materials such as grass and soil are monitored.

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

Grass is a useful indicator of radioactivity as it is an efficient collector of atmospheric contaminants. As cows graze significant areas of grass, and many important radionuclides are passed from grass into milk, then milk is generally the most important foodstuff for monitoring purposes. Milk is also a convenient product to sample regularly and analyse and is an important part of the diet, especially for young children and infants. For most analyses of milk, weekly or monthly collections are combined (bulked) to provide four quarterly samples for analysis each year, although some analyses are carried out more frequently, e.g. weekly iodine-131 analysis. Annual bulking of some milk samples is carried out for analysis of tritium, carbon-14 and caesium ratios (by the analysis of caesium-134 and caesium-137). The frequency of analysis of other foodstuffs is generally annual. This allows for a wide range of sample types to be collected throughout the year. Samples are collected from locations as close to the sites as practicable as these are usually the most sensitive to the effects of disposals. In the case of milk, sampling may take place at several farms and these are labelled either as ‘near’ or ‘far’ in the tables of results depending on their distance from the site. The threshold for distinguishing between ‘near’ and ‘far’ farms is that ‘near’ farms are up to 8 km from the site, and ‘far’ farms 8-16 km from the site.

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

2.1.2 Industrial and landfill sites

Whilst the main focus of the programme is the nuclear industry, a watching brief is kept on other activities which may have a radiological impact on the food chain. This part of the programme considers the impact of disposals of natural and man-made radionuclides from non-nuclear industries and of disposal into landfill sites other than at Drigg and Dounreay. The sites considered in 2000 are shown in Figure 2.1.

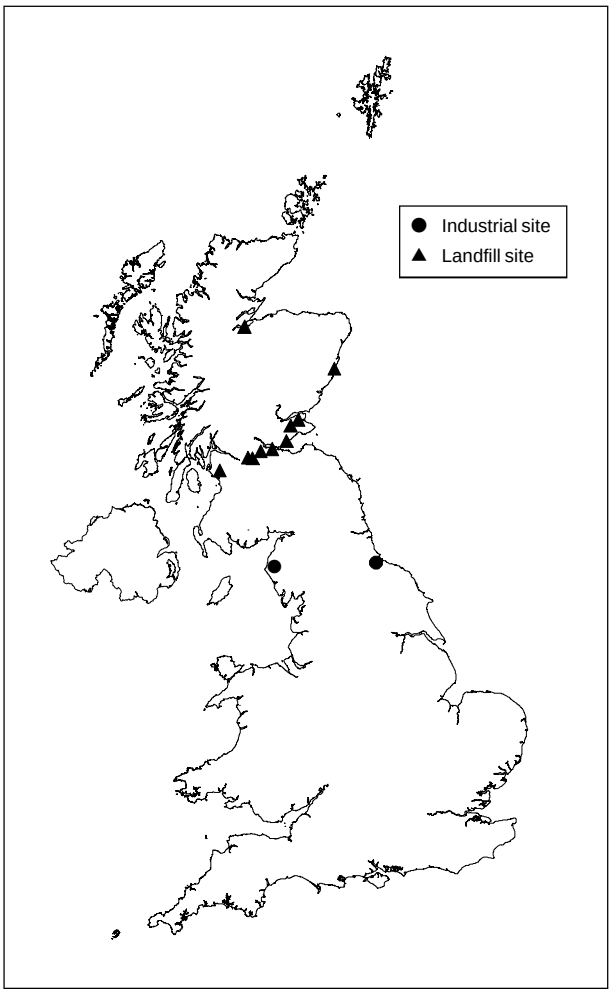

Figure 2.1 Industrial and landfill sites studied in 2000 (landfill sites in England and Wales are monitored by the Environment Agency and are therefore not covered in this report)

Industrial sites are chosen because either they are known from previous research to have a measurable radiological impact on the food chain or they represent a type of industrial activity that has potential effects on the environment and/or food chain. These sites do not require licensing under the Nuclear Installations Act. Examples are hospitals, incinerators, steel works and radiochemical manufacturers. In 2000, the industrial sites studied were in Whitehaven, Cumbria, and in the vicinity of Billingham, Cleveland.

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

Twelve landfill sites were monitored in Scotland. They are studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment. Monitoring of landfill sites in England and Wales has continued to be undertaken by the Environment Agency.

2.1.3 Chernobyl fallout

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

2.1.4 Additional monitoring

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

- monitoring of the Isle of Man and the Channel Islands;
- dietary surveys;
- sampling of milk, crops, bread and meat;
- drinking water and airborne particulates* in Scotland;
- seawater surveys.

Isle of Man and the Channel Islands

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

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

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

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information that is useful in interpreting site-related measurements and also helps ensure that all significant sources of contamination form part of the site-related programme. Representative mixed diet samples are collected from regions throughout the United Kingdom. Normal culinary techniques are used in preparing samples (e.g. removal of outer leaves if necessary) and samples are combined in amounts that reflect the relative importance of each food in the average United Kingdom diet. Some samples are analysed for a range of contaminants including radionuclides. Part of this data is also supplied to the European Commission (EC) in support of the Euratom Treaty.

Specific foods, freshwater and airborne particulates

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

Milk sampling took place at dairies throughout the United Kingdom in 2000. Samples were taken monthly and some of the results are reported to the EC to allow comparison with those from other member states.

** Data for airborne particulate will be published in RIFE 2001*

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

Freshwater was sampled throughout Scotland and is reported in Table 11.11. The results of monitoring of drinking water in England and Wales are summarised in the Environment Agency's surveillance report (Environment Agency, 2000). SEPA samples airborne particulates at one location in Scotland. As part of the review of the monitoring programme, SEPA intends to carry out routine air sampling around nuclear sites using medium volume air samplers.

Seawater surveys

Seawater surveys are carried out in the Irish Sea, Scottish waters and the North Sea on behalf of DEFRA to provide information on radionuclide levels and fluxes in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the aegis of the Oslo and Paris Conventions (OSPAR, 2000) to which the 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 collected from the environment and analysed for their radionuclide content in a laboratory; and (ii) dose rates are measured directly in the environment.

2.2.1 Sample analysis

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

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

- CEFAS Centre for Environment, Fisheries and Aquaculture Science,
  analysis of dry cloths and aquatic samples excluding those from Scotland

- IC Imperial College, University of London,
  total uranium analysis of terrestrial samples from England and Wales

- NRPB National Radiological Protection Board,
  gamma-ray spectrometry and radiochemistry of samples from Scotland, and diet and industrial samples from England and Wales

- VLA Veterinary Laboratory Agency,
  gamma-ray spectrometry and radiochemistry (excluding total uranium analysis) of terrestrial samples excluding those from Scotland

Each laboratory operates quality control procedures to the standards required by the Food Standards Agency or SEPA involving regular calibration of detectors and intercomparison exercises with other laboratories. The methods of measurement used are summarised in Table 2.3.

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

The analysis of foodstuffs is carried out on that part of the sampled material that is normally eaten. The shells of shellfish and the pods of legumes are discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish samples are boiled soon after collection to minimise losses from the digestive gland. For a few radionuclides, some activity may be lost in the cooking process during sample preparation. These losses generally 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. For certain key public activities, for example for people living on houseboats or for wildfowlers lying on the ground, measurements at other distances from the ground may be made. External beta doses are measured on contact with the source, for example fishing nets, using Berthold* LB 1210B contamination monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all others. In this report we have presented the total gamma dose rate. NRPB reports terrestrial gamma dose rates to SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 $\mu Gy\ h^{-1}$ which is an approximation of the contribution made by cosmic radiation (HMIP, 1995).

2.2.3 Dry cloths

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

This is the last year that results from dry cloths will be reported. The programme is under review and it is anticipated that the programme will cease in 2001.

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

Table 2.1. Scope of the monitoring programmes

Programme	Sub-programme	Main purpose
Nuclear sites[a]		Support for RSA 93[c], food safety assessment of waste disposal
Industrial sites	Chemical works	Support for RSA 93[c], food safety assessment of waste disposal
	Landfill sites[c]	Support for RSA 93, assessment of waste disposal
Chernobyl fallout	Sheep monitoring	Support for FEPA 85, guidance on restrictions
	Freshwater fish	Support for FEPA 85, trend analysis
Regional[b]	Milk	General food safety, support for EURATOM Treaty
	Crops, bread and meat	General food safety, support for EURATOM Treaty[c]
	Diet	General food safety, support for EURATOM Treaty
	Isle of Man	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 2000

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-ray spectrometry, ^{3}H, organic ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, $^{134/137}Cs$, Th, U, transuranics	Fish, crustaceans, molluscs, edible aquatic plants	Cod, plaice, grey mullet, bass, dab, ray, herring, flounder, sea trout, dogfish, whiting, whitebait, fish oil, salmon, sole, spurdog, mackerel, pollack, haddock, crabs, lobsters, squat lobsters, winkles, native oysters, mussels, limpets, whelks, cockles, elvers, *Nephrops*, pacific oysters, shrimps, prawns, squid, scallops, queens, ormers, *Porphyra*, laverbread, samphire, pike, brown trout, rainbow trout, perch spider crabs, prawns, saithe, lesser spotted dogfish, eel, green crabs and sea mouse
Analysis of indicator materials	Annually to weekly	Total beta, gamma-ray spectrometry, ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, $^{134/137}Cs$, Th, U, transuranics	Water, sediments, salt marsh, seaweeds, aquatic plants and coarse fish	Fish meal, mud, sand, clay, salt marsh, turf, sludge, seawater, freshwater, *Fucus spp.*, *Rhodymenia spp.*, *Elodea canadensis*, *Nuphar lutea*, *Ascophyllum nodosum*, rudd, chub, barbel, grayling and roach
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-ray spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{55}Fe, ^{90}Sr, ^{99}Tc, Ru, ^{131}I, ^{129}I, ^{147}Pm, Cs, ^{210}Po, U, ^{210}Pb transuranics	Milk, crops and animals	Cows' milk, beef meat, kidney and liver, sheep meat and offal, chicken, duck, pheasant, rabbits, honey, hazelnuts, beetroot, wheat, barley, elderberries, apples, blackberries, strawberries, raspberries, cabbage, sea kale, lettuce, potatoes, runner beans, turnips, leeks, carrots, swede, sprouts, broad beans, kale, peas, cauliflower, pears, marrow, courgettes, onions, leaf beet, French beans, hares, pigeons, rape oil, broccoli, wood pigeon, widgeon, rhubarb, plums, mallard, damsons, maize, rosehips, rowan berries, cereal, blackcurrants, loganberries, hens and duck eggs, garlic, onions, gooseberries, parsnips, red onions, tayberries, sweetcorn, tomatoes, sugar beet and carrot tops
Analysis of indicator materials	Annually to monthly	Total alpha, beta and gamma, gamma-ray spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{55}Fe, ^{63}Ni, ^{90}Sr, ^{99}Tc, Ru, ^{131}I, ^{129}I, ^{147}Pm, Cs, ^{210}Po, U, ^{210}Pb transuranics	Grass, soil, faeces, dry cloths and animal food	Grass, soil, silage, animal faeces, fodder beet, lucerne, rainwater , ground elder, dry cloths, nettles and rosebay willow herb

Table 2.3. Analytical methods

Radionuclides	Sample type	Method of measurement
^{3}H ^{3}H (organic) ^{14}C ^{32}P ^{35}S ^{147}Pm ^{241}Pu	All	Beta counting by liquid scintillation
^{90}Sr	High-level aquatic samples	Cerenkov counting by liquid scintillation
^{90}Sr	Terrestrial and low-level aquatic samples	Beta counting using gas proportional detectors
^{99}Tc ^{210}Pb beta	All	Beta counting using gas proportional detectors
^{63}Ni ^{55}Fe $^{103+106}Ru$ ^{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-ray spectrometry using germanium detectors
^{129}I	Terrestrial samples[S]	Gamma-ray spectrometry using germanium detectors
^{129}I ^{131}I	Aquatic samples	Gamma-ray spectrometry using germanium detectors
U	Terrestrial samples	Activation and delayed neutron counting
^{210}Po ^{226}Ra* ^{234}U ^{235}U $^{235+236}U$ ^{238}U ^{237}Np ^{228}Th ^{230}Th ^{238}Pu $^{239+240}Pu$ ^{241}Am ^{242}Cm $^{243+244}Cm$	All	Alpha spectrometry
^{226}Ra	Terrestrial samples	Alpha counting using thin window proportional detectors
Alpha	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 concentration of radionuclides in the each food component of the foodchain, the rate of consumption of each food, 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 Temporal averaging

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

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

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean in the year at the farm where the highest concentrations are observed. This is labelled ‘max’ in the tables of results to distinguish it from the values which are averaged over a range of farms. For other terrestrial foods an alternative approach is adopted, since it is recognised that the possible storage of foods harvested during a particular time of the year has to be taken into account. Greater public exposures would be observed when foods are harvested at times when levels of contamination are high. For such foods, we have presented the maximum concentration observed of each radionuclide at any time in 2000 as well as the mean value. The maximum is labelled ‘max’ in the tables and forms the basis for the assessment of dose.

3.2 Spatial averaging

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

The numbers of farms that are sampled to provide information on activities in milk at nuclear sites are indicated in the tables of results. The bulking regimes are described in Section 2.1.1. Otherwise, the number of sampling observations in the tables of concentrations refers to the number of samples that were prepared for analysis during the year. In the case of small animals such as molluscs, one sample may include several hundred individual animals.

The number of sampling observations does not necessarily indicate the number of individual analyses carried out for a specific radionuclide. In particular, determinations by radiochemical methods are sometimes carried out less frequently than those by gamma spectrometry. However, the results are generally 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 only reported when the radionuclide is one which is likely to be discharged from the nuclear site under study, or when a positive result is detected in any other sample presented in the table in 2000.

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

3.4 Additional information

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

The main categories of additional data are:

- data for individual samples prior to averaging
- uncertainties in measurements
- data for very short-lived radionuclides supported by longer-lived parents
- data which are not relevant to a site's discharges for natural radionuclides and artificial radionuclides below detection limits
- measurements carried out as part of the research programme described in Section 12.

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

3.5 Radiation protection standards

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

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

order to implement the Basic Safety Standards Directive, Scottish Ministers have provided SEPA with a Direction concerning radiation doses to the public and their methods of estimation and regulation (Scottish Executive, 2000). The Environment Agency were issued a similar Direction for England and Wales in May 2000 (DETR, 2000a). The methods and data used in this report are consistent with the Direction.

The relevant dose limits for members of the public are 1 mSv (millisievert) per year for whole-body (more formally 'committed effective dose') and 50 mSv per year specifically for skin. The latter limit exists to ensure that specific effects on skin due to external exposure are prevented. It is applicable, for example, in the case of handling of fishing gear. These limits do not apply to natural radionuclides. The limits are for controlled releases of radionuclides from artificial sources.

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 doses have been assessed to different age groups and it has been determined which of those age groups forms the critical group.

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

Accidental releases may be judged against EU and ICRP standards in emergency situations (CEC, 1989 and ICRP, 1993). In addition, it is Government policy that EU food intervention levels will be taken into account when setting discharge limits. Where appropriate, measured concentrations are compared with intervention levels in this report. The Food Standards Agency has recently publically consulted (Food Standards Agency, 2001a) on the EC's intention to introduce legislation setting Maximum Permitted Levels for radioactivity in foodstuffs offered for sale on the common market.

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 2000. These data provide information on two main pathways: (i) ingestion of foodstuffs; and (ii) external exposure from contaminated materials in the aquatic environment. In both cases, the assessment estimates exposures from these pathways for potential critical groups, that is the groups of people who are likely to be most exposed. There are three factors to consider in the assessment of the ingestion pathway: (i) the concentrations of radionuclides in foodstuffs; (ii) the amounts of food eaten; and (iii) the dose coefficients relating an intake of activity to a dose.

3.6.1 Radionuclide concentrations in foodstuffs

In nearly all cases, the radionuclide concentrations in foodstuffs are determined by monitoring and are given later in this report. The Sellafield and Isle of Man terrestrial assessments are supplemented by information from foodchain models (see Appendix 2). The concentrations chosen for the assessment are intended to be representative of the intakes of the most exposed consumers in the population. All of the positively determined concentrations tabulated are included irrespective of the origin of the radionuclide. In some cases, this means that the calculated exposures include contributions due to disposals from other sites as well as from weapon test fallout and activity deposited following the Chernobyl accident. Where 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 concentration from the areas where harvesting of seafood is known to take place near the site in question. For milk, the mean concentration 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 other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

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

3.6.2 Consumption rates

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

In assessments of terrestrial foodstuffs, the amounts of food consumed are derived from national surveys of diet and are defined for 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 *et al*., 1999). However, it has been found that when the consumption rates for a variety of staple foodstuffs are examined, the contributions of cows' milk in the infant diet and vegetable consumption by young adults are generally the most important pathways for radionuclide intake.

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

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

3.6.3 Summation of aquatic and terrestrial doses

In October 2000 the Food Standards Agency held a Consultative Exercise on Dose Assessments (CEDA) at the Institute of Development Studies at the University of Sussex in Brighton. The aims of the exercise were to inform others of the Food Standards Agency's methods of assessment, why they were used, and to allow a wide-ranging debate on these and alternative methods.

Fifty representatives from nuclear operators, regulators, Government departments, Government agencies, environmental groups and members of the public attended. The Food Standards Agency undertook to re-examine its methods of dose assessment, where necessary, in light of the final report (Food Standards Agency, 2001b).

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

The environmental data and the individuals affected that are assessed in this report naturally fall into two separate groups: those influenced by liquid waste disposal and those by gaseous waste disposal. We have therefore calculated doses separately in these two cases. This information can form the basis for a formal comparison with dose limits. The simple addition of 'liquid' and 'gaseous' doses will overestimate the dose received at that location due to radioactive waste disposal because the population groups most affected by atmospheric and liquid discharges are different. A given individual is unlikely to consume both aquatic and terrestrial foods at such high rates.

As an example, in the RIFE calculations for 1998, the dose to an adult member of the public around Sizewell was estimated to be 0.005 mSv from the aquatic pathway and 0.0044 mSv from the terrestrial pathway (Brownless *et al.*, 2001). If the habits leading to these exposures were all exhibited by the same person then their total dose would be 0.0094 mSv. However, this is unlikely to be the case and real doses will be lower. The Food Standards Agency is investigating several methods by which doses from separate pathways can be combined to give a better estimate of total dose. These methods, involving various statistical techniques, or the derivation of distributions of dose based on the real combinations of habits of individuals, would provide doses for the combined pathways in the range 0.0024 to 0.0075 mSv (Brownless *et al.*, 2001). A paper explaining this approach is being prepared and comments on the methods described will be sought (Camplin *et al.*, in preparation).

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 amount of radioactivity ingested. The dose coefficients used in this report are provided in Appendix 5 for ease of reference. In past reports (e.g. The Scottish Office 1996), the dose received by infants from the consumption of milk has been calculated using the dose per unit intake values appropriate to 3-month-old infants. In this report, for uniformity with the calculations carried out for England and Wales, the values appropriate to a 1-year-old have been used. This should be considered when comparing the dose estimates reported for Scottish sites with those reported previously.

The dose assessments include the use of appropriate gut uptake factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut uptake factors for a radionuclide, we have generally chosen the one that 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 for the reason explained below.

The current ICRP advice is that a gut uptake factor of 0.5 is appropriate for dietary intakes of polonium by adults (ICRP, 1994). A study involving the consumption of crabmeat containing natural levels of polonium-210 has suggested that the factor could be as high as 0.8 (Hunt and Allington, 1993). Estimates of the exposures due to polonium intake have therefore been calculated using the conservative assumption that a factor of 0.8 applies to all seafood. We have retained a factor of 0.5 for other food.

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

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

3.6.5 External exposure

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

For external exposure of skin, the measured quantity is contamination in Bq cm^{-2}. In this case, dose rate factors in Sv y^{-1} per Bq cm^{-2} are used which are calculated for a depth in tissue of 7 mg cm^{-2} (Kocher and Eckerman, 1987). The 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, dose rates due to background levels are subtracted. When assessing internal exposures due to ingestion of carbon-14 and radionuclides in the uranium and thorium decay series in seafood, concentrations due to natural background levels are subtracted. Background carbon-14 concentrations in terrestrial foods are also subtracted. The estimates of background concentrations are given in Appendix 6. On the basis of measurements made previously as part of the programmes reported here, the gamma dose rate backgrounds in the aquatic environment were taken to be 0.05 µGy h^{-1} for sandy substrates, 0.07 µGy h^{-1}

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

for mud and salt marsh and 0.06 µGy h^{-1} for other substrates. These data are compatible with those presented by McKay *et al*. (1995). However, where it is difficult to distinguish the result of a dose rate measurement from natural background, the method of calculating exposures based on the concentrations of man-made radionuclides in sediments has been used (Hunt, 1984). Estimates of external exposures to beta radiation include a component due to natural (and un-enhanced) sources because of the difficulty in distinguishing between natural and man-made contributions. Such estimates are therefore conservative when compared with the relevant dose limit that excludes natural sources of radiation.

3.7 Uncertainties in dose assessment

The dose estimates in this report employ a number of assumptions and therefore the values contain uncertainties. These uncertainties arise from a variety of sources including sampling, analysis and in the calculation of doses.

3.7.1 Sampling uncertainties

The environment is highly spatially and temporally variable. Potential variations in radionuclides concentrations are accounted for by taking samples from a variety of sources over the year, however, such sample collection may be constrained by the availability of the samples. The data presented in the report has been corrected for any radioactive decay of the short-lived radionuclides between the time of collection and measurement in the laboratory, but where monthly bulking of milk samples is undertaken the date of collection is assumed to be the middle of the bulking period. These uncertainties are described in sections 2.2.1, 3.1 and 3.2.

3.7.2 Analytical uncertainties

Another potential source of uncertainty arises from the way radioactivity is measured in samples, although this is minimised as each laboratory used by Food Standards Agency and SEPA (section 2.2.1) operates quality control procedures to ensure standard methods are used. Analytical uncertainty of radionuclide concentrations includes potential errors due to counting statistics although these are not specifically reported in the tables for reasons of brevity and clarity.

3.7.3 Uncertainties in surveys of consumers' eating habits

The types of foods sampled and the locations from which they are taken are chosen to be representative of existing or potential exposure pathways. Knowledge of these pathways is gained from surveys of local consumers' habits. Uncertainties are associated with these habit surveys as peoples' habits may vary over time, or may differ from those that they report in the survey. Although individuals that are likely to be the most exposed people are consulted, not every individual can be consulted and often assumptions are made about the diet of children as there is often insufficient data from the surveys. A discussion of uncertainties due to consumption rates can be found in section 3.6.2.

3.7.4 Dose calculation uncertainties

Calculations of dose to members of the public via the foodchain are based on the consumption of foods contaminated at the levels of activity reported in the tables of monitoring data. The radionuclide concentrations chosen for the dose assessment are intended to be representative of the intakes of the most exposed consumers in the population, the 'critical group' as described in section 3.5. Assumptions are made in the calculation of dose to these groups. For example, for milk samples, the dose assessment is based on the mean concentration at the farm where the highest concentrations were recorded (section 3.1). For other foods, the maximum observed concentrations are used in the assessment which assumes that these food samples are stored and consumed throughout the year.

Further uncertainties arise because the dose assessment methodology uses radionuclide concentrations that include 'less than' values which are treated as actual values in some circumstances, as described in section 3.6.1. Although this approach will produce an overestimation of dose, particularly from locations where radionuclide concentrations are low, the methodology ensures that estimated exposures are unlikely to be underestimated.

Dose coefficients used in the report are based on those recommended by ICRP (ICRP, 1996a) and these 'dose per unit intake' values are provided in Appendix 5. However, uncertainties may arise in the dose assessments because of the choice of the appropriate gut uptake factor used. Generally, the factor that results in the highest predicted exposure has been used although account has been taken of any specific research results as discussed in section 3.6.4.

In this report, assessments of exposure from the ingestion of carbon-14 in foods and radionuclides in the uranium and thorium decay series in seafood do not generally include natural background levels. Uncertainties may arise in the estimates of background concentrations to subtract and these are given in Appendix 6 and discussed in section 3.6.6.

The results of dose calculations taking into account all the various uncertainties would produce a range of possible doses and their associated probability. This is illustrated for a hypothetical case in Figure 3.1. In this report the 97.5 percentile dose has been used although there are differing opinions on the use of alternative methods as mentioned in section 3.6.3.

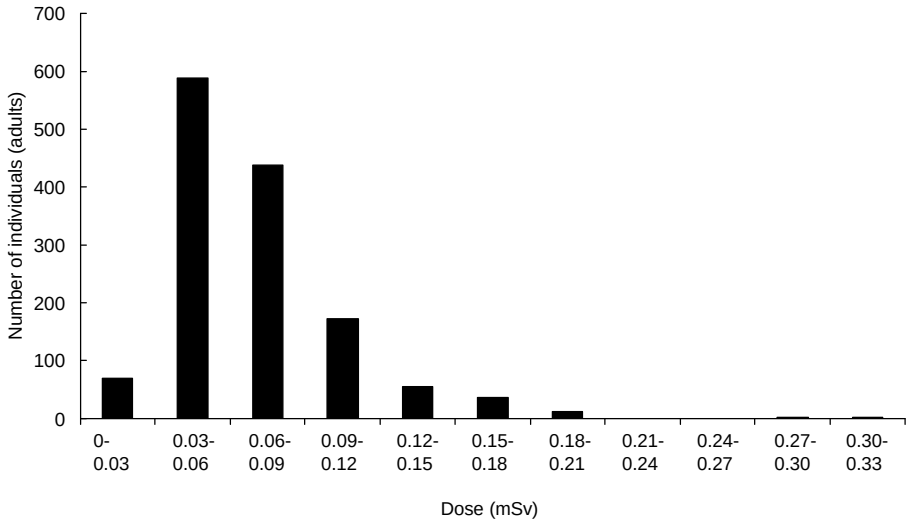

Figure 3.1. Distribution of food dose

Further discussion of the sources of uncertainty in the components of dose assessment and their effect on the calculated doses are given in a report commissioned by the Food Standards Agency from the NRPB (Smith *et al.*, 1998).

4. BRITISH NUCLEAR FUELS PLC

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

4.1 Sellafield and Drigg, Cumbria

Operations and facilities at Sellafield include fuel element storage, the Magnox and oxide fuel reprocessing plants, mixed oxide fuel manufacture, decommissioning of some nuclear facilities, and the Calder Hall Magnox nuclear power station. Radioactive waste discharges include a very minor contribution from the adjoining UKAEA Windscale site which includes facilities operated by AEA Technology. The most significant discharges are made from the BNFL fuel element storage ponds and the reprocessing plants, which handle irradiated Magnox and oxide fuel from the United Kingdom nuclear power programme, and some fuel from abroad. The authorised limits for discharges were revised with effect from 1 January 2000. The liquid discharge limit for technetium-99 was reduced from 200 TBq y^{-1} to 90 TBq y^{-1}. The tritium liquid discharge limit was reduced from 31000 TBq y^{-1} to 30000 TBq y^{-1}. Small discharges of liquid and gaseous radioactivity are made from the Drigg site, as a result of the solid waste management practices. Historically discharges from Sellafield have had the greatest impact on food and the environment of the United Kingdom. Current surveillance of the site reflects both historic and present day activities and, in view of its importance is considered in depth in this report.

4.1.1 The aquatic monitoring programme

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

Discharges from the Sellafield pipelines during 2000 are summarised in Appendix 1. Total alpha and beta discharges were 0.119 and 77 TBq respectively (1999: 0.133 and 110 TBq respectively). Most discharges of individual radionuclides decreased in 2000 but there were small increases for cobalt-60. Technetium-99 discharges reduced to 44.4 TBq in 2000 and are now much lower than the peak reached in 1995 of 192 TBq. All discharges were within the limits set in the authorisations.

The main function of the Drigg site is to receive low level solid radioactive wastes from Sellafield and other United Kingdom sites and to dispose of them in engineered trenches or vaults on land. The authorisation for discharges allows for the discharge of leachate from the trenches through a marine pipeline. The limits for activity to be discharged through the marine pipeline and for concentrations of residual activity in the Drigg Stream are given in Appendix 1. These discharges are small compared with those discharged from the Sellafield site. Marine monitoring of the Drigg site is subsumed within the Sellafield programme that is described in the remainder of this Section. The contribution to exposures due to Drigg discharges is negligible compared with that attributable to Sellafield and any effects of Drigg discharges could not be detected in 2000 above those due to Sellafield. Regulatory monitoring of the Drigg Stream is carried out by the Environment Agency.

Regular monitoring of the marine environment near Sellafield continued during 2000. 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 2000, 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.

4. British Nuclear Fuels plc (BNFL)

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 discharges from the beginning of operations in 1952 through to 1993. A recent review of changes in discharges and effects from the site is given by Smith *et al*. (2000a).

The fish and shellfish consumption pathway

Concentrations of radioactivity

Time trends of activity concentrations of carbon-14, cobalt-60, technetium-99, caesium-137, plutonium-239/240 and americium-241 are shown in Figures 4.1 - 4.6 respectively.

Concentrations of beta/gamma activity in fish from the vicinity of the Irish Sea and from further afield are given in Table 4.1. Concentrations in 2000 were generally similar to those in 1999. Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments that reflect Sellafield discharges are given later in this report. The 'Sellafield Coastal Area' extends 15 km to the north and to the south of Sellafield from St Bees Head to Selker and 11 km offshore; most of the fish and shellfish consumed by the local 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, when significant reductions in discharges were achieved. There is therefore a greater contribution from historical sources. Radiocaesium in fish from the Baltic is not due to Sellafield discharges but is substantially from the Chernobyl accident. Concentrations of radiocaesium in fish known to have been caught in Icelandic waters remained typical of those from weapon test fallout, at a value of about 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents and Celtic Seas are similar. In the Irish Sea, the ratios of caesium-137 to caesium-134 in seawater were generally higher than those in recent discharges from Sellafield, even allowing for residence time in the water (or sediment) and fish. This suggests that a significant contribution from aged radiocaesium is present, due to remobilisation from the sediment of the Irish Sea. Data for cod from the 'Offshore Area' typify the time trends in concentrations in fish (Figure 4.4).

Low concentrations of man-made radioactivity were found in fishmeal which is fed to farmed fish, poultry, pigs, cows and sheep. A study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is of little radiological significance (Smith and Jeffs, 1999).

A sample of rainbow trout from a small lake near Sellafield was again collected this year. The lake had been stocked and the caesium-137 concentration in the sample, at 390 Bq kg^{-1}, was much higher than in 1999 (17 Bq kg^{-1}); however, the variability in activities in samples of freshwater fish is known to be high (Camplin *et al.*, 1989). Although the evidence is not conclusive, the source of activity in this lake is likely to be Sellafield. A relatively high concentration of caesium-137 (240 Bq kg^{-1}) was also found in brown trout from the River Calder which runs through the Sellafield site.

Concentrations of most other beta/gamma emitting radionuclides in fish tend to be lower. However, with an expected carbon-14 concentration being about 25 Bq kg^{-1} from natural sources, the data suggest there is a local enhancement of carbon-14 due to discharges from the site. The highest concentrations of radioactivity in marine fish are found for tritium at about 100 Bq kg^{-1}. Similar concentrations are found from determinations of organically associated tritium in the fish. Concentrations of tritium in local seawater at St Bees are less than 20 Bq l^{-1} (Table 11.12). Taken with data for other sites around the UK, it

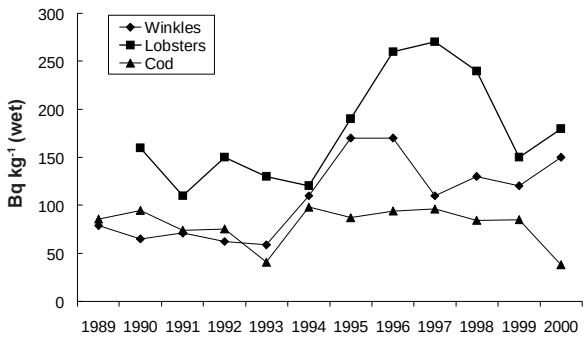

Figure 4.1. Carbon-14 concentrations in cod, lobsters and winkles from Sellafield

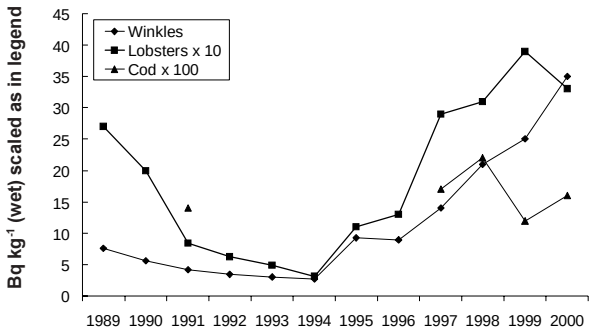

Figure 4.2 Cobalt-60 concentrations in cod, lobsters and winkles from Sellafield

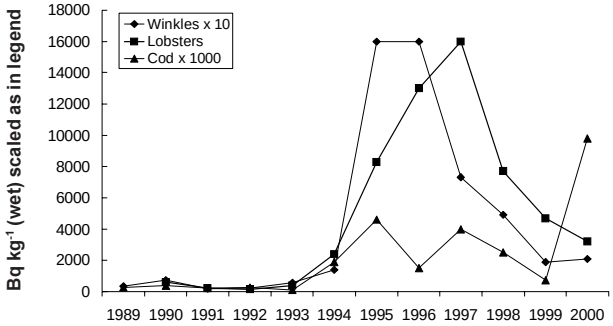

Figure 4.3. Technetium-99 concentrations in cod, lobsters and winkles from Sellafield

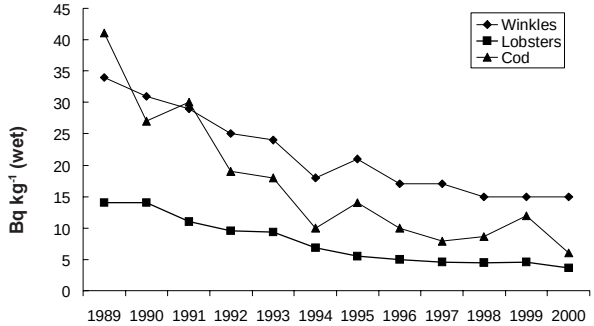

Figure 4.4. Caesium-137 concentrations in cod, lobsters and winkles from Sellafield

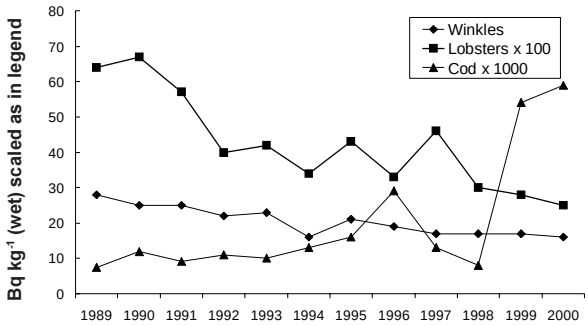

Figure 4.5. Plutonium-239/240 concentrations in cod, lobsters and winkles from Sellafield

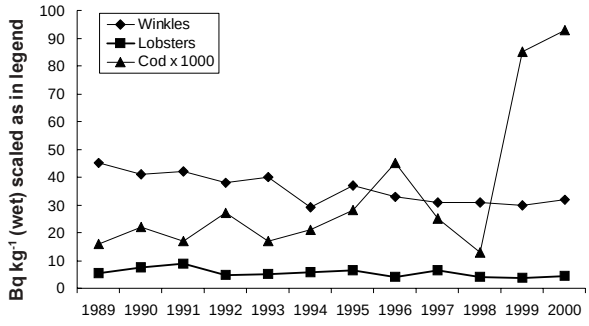

Figure 4.6. Americium-241 concentrations in cod, lobsters and winkles from Sellafield

now seems clear that some degree of bioaccumulation of tritium is taking place. However the radiotoxicity of tritium is very low, and the radiological importance of these concentrations, as determined later in this report, is much less than that of other radionuclides. A research project is underway to obtain more information on tritium distributions in seafood in the Irish Sea and further afield.

For shellfish, a wide range of radionuclides contribute to radiation exposure of consumers owing to generally greater uptake of radioactivity in these organisms than in fish. Table 4.2 lists concentrations of beta/gamma-emitting nuclides (except plutonium-241) and total beta activity in shellfish from the Irish Sea and further afield. Crustaceans and molluscs are of particular radiological importance to the most exposed group near to Sellafield, as described later in this Section. In addition to sampling by CEFAS, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield coastal area.

Concentrations of artificial radionuclides in shellfish, as with fish, generally diminish with increasing distance from Sellafield. There can be substantial variations between species: for example, lobsters tend to concentrate more technetium-99 in comparison with crabs (see also Knowles *et al.*, 1998; Swift and Nicholson, 2001). However as a general rule, molluscs tend to contain higher levels of radionuclides than crustaceans, which in turn tend to contain more than fish. The highest concentrations due to Sellafield discharges are found for tritium, carbon-14 and technetium-99. When comparing 1999 and 2000 data across a wide range of sampling locations and shellfish species, few significant changes in concentrations were found. Some increases in cobalt-60 concentrations were apparent (Figure 4.2) and these probably reflect the increase in discharges in recent years. Technetium-99 levels generally continued to reduce. The observed increase in technetium-99 in cod (Figure 4.3) now brings this species to levels which are similar to those found in other fish species near Sellafield.

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 2000 are presented in Table 4.3. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish as compared to fish, and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Concentrations in shellfish in 2000 were similar to or less than those in 1999 (Figures 4.5 and 4.6). Those in samples from the northeastern Irish Sea remain the highest levels of such nuclides to be found in foodstuffs in the United Kingdom. The concentrations in cod caught offshore of Sellafield in 2000 were again relatively high compared with earlier results obtained for this species. However, relative to shellfish, fish species contain very low concentrations of transuranic radionuclides.

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 2000 from artificial radionuclides in fish and shellfish. The dose to the local most exposed group of consumers was 0.15 mSv. This includes a contribution due to external exposure**.** The decrease in dose from 0.21 mSv reported for 1999 (Food Standards Agency and SEPA, 2000) 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 habit survey, included decreased consumption of molluscs. Most of the dose from the ingestion of seafood and external irradiation due to Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed about 13% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose were plutonium-239/240 and americium-241.

Data for natural radionuclides in fish and shellfish are discussed in Section 10. However, the effects on the Sellafield most exposed group from controlled discharges of natural radionuclides from another west Cumbrian source, Rhodia Consumer Specialties Ltd., Whitehaven, are also considered here. The increase in natural radionuclide concentrations is difficult to determine above a variable background. However using maximising assumptions, the dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 2000 was estimated to be 0.38 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 0.53 mSv. These doses may be compared with an average dose rate of approximately 2.2 mSv year^{-1} to members of the United Kingdom public from all natural sources of radiation (Hughes, 1999).

Exposures of groups representative of the wider fishing communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland, north Wales and the Isle of Man have been kept under review (Table 4.4). The doses received by all these groups are significantly less than that for the local Sellafield group because of the lower concentrations observed further afield. There were small changes in the doses in each area when compared with those in 1999 (see following text table). It is expected that there will be fluctuations in concentrations due to normal sampling variability. All doses were well within the principal dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, appropriate to a consumption rate of 15 kg year^{-1} of fish from landings at Whitehaven and Fleetwood, is also given in Table 4.4. This consumption rate represents an average for typical fish-eating members of the public. Their dose was very low, 0.001 mSv in 2000.

Seafood doses from artificial radionuclides in the Irish Sea		
Group	Dose, mSv	
	1999	2000
Northern Ireland	0.013	0.015
Dumfries and Galloway	0.028	0.033
Whitehaven	0.038	0.030
Sellafield	0.21	0.15
Isle of Man	0.010	0.008
Morecambe Bay	0.071	0.066
Fleetwood	0.021	0.023
North Wales	0.006	0.010

The review of seafood consumption rates at Sellafield undertaken in 2000 revealed that consumption of material caught as by-catches of fishing in the local area, as reported in the 1998 report (MAFF and SEPA, 1999), was no longer taking place. A single family had been involved. The material included species that are not normally eaten, for example, sea mice (*Aphrodite aculeata*), sea urchins (*Echinoidea*), brittle stars (*Ophiuroidea*), common shore crabs (*Carcinus maenas*), and hermit crabs (*Eupagurus spp.*). We will continue to monitor this pathway at Sellafield, and have begun a research project to investigate these uncommon foods at United Kingdom nuclear sites.

The exposure of potential consumers of trout from a tarn at a local farm was also considered in 2000. Their dose was 0.035 mSv which was less than 4% of the principal dose limit to members of the public of 1 mSv. This includes a contribution due to Chernobyl and weapons test fallout. Current evidence indicates that no such consumption is taking place, although there has been consumption in the past, and as it is a potential pathway for the future it was considered in this report.

External exposure

A further important pathway leading to radiation exposure as a result of Sellafield discharges arises from uptake of gamma-emitting radionuclides by intertidal sediments in areas frequented by the public. These exposures can make a significant contribution to the dose received by local consumers, a programme of direct measurements has therefore been maintained. In general, it is the fine-grained muds and silts prevalent in estuaries and harbours, rather than the coarser-grained sands to be found on open beaches, which adsorb the radioactivity more readily. Gamma dose rates currently observed in intertidal areas are mainly due to radiocaesium and natural radionuclides.

A range of coastal locations is regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation meters. Table 4.5 lists the locations monitored by the Food Standards Agency and SEPA together with the dose rates in air at 1 m above ground. Dose rates on Irish Sea shorelines, near other nuclear establishments that reflect Sellafield discharges, 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 2000 were similar to those data for the same locations in 1999 (Food Standards Agency and SEPA, 2000).

Concentrations of radionuclides in surface sediments are also regularly monitored, both because of relevance to dose rates and in order to keep under review distributions of adsorbed radioactivity. Concentrations of beta/gamma emitting radionuclides and transuranics, taken mostly at the same locations as the dose rate measurements, are given in Table 4.6. Concentrations in sediments vary for reasons similar to those causing variation in dose rates, results are comparable with those for 1999 (Food Standards Agency and SEPA, 2000). Kershaw *et al*. (1999a) have published a review of plutonium and americium in Irish Sea sediments.

The contribution of external dose to the total dose to high rate seafood consumers around the Irish Sea is included in the assessment noted earlier in this report. As a general rule about 20% of the total dose is due to external radiation. The Environment Agency considers other groups exposed to external gamma radiation in England and Wales.

Inhalation of resuspended beach sediments and inadvertent ingestion of the same material give rise to only minor radiation exposures to the public compared with seafood consumption and the external radiation pathway considered in this section (Wilkins *et al.*, 1994).

Fishing gear

During immersion in seawater, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination meters. Results for 2000 are presented in Table 4.7. Measured dose rates were generally similar to those for 1999. 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 2000, including a component due to natural radiation, was 0.12 mSv, which was less than 1% of the appropriate dose limit. Handling of fishing gear is therefore a minor pathway of radiation exposure.

4.1.2 The terrestrial monitoring programme

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

Sellafield

Discharges of gaseous wastes from Sellafield are summarised in Appendix 1. There was a decrease in the overall discharge of alpha activity from the site and small changes for some radionuclides. However, none of these were of sufficient magnitude to cause substantial changes in environmental levels.

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

The results of routine monitoring in 2000 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 sulphur-35, strontium-90 and radiocaesium indicated a factor nearer 2. Some evidence for a site-related effect was also found by examination of the maximum concentrations in milk of near and far farms. Concentrations in milk were generally similar to those in 1999 (Food Standards Agency and SEPA, 2000).

Levels of activity in bovine and ovine meat and offal continued to be analysed in 2000. In addition, chickens, hare, pheasants and pigeons were collected. Concentrations of radionuclides were generally low, with limited evidence of the effects of Sellafield derived activity in data for tritium, carbon-14, sulphur-35 and strontium-90. Plutonium concentrations, whilst much lower than those found in seafood, gave isotopic ratios ((239 + 240)/238) less than 20. With a ratio of about 40 expected for background weapon test fallout, these data demonstrate the site to be the source.

The fruit and vegetables that were sampled in 2000 included apples, blackberries, cabbage, carrots, cauliflower, elderberries, french beans, potatoes, runner beans, swede and turnips. The results were similar to those in previous years. In common with meat and offal samples, limited evidence for the effects of Sellafield discharges was found in data for tritium, carbon-14, sulphur-35 and strontium-90. Concentrations of transuranic radionuclides were generally very low, but the characteristic Sellafield signal in the plutonium isotopic ratio was observed in blackberries and elderberries.

Barley was sampled as being representative of cereals in 2000. It was a particularly good indicator of the effects of Sellafield with relatively high values of most radionuclides compared with other terrestrial foodstuffs.

The dose received by the most exposed group of terrestrial food consumers was calculated using the methods and data presented in Section 3. The results are presented in Table 4.9. Calculations were performed for four ages (adults, 15y, 10y and 1y) and the doses received by 1-year-olds were found to be the highest, at 0.033 mSv (Adult: 0.019; 15y: 0.024: 10y: 0.021). 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 more than 60% of the dose. The exposure is likely to be an upper estimate of the effects of Sellafield discharges because: (i) it is based on the assumption that a radionuclide which is not detected in a sample is present at a concentration equivalent to the limit of detection; (ii) the effects of the background of artificial 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 to high-rate consumers in 2000 were lower than those in 1999 (1y: 0.044 mSv), largely due to a reduction in the maximum observed concentration of carbon-14 in milk. The dose received by a typical adult consumer obtaining food from the vicinity of Sellafield, 0.011 mSv, was much less than this.

Previous reports in this series have dealt with the issue of contamination associated with pigeons in the vicinity of Sellafield. Internal contamination, mainly of caesium-137, in birds sampled by MAFF was found up to 0.11 MBq kg^{-1}. This is far in excess of the EU Food Intervention Levels that would apply in the event of an accident. Consuming the breast meat of 20 birds contaminated at the highest level would have resulted in a dose of 1 mSv, the annual dose limit for members of the public. Remedial measures, including a substantial cull of pigeons in the area, were undertaken by BNFL. Nevertheless the advice issued by MAFF on 14th February 1998 remains in place as a precaution. People were advised not to handle, slaughter or consume pigeons within a 10 miles radius of the site. A full review of the incident was published in 1999 (CBC *et al*, 1999).

4.1.3 Drigg

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

Results for 2000 are given in Table 4.10. The only evidence of Drigg leachate transferring to foods was enhanced tritium levels in potatoes. However, the levels were of negligible radiological significance. In general concentrations of other radionuclides detected were similar to, or lower than those found near Sellafield. The radiation dose to the most exposed group, including a component due to Chernobyl and weapon test fallout, was 0.015 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv (Table 4.9). This compares with 0.020 mSv in 1999.

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 2000 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 contamination monitors are presented in Table 4.11.

The skin dose to anglers who dig bait, based on a time handling sediment of 950 h $year^{-1}$, was 0.16 mSv in 2000 which was less than 1% of the appropriate dose limit.

Ravenglass

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

The results of measurements in 2000 are presented in Table 4.12. In general, the data are similar to those for 1999 (Food Standards Agency and SEPA, 2000) and show lower concentrations than are found in the

direct vicinity of Sellafield. In general the evidence shows sea-to-land transfer is a limited process with technetium-99 and promethium-147 only detected in grass samples from Ravenglass and concentrations of plutonium isotopes in some samples indicating a local source. That is the plutonium-239/240 to plutonium-238 ratio was substantially less than that expected due to weapon test fallout.

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

The exposure due to consumption of terrestrial foods from Ravenglass in 2000 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 calculated to be 0.018 mSv which was less than 2% of the principal dose limit for members of the public of 1 mSv. This compares with 0.026 mSv for 1999 (Food Standards Agency and SEPA, 2000). Sea-to-land transfer therefore, does not have a major effect on the terrestrial food chain in the Ravenglass area.

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 discharges, a number of further investigations were 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 2000 on marine plants from shorelines of the Cumbrian coast and further afield. Although small quantities of samphire and *Rhodymenia* (a red seaweed) may be eaten, concentrations of radioactivity were of negligible radiological significance. *Fucus* seaweeds are useful indicators, particularly of fission product radionuclides other than ruthenium-106; samples of *Fucus vesiculosus* seaweed were collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. These clearly showed the effects of increases in discharges of technetium-99 from Sellafield in recent years, though at a reduced level compared with 1999. Such seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2000. The results are shown in Table 4.14.

The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al*, 2000). In 2000, seaweed harvesting in the Sellafield area continued to be rare. However, three plots of land fertilised by seaweed were identified and were investigated further. Samples of soil were analysed for a range of radionuclides by gamma spectrometry and for technetium-99. The soil and compost data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged from about less than 1 to 850 Bq kg^{-1} in the edible parts. The higher concentrations were found in leaf beet. Small concentrations of gamma emitting radionuclides were found in some vegetables.

Consumption rates of people who were supplied with vegetables from the plots were investigated as well as their consumption of local seafood. Based on pessimistic assumptions, the maximum dose received by the consumers was estimated to be 0.027 mSv, most of which was due to the seafood component of their diet. The highest dose due to technetium-99 in vegetables was 0.002 mSv. Whilst the doses due to consumption of seafood and external radiation from sediments remain more important, the seaweed/ vegetable pathway will be kept under review.

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered in the report for 1997 (MAFF and SEPA, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow up sampling at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2000 suggests that this dose estimate remains valid (Table 4.14). In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. However our investigations show that this does not take place to a significant extent in the Sellafield area. In addition no harvesting of seaweed for alginate production takes place.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2000; this pathway has therefore remained essentially dormant. However, monitoring of porphyra has continued in view of its potential importance, historical significance and the value of *Porphyra* as an indicator material. Samples of *Porphyra* are regularly collected from selected locations along United Kingdom shorelines of the Irish Sea. Results of analyses for 2000 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 2000 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 discharges are made by pipeline to the Ribble estuary. Discharges of beta emitting radionuclides, which result in the greatest contribution to the radiological impact, reduced from 128 TBq (1999) to 71 TBq in 2000. Discharges of gaseous effluents remained very low at a similar level to those for 1999.

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

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

Results for 2000 are shown in Tables 4.15(a) and (b). Radionuclides detected which were partly or wholly due to Springfields discharges were isotopes of thorium, uranium and their decay products. Natural sources also contributed to these activities. Artificial radionuclides present were mainly from Sellafield.

Concentrations of radionuclides in seafood and measurements in other materials from the estuary were similar to those for 1999. The dose for individual aquatic pathways changed according to the changes in habits data representing the critical group but the increases and decreases cancelled each other out such that the overall dose to seafood consumers was unchanged in 2000 at 0.025 mSv. The majority of the dose is attributable to Sellafield discharges transferred to the Springfields area with only a small percentage resulting from emissions from the Springfields site itself.

Skin irradiation of fishermen handling nets was 0.80 mSv in 2000. This is less than 2% of the relevant dose limit for members of the public.

In 2000 the most exposed group of terrestrial food consumers were children aged 15 consuming vegetables at high rates. Their dose was 0.007 mSv; this includes a contribution due to weapons testing and Chernobyl fallout and natural sources. A significant part of the dose 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 consist of tritium, uranium plus its daughter products, technetium-99 and neptunium-237 (from recycled fuel). In 2000 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 was carried out to investigate the different pathways that could be of radiological significance. Plants, rain water, animal faeces, soil and dry cloths are also sampled as indicator materials.

Results for 2000 are presented in Table 4.16. Concentrations of radionuclides in samples from the land and from the Rivacre Brook were generally similar to those for 1999. The concentrations of artificial radionuclides in marine samples are consistent with values expected at this distance from Sellafield. The occurrence of relatively high levels of tritium in shrimps found in 1999 was not repeated in 2000. The hypothetical most exposed group for liquid discharges 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 less than 0.005 mSv in 2000. The dose to the most exposed group of terrestrial food consumers was less than 0.005 mSv in 2000.

4.4 Chapelcross, Dumfries and Galloway

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

The results of routine monitoring in 2000 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 discharges, and the general levels of nuclides are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years.

The whole-body dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.032 mSv in 2000 which was 3% of the principal dose limit for members of the public of 1 mSv. This estimate takes into account the new consumption rate data obtained from the recent habits survey. Measurements of the contact beta dose-rate on fishing nets were below the limit of detection. A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the total dose to the local population; the greater proportion of the dose can be attributed to the long distance consequences of emissions from Sellafield.

4. British Nuclear Fuels plc (BNFL)

Since 1992, a number of particles has been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Monitoring of this area continues, although work carried out by the operator in recent years has led to a progressive decline in the number of these particles being found in the environment. Improvement works were carried out at the outfall in mid 1999 and further improvements to the effluent management system are now planned. During 2000 three particles of limescale were found compared to 10 in 1999.

Concentrations of radionuclides in milk and grass were generally similar to, or slightly greater than those observed in 1999. The more extensive dataset now available on terrestrial foods shows that the effects of discharges from Chapelcross can be seen in the levels of tritium and sulphur-35 in a range of foods. The presence of caesium-137 in duck and other wildfowl is probably a result of grazing of salt marsh and is therefore marine-derived. 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 0.034 mSv which was 3% of the principal dose limit for members of the public of 1 mSv. The increase in estimated dose is not directly comparable with the estimated dose in 1999 (0.017 mSv) as the monitoring programme and method of calculation of dose were changed in 2000.

Table 4.1. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}											
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Sellafield coastal area	Cod	5			<0.33		<0.31	<0.45		<0.81	<0.10	9.7	<0.54	170
Sellafield coastal area	Plaice[a]	4	130		0.27		<0.29	<0.35		<0.83	<0.09	6.5	<0.41	150
Sellafield coastal area	Bass	1			<0.09		<0.33	<0.51		<0.81	<0.09	16	<0.41	
Sellafield offshore area	Cod	2		38	<0.16	<0.072	<0.33	<0.37	9.8	<1.1	<0.12	6.0	<0.64	
Sellafield offshore area	Plaice[b]	2		88	0.19	0.088	<0.14	<0.16	15	<0.40	<0.04	5.7	<0.20	
Sellafield offshore area	Dab	2			0.54		<0.25	<0.30		<0.77	<0.08	9.1	<0.44	
Sellafield offshore area	Whiting	2			<0.07		<0.19	<0.21		<0.64	<0.07	12	<0.31	
Sellafield offshore area	Spurdog	1			<0.08		<0.60	<1.4		<0.92	<0.09	11	<0.65	
Sellafield offshore area	Lesser spotted dogfish	1			<0.09		<0.31	<0.42		<0.90	<0.10	14	<0.48	
Ravenglass	Cod	4			0.33		<0.29	<0.37		<0.84	<0.09	11	<0.54	
Ravenglass	Plaice	4	150		0.22		<0.31	<0.44		<0.79	<0.09	6.2	<0.48	
Whitehaven	Cod	4		48	<0.11	0.090	<0.26	<0.26		<0.81	<0.08	6.8	<0.39	
Whitehaven	Plaice	4			<0.11	0.061	<0.26	<0.28		<0.81	<0.09	4.9	<0.44	
Whitehaven	Ray	4			<0.11		<0.38	<0.49		<1.0	<0.11	8.8	<0.50	
Whitehaven	Herring	1			<0.09		<0.16	<0.10		<0.70	<0.08	2.1	<0.32	
Parton	Cod	4			<0.11		<0.25	<0.26		<0.86	<0.09	13	<0.39	
Morecambe Bay (Flookburgh)	Flounder	4		57	<0.11		<0.36	<0.46		<1.0	<0.11	14	<0.49	
Morecambe Bay (Morecambe)	Plaice[c]	4	52		<0.09	0.039	<0.34	<0.48	12	<0.81	<0.08	6.3	<0.40	
Morecambe Bay (Morecambe)	Bass	2			<0.10		<0.39	<0.51		<1.0	<0.11	15	<0.53	
Morecambe Bay (Sunderland Point)	Whitebait	1			<0.07	0.17	<0.22	<0.28		<0.54	<0.06	6.9	<0.37	
River Calder	Brown trout	1			<0.10		<0.70	<1.7		<2.1	0.35	240	<1.5	
River Calder	Sea trout	1			<0.16		<0.64	<0.96		<1.6	<0.15	0.80	<0.63	
Calder	Rainbow trout	2			<0.19		<0.42	<0.55		<2.0	<0.49	390	<1.1	
River Duddon	Sea trout	1			<0.14		<0.41	<0.49		<1.3	<0.13	11	<0.51	
River Kent	Sea trout	1			<0.14		<1.0	<2.6		<1.5	<0.15	2.5	<0.73	
River Derwent	Sea trout	1			<0.09		<1.1	*		<0.96	<0.09	5.8	<0.68	
Fleetwood	Cod	4		40	<0.09	0.048	<0.23	<0.21	0.41	<0.75	<0.09	3.8	<0.35	
Fleetwood	Plaice	4			<0.07		<0.24	<0.29		<0.63	<0.07	4.9	<0.29	
Isle of Man	Cod	3			<0.08		<0.39	<0.57		<0.81	<0.09	2.8	<0.45	
Isle of Man	Herring	3			<0.10		<0.45	<0.77		<0.95	<0.10	1.3	<0.52	
Inner Solway	Flounder	4	11	62	<0.10	<0.10	<0.61	<2.0	7.9	<0.75	<0.10	18	<0.46	
Inner Solway	Salmon	1	9.8		<0.10		<0.14	<0.17		<0.33	<0.10	0.28	<0.26	
Inner Solway	Sea trout	1	37		0.59		<0.19	<0.26		<0.35	<0.10	3.0	<0.25	
North Solway Coast	Plaice	4			<0.12		<0.29	<0.46		<0.59	<0.10	0.95	<0.38	
North Solway Coast	Mullet	3			<0.25		<0.57	<0.67		<0.62	<0.10	1.6	<0.31	
Kirkcudbright	Plaice	4			<0.14		<0.37	<0.50		<1.0	<0.12	7.9	<0.58	
North Anglesey	Plaice	2		35	<0.08		<0.23	<0.28		<0.67	<0.08	1.6	<0.30	
North Anglesey	Ray	2			<0.12		<0.51	<0.68		<1.4	<0.13	2.6	<0.74	
Ribble Estuary	Flounder	1			<0.17		<0.67	<1.0		<1.8	<0.18	7.8	<0.93	
Ribble Estuary	Salmon	1			<0.06		<0.18	<0.18		<0.65	<0.07	0.39	<0.43	
Ribble Estuary	Bass	1			<0.12		<1.4	*		<1.3	<0.14	14	<0.76	
Ribble Estuary	Sea trout	1			<0.14		<0.61	<1.0		<1.4	<0.14	5.4	<0.70	
Ribble Estuary	Mullet	2			<0.17		<0.62	<0.80		<1.7	<0.17	5.4	<0.81	

Table 4.1. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce
Northern Ireland	Cod	6	31	<0.08		<0.28	<0.38	<0.69	<0.08	2.9	<0.35
Northern Ireland	Whiting	7		<0.11		<0.47	<0.72	<1.1	<0.11	3.3	<0.46
Northern Ireland	Herring	2		<0.15		<0.72	<1.2	<1.7	<0.17	1.3	<0.89
Northern Ireland	Spurdog	5		<0.08		<0.36	<0.53	<0.84	<0.08	3.0	<0.48
Sound of Mull	Salmon	1		<0.07		<0.30	<0.41	<0.73	<0.08	0.34	<0.35
Minch	Cod	4	27	<0.08		<0.26	<0.36	<0.74	<0.08	0.58	<0.37
Minch	Plaice	4		<0.09		<0.40	<0.62	<0.96	<0.09	0.79	<0.39
Minch	Haddock	4		<0.05		<0.20	<0.26	<0.52	<0.06	0.33	<0.28
Minch	Herring	4		<0.05		<0.21	<0.29	<0.51	<0.06	0.26	<0.30
Shetland	Fish meal[d]	4		<0.18	<0.27	<0.63	<0.82	<1.7	<0.18	0.62	<0.90
Shetland	Fish oil[d]	4		<0.12		<0.45	<0.64	<1.1	<0.12	<0.11	<0.64
Northern North Sea	Cod	4	22	<0.05	<0.036	<0.21	<0.33	<0.48	<0.05	0.41	<0.24
Northern North Sea	Plaice	3		<0.05		<0.26	<0.46	<0.52	<0.05	0.31	<0.29
Northern North Sea	Haddock	4	28	<0.07		<0.28	<0.45	<0.63	<0.07	0.42	<0.31
Northern North Sea	Herring	1		<0.10		<0.45	<0.73	<0.92	<0.10	0.21	<0.49
Northern North Sea	Mackerel	1		<0.06		<0.34	<0.56	<0.70	<0.07	0.24	<0.49
Mid North Sea	Cod	4	18	<0.07	<0.040	<0.27	<0.39	<0.65	<0.07	0.40	<0.30
Mid North Sea	Plaice	4	25	<0.06	<0.040	<0.37	<0.19	<0.58	<0.06	0.25	<0.26
Mid North Sea	Herring	1		<0.06		<0.29	<0.46	<0.62	<0.06	0.43	<0.30
Southern North Sea	Cod	2		<0.04	<0.038	<0.12	<0.13	<0.36	<0.04	0.47	<0.18
Southern North Sea	Plaice	2		<0.05	<0.049	<0.17	<0.24	<0.47	<0.05	0.28	<0.21
Southern North Sea	Herring	2		<0.09		<0.41	<0.63	<0.96	<0.10	0.38	<0.52
English Channel-East	Cod	4		<0.05	<0.038	<0.15	<0.19	<0.46	<0.05	0.25	<0.25
English Channel-East	Plaice	4		<0.05	<0.037	<0.15	<0.17	<0.46	<0.05	0.16	<0.26
English Channel-West	Mackerel	4		<0.07		<0.26	<0.38	<0.66	<0.07	0.25	<0.38
English Channel-West	Plaice	4	22	<0.06	<0.039	<0.22	<0.28	<0.57	<0.06	<0.10	<0.29
English Channel-West	Whiting	4		<0.04	<0.040	<0.15	<0.19	<0.41	<0.05	0.38	<0.25
Gt Yarmouth (retail shop)	Cod	4		<0.05		<0.13	<0.15	<0.43	<0.05	0.20	<0.20
Gt Yarmouth (retail shop)	Plaice	4		<0.05		<0.17	<0.24	<0.45	<0.05	0.67	<0.25
Skagerrak	Cod	2		<0.05		<0.14	<0.17	<0.40	<0.04	0.58	<0.18
Skagerrak	Herring	2		<0.05		<0.17	<0.21	<0.44	<0.05	0.52	<0.23
Iceland area	Cod	1		<0.05		<0.18	<0.23	<0.46	<0.05	0.20	<0.30
Iceland processed	Cod	2	21	<0.06		<0.18	<0.21	<0.52	<0.06	0.28	<0.24
Barents Sea	Cod	4		<0.06		<0.34	<0.63	<0.58	<0.06	0.24	<0.28
Baltic Sea	Cod	4		<0.08		<0.95	<0.17	<0.96	<0.10	12	<0.64
Baltic Sea	Herring	4		<0.07		<1.1	<0.15	<0.85	<0.09	7.2	<0.44
Norwegian Sea	Cod	1		<0.04		<0.22	<0.41	<0.37	<0.04	0.28	<0.19
Norwegian Sea	Mackerel	1		<0.10		<0.52	<0.95	<1.1	<0.12	0.51	<0.73
Norwegian Sea	Saithe	1		<0.04		<0.23	<0.42	<0.42	<0.04	0.29	<0.29
Celtic Sea	Cod	4	21	<0.05	<0.036	<0.15	<0.17	<0.42	<0.05	1.1	<0.19
Celtic Sea	Haddock	2		<0.06		<0.25	<0.37	<0.53	<0.06	0.14	<0.25
Celtic Sea	Whiting	2		<0.04		<0.16	<0.21	<0.42	<0.05	0.36	<0.24

** not detected by the method used*

[a] *The concentrations of organic ^{3}H and ^{147}Pm were 150 and <0.042 Bq kg^{-1} respectively*

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

[c] *The concentration of organic ^{3}H was 26 Bq kg^{-1}*

[d] *Concentrations refer to weight of sample as supplied*

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Sellafield coastal area	Crabs[a]	8	130	100	3.9	<0.25	1.5	<0.38	<0.43	35	<0.48	<1.1
Sellafield coastal area	Lobsters[b]	8	270	180	3.3	<0.28	0.37	<0.34	<0.45	3200	<0.34	<1.1
Sellafield coastal area	*Nephrops*	2			0.51	<0.14		<0.15	<0.13	640	<0.12	<0.57
Sellafield coastal area[c]	Winkles	4		110	18	<0.44	8.5	<0.48	<0.54	340	<0.42	16
Sellafield coastal area[c]	Mussels	4			13	<0.19	0.63	<0.21	<0.21		<0.16	12
Sellafield coastal area[c]	Limpets	4		48	7.0	<0.22	3.5	<0.24	<0.27	1100	<0.20	9.6
Sellafield coastal area	Whelks	2		140	3.9	<0.43	0.28	<0.57	<0.77	52	<0.53	<5.3
St Bees	Winkles[d]	4	27	120	19	<0.21	3.9	<0.23	<0.28	240	<0.20	20
St Bees	Mussels	4			11	<0.38		<0.25	<0.27		<0.21	13
St Bees	Limpets	4			8.1	<0.31		<0.29	<0.28		<0.22	10
Seascale	Sea Mouse[e]	1			20	<0.26	1.4	<0.44	<0.57	120	<0.42	4.6
Nethertown	Winkles	12	<25	150	35	<0.41	7.6	<0.43	<0.47	210	<0.34	31
Nethertown	Mussels	4		170	22	<0.42		<0.31	<0.31	790	<0.24	26
Whitriggs	Shrimps	1			0.87	<0.54		<1.7	*		<3.4	<2.1
Drigg	Winkles	4		170	16	<0.41		<0.40	<0.46	410	<0.31	18
Ravenglass	Crabs	4			2.0	<0.20	0.77	<0.26	<0.34	23	<0.25	<0.95
Ravenglass	Lobsters	6			1.4	<0.19	0.32	<0.25	<0.34	1600	<0.25	<0.71
Ravenglass	Winkles	2			9.3	<0.33		<0.32	<0.32		<0.24	11
Ravenglass	Cockles	4		160	30	<0.29	0.92	<0.36	<0.41	51	<0.29	11
Ravenglass	Mussels	4	<25		12	<0.31		<0.27	<0.28	660	<0.22	13
Tarn Bay	Winkles	2			33	<0.40		<0.37	<0.38		<0.27	17
Saltom Bay	Winkles	4			7.3	<0.27		<0.26	<0.26		<0.22	8.9
Whitehaven	*Nephrops*[f]	4	<25	38	<0.10	<0.20	0.086	<0.24	<0.27	320	<0.22	<0.77
Whitehaven	Whelks	4		78	2.5	<0.27	0.13	<0.25	<0.25		<0.19	<1.8
Silloth	Mussels	4	<25		0.78	<0.18		<0.26	<0.31		<0.26	<1.3
Parton	Crabs	4			1.9	<0.37		<0.49	<0.66		<0.47	<1.6
Parton	Lobsters	4			1.2	<0.17		<0.18	<0.21		<0.17	<0.65
Parton	Winkles	4			4.8	<0.30		<0.31	<0.33		<0.26	7.0
Haverigg	Cockles	2			7.3	<0.17		<0.16	<0.13		<0.11	2.0
Millom	Mussels	2			1.9	<0.16		<0.19	<2.1		<0.17	2.0
Morecambe Bay (Flookburgh)	Shrimps	4		75	<0.10	<0.13		<0.16	<0.19	4.7	<0.17	<0.48
Morecambe Bay (Morecambe)	Mussels[g]	4	75	70	0.89	<0.14		<0.18	<0.20	150	<0.17	<0.94
Morecambe Bay (Flookburgh)	Cockles	4		87	3.8	<0.17	0.31	<0.21	<0.24	74	<0.19	<0.70
Morecambe Bay (Middleton sands)	Cockles	2			4.4	<0.16		<0.20	<0.22		<0.17	<0.61

Table 4.2. continued

Location	Material	No. of sampling observ-ations	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[a]	8	<1.2	<0.29	<0.09	2.4	<0.41	0.37	<0.24	<0.16	140
Sellafield coastal area	Lobsters[b]	8	<2.2	<0.25	<0.11	3.6	<0.45	0.60	<0.30	<0.20	2200
Sellafield coastal area	*Nephrops*	2	0.21	<0.17	<0.06	6.8	<0.35		<0.18	<0.18	
Sellafield coastal area[c]	Winkles	4	4.0	1.6	<0.18	9.2	<0.83	1.2	<0.45	<0.38	
Sellafield coastal area[c]	Mussels	4	<0.16	0.71	<0.08	2.3	<0.43		<0.21	<0.17	
Sellafield coastal area[c]	Limpets	4	2.7	2.6	<0.09	4.8	<0.48		<0.24	<0.18	
Sellafield coastal area	Whelks	2	2.2	<0.40	<0.17	1.7	<0.77		<0.49	<0.35	
St Bees	Winkles[d]	4	4.1	1.8	<0.08	10	<0.47	1.4	<0.27	<0.19	
St Bees	Mussels	4	<0.18	0.89	<0.09	3.3	<0.48		<0.25	<0.17	
St Bees	Limpets	4	2.7	2.6	<0.13	5.6	<0.62		<0.34	<0.29	
Seascale	Sea Mouse[e]	1	<0.21	6.6	<0.13	11	<0.51		0.52	1.2	
Nethertown	Winkles	12	5.5	1.9	<0.17	15	<1.2	2.1	<0.54	<0.33	430
Nethertown	Mussels	4	<0.25	1.4	<0.13	3.8	<0.93		<0.39	<0.26	790
Whitriggs	Shrimps	1	<0.38	<0.44	<0.18	3.7	<1.2		<0.46	<0.39	
Drigg	Winkles	4	6.1	1.2	<0.17	6.2	<0.71	1.4	<0.41	<0.31	470
Ravenglass	Crabs	4	0.73	<0.19	<0.08	2.0	<0.37		<0.22	<0.17	110
Ravenglass	Lobsters	6	1.2	<0.18	<0.07	3.1	<0.35		<0.21	<0.16	1200
Ravenglass	Winkles	2	3.9	1.4	<0.14	14	<0.55		<0.36	<0.25	
Ravenglass	Cockles	4	<0.24	<0.35	<0.12	5.6	<0.54		0.41	<0.25	180
Ravenglass	Mussels	4	<0.19	0.66	<0.10	2.6	<0.43		<0.20	<0.20	
Tarn Bay	Winkles	2	3.4	1.0	<0.17	15	<0.97		<0.45	<0.26	
Saltom Bay	Winkles	4	1.0	3.9	<0.11	9.9	<0.58		<0.29	<0.27	
Whitehaven	*Nephrops*[f]	4	<0.14	<0.19	<0.08	4.0	<0.35		<0.25	<0.16	320
Whitehaven	Whelks	4	1.2	<0.26	<0.11	1.6	<0.47		<0.32	<0.23	160
Silloth	Mussels	4	<0.14	<0.21	<0.08	4.4	<0.45		<0.21	<0.21	
Parton	Crabs	4	<0.72	<0.35	<0.15	2.4	<0.66		<0.42	<0.30	
Parton	Lobsters	4	0.86	<0.17	<0.07	3.7	<0.32		<0.20	<0.15	
Parton	Winkles	4	1.0	1.1	<0.13	9.9	<0.59		<0.37	<0.30	
Haverigg	Cockles	2	<0.13	0.25	<0.07	5.0	<0.28		<0.19	<0.20	
Millom	Mussels	2	<0.13	<0.18	<0.07	2.2	<0.36		<0.18	<0.18	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.09	<0.13	<0.05	6.1	<0.29		<0.15	<0.13	
Morecambe Bay (Morecambe)	Mussels[g]	4	<0.11	<0.23	<0.06	3.5	<0.30		<0.16	<0.14	
Morecambe Bay (Flookburgh)	Cockles	4	<0.13	<0.18	<0.07	4.5	<0.31		<0.18	<0.15	
Morecambe Bay (Middleton sands)	Cockles	2	<0.13	<0.16	<0.07	3.9	<0.28		<0.18	<0.14	77

Table 4.2. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Fleetwood	Lobsters	2			0.68	<0.21		<0.26	<0.34	2100	<0.25	<0.72
Fleetwood	Squid	1			<0.06	<0.17		<0.25	<0.39		<0.31	<0.55
Fleetwood	Whelks	4		88	0.40	<0.12	0.044	<0.14	<0.15	41	<0.13	<0.47
Isle of Man	Lobsters	4			<0.07	<0.18		<0.20	<0.21	220	<0.17	<0.65
Isle of Man	Scallops	4			<0.04	<0.11		<0.13	<0.15		<0.12	<0.37
Inner Solway	Shrimps[h]	4	8.1		<0.11	<0.32		<0.69	<3.11	160		<0.84
Southerness	Winkles	4	<6.3		7.0	<0.15	0.48	<0.14	<0.20	400		<3.0
Kirkcudbright	Scallops	6			<0.11	<0.12		<0.15	<0.22		<0.10	<0.38
Kirkcudbright	Queens	8			<0.08	<0.14		<0.18	<0.14		<0.09	<0.41
North Solway coast	Crabs[i]	8	<25	88	0.62	<0.24	0.26	<0.27	<0.32	16	<0.33	<0.81
North Solway coast	Lobsters	8		55	<0.23	<0.41	0.085	<0.53	<0.73	610	<0.82	<1.4
North Solway coast	Squat lobsters	1								9.9		
North Solway coast	Winkles	7	8.2		3.5	<0.21	0.35	<0.22	<0.28	400	<0.16	<2.7
North Solway coast	Cockles	8	<14	68	<2.1	<0.15	<0.43	<0.25	<0.68	7.6	<0.16	<0.60
North Solway coast	Mussels	7	<12	60	0.73	<0.14		<0.15	<0.14	190	<0.11	<0.76
Wirral	Shrimps	2	<25		<0.12	<0.31		<0.53	<0.82	4.9	<0.62	<1.3
Wirral	Cockles	4			0.36	<0.15		<0.20	<0.22	33	<0.19	<0.65
Liverpool Bay	Mussels	2	<25									
Mersey Estuary	Mussels	2	<25									
Ribble Estuary	Cockles	2			1.6	<0.23		<0.23	<0.20		<0.16	<0.95
Ribble Estuary	Shrimps	2		59	<0.06	<0.14		<0.15	<0.14	4.1	<0.12	<0.49
Knott End	Cockles	1			6.3	<0.19		<0.23	<0.28		<0.21	<0.70
Conwy	Mussels	2			<0.05	<0.12		<0.13	<0.13		<0.11	<0.45
Northern Ireland	Lobsters	5			<0.19	<0.47		<0.73	<1.0	130	<0.75	<1.9
Northern Ireland	*Nephrops*	8		36	<0.11	<0.30		<0.50	<0.78	60	<0.60	<1.2
Northern Ireland	Winkles	4			<0.12	<0.22		<0.31	<0.41		<0.32	<0.87
Northern Ireland	Mussels	1								58		
Skye	Lobster	1			<0.10	<0.19		<0.42	<1.1			<0.51
Skye	Mussels	1			<0.07	<0.20		<0.28	<0.37			<0.64
Islay	Crabs	1			<0.10	<0.18		<0.45	<0.98			<0.55
Islay	Scallops	1			<0.09	<0.28		<0.31	<0.38			<0.74
Minch	*Nephrops*	2			<0.09	<0.22		<0.32	<0.42	16	<0.34	<0.91
Stornaway	Prawns	1			<0.10	<0.22		<0.28	<0.30			<0.77
Northern North Sea	*Nephrops*	1			<0.03	<0.11		<0.18	<0.31	2.0	<0.23	<0.33
Mid North Sea	Mussels[j]	2			<0.03	<0.08		<0.09	<0.07		<0.07	<0.35
Southern North Sea	Cockles	2			<0.04	<0.09		<0.10	<0.11		<0.09	<0.35
Southern North Sea	Cockles[k]	2			<0.09	<0.17		<0.25	<0.31	0.035	<0.26	<0.73
Southern North Sea	Mussels	4			<0.08	<0.19		<0.26	<0.32	1.7	<0.26	<0.83
English Channel-East	Scallops	4		13	<0.14	<0.20		<0.22	<0.22		<0.19	<0.79
English Channel-West	Crabs	4		23	<0.09	<0.22		<0.29	<0.34		<0.28	<0.85
English Channel-West	Lobsters	3			<0.12	<0.29		<0.36	<0.44	0.44	<0.33	<1.2
English Channel-West	Scallops	4		15	<0.07	<0.20		<0.24	<0.31		<0.25	<0.70

Table 4.2. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Fleetwood	Lobsters	2	0.36	<0.17	<0.08	2.2	<0.30	<0.23	<0.13	1300
Fleetwood	Squid	1	<0.11	<0.13	<0.06	0.18	<0.28	<0.18	<0.11	
Fleetwood	Whelks	4	<0.16	<0.12	<0.05	1.2	<0.25	<0.14	<0.11	
Isle of Man	Lobsters	4	<0.12	<0.15	<0.07	0.62	<0.30	<0.21	<0.14	210
Isle of Man	Scallops	4	<0.08	<0.09	<0.04	0.42	<0.20	<0.13	<0.09	
Inner Solway	Shrimps[h]	4	<0.15	<0.23	<0.11	4.1	<0.52	<0.12	<0.21	
Southerness	Winkles	4	<1.3	<0.71	<0.10	2.6	<0.20	<0.10	<0.11	
Kirkcudbright	Scallops	6	<0.09	<0.11	<0.07	0.33	<0.20	<0.13	<0.11	
Kirkcudbright	Queens	8	<0.09	<0.11	<0.07	0.33	<0.22	<0.13	<0.11	
North Solway coast	Crabs[i]	8	<0.26	<0.20	<0.11	1.3	<0.40	<0.23	<0.18	
North Solway coast	Lobsters	8	<0.26	<0.32	<0.15	1.7	<0.61	<0.34	<0.26	
North Solway coast	Squat lobsters	1								
North Solway coast	Winkles	7	<0.73	<0.71	<0.09	2.3	<0.31	<0.17	<0.15	
North Solway coast	Cockles	8	<0.10	<0.14	<0.08	4.1	<0.28	<0.13	<0.13	
North Solway coast	Mussels	7	<0.10	<0.18	<0.08	2.8	<0.27	<0.14	<0.13	
Wirral	Shrimps	2	<0.25	<0.31	<0.13	2.6	<0.75	<0.35	<0.34	
Wirral	Cockles	4	<0.11	<0.17	<0.07	2.1	<0.34	<0.17	<0.15	
Liverpool Bay	Mussels	2								
Mersey Estuary	Mussels	2								
Ribble Estuary	Cockles	2	<0.17	<0.23	<0.10	4.3	<0.37	<0.29	<0.16	
Ribble Estuary	Shrimps	2	<0.10	<0.13	<0.05	3.3	<0.22	<0.17	<0.10	
Knott End	Cockles	1	<0.14	<0.16	<0.07	4.3	<0.26	<0.18	<0.11	
Conwy	Mussels	2	<0.08	<0.11	<0.05	0.25	<0.23	<0.13	<0.11	
Northern Ireland	Lobsters	5	<0.34	<0.43	<0.19	<0.31	<0.81	<0.52	<0.35	
Northern Ireland	*Nephrops*	8	<0.21	<0.26	<0.11	1.3	<0.55	<0.32	<0.22	
Northern Ireland	Winkles	4	<0.16	<0.21	<0.09	0.44	<0.43	<0.24	<0.20	
Northern Ireland	Mussels	1								
Skye	Lobster	1	<0.10	<0.13	<0.10	0.25	<0.31	<0.10	<0.12	
Skye	Mussels	1	<0.08	<0.17	<0.07	<0.07	<0.47	<0.63	<0.24	
Islay	Crabs	1	<0.10	<0.16	<0.10	0.29	<0.44	<0.10	<0.18	
Islay	Scallops	1	<0.10	<0.20	<0.07	0.20	<0.50	<0.90	<0.26	
Minch	*Nephrops*	2	<0.16	<0.21	<0.09	0.30	<0.50	<0.25	<0.22	
Stornaway	Prawns	1	<0.10	<0.21	<0.10	0.33	<0.44	<0.10	<0.19	
Northern North Sea	*Nephrops*	1	<0.07	<0.07	<0.03	0.12	<0.16	<0.11	<0.07	
Mid North Sea	Mussels[j]	2	<0.06	<0.10	<0.04	0.09	<0.20	<0.10	<0.09	35
Southern North Sea	Cockles	2	<0.06	<0.09	<0.04	0.17	<0.21	<0.11	<0.10	
Southern North Sea	Cockles[k]	2	<0.13	<0.18	<0.07	<0.10	<0.41	<0.18	<0.18	
Southern North Sea	Mussels	4	<0.15	<0.20	<0.09	<0.20	<0.37	<0.22	<0.16	
English Channel-East	Scallops	4	<0.14	<0.18	<0.08	<0.08	<0.34	<0.24	<0.14	
English Channel-West	Crabs	4	<0.16	<0.20	<0.09	<0.08	<0.42	<0.24	<0.18	
English Channel-West	Lobsters	3	<0.20	<0.26	<0.11	<0.10	<0.49	<0.33	<0.21	
English Channel-West	Scallops	4	<0.13	<0.16	<0.07	<0.08	<0.36	<0.22	<0.16	

** not detected by the method used*
[a] *The concentrations of organic ^{3}H and ^{129}I were 120 Bq kg^{-1} and <0.39 Bq kg^{-1} respectively*
[b] *The concentration of organic ^{3}H was 230 Bq kg^{-1}*
[c] *Samples collected by Consumer 116*
[d] *The concentrations of organic ^{3}H and ^{129}I were <25 and <0.56 Bq kg^{-1} respectively*
[e] *Aphrodite aculeata, an annelid worm*
[f] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*
[g] *The concentration of organic ^{3}H was 56 Bq kg^{-1}*
[h] *The concentration of ^{54}Mn was <0.11 Bq kg^{-1}*
[i] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*
[j] *Landed in Denmark*
[k] *Landed in Holland*

Table 4.3. Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Sellafield coastal area	Cod	2		0.0041	0.021		0.032	*	0.000049
Sellafield coastal area	Plaice	1		0.0027	0.014		0.026	0.000043	0.000047
Sellafield coastal area	Bass	1					<0.08		
Sellafield coastal area	Crabs	2	0.0047	0.079	0.39	5.0	1.6	0.0022	0.00098
Sellafield coastal area	Lobsters	2	0.031	0.051	0.25	3.0	4.5	*	0.0060
Sellafield coastal area	*Nephrops*[a]	1		0.063	0.32		1.7	*	0.0022
Sellafield coastal area	Winkles[b]	1	0.031	2.3	11	130	21	0.022	0.034
Sellafield coastal area	Mussels[b]	1		1.4	6.3	71	13	*	0.025
Sellafield coastal area	Limpets[b]	1		1.3	6.5	72	11	*	*
Sellafield coastal area	Whelks	1		0.51	2.5	28	6.1	0.0085	0.014
Sellafield offshore area	Cod	1		0.012	0.059		0.093	0.00021	0.00023
Sellafield offshore area	Plaice	1	0.00014	0.0090	0.046		0.076	*	*
Sellafield offshore area	Dab	2					<0.23		
Sellafield offshore area	Whiting	2					<0.12		
Sellafield offshore area	Spurdog	1					<0.23		
Sellafield offshore area	Lesser spotted dogfish	1					<0.28		
St Bees	Winkles	1	0.022	2.7	13	140	24	0.046	0.047
St Bees	Mussels	2		1.2	6.4	69	14	*	0.031
St Bees	Limpets	1		1.6	7.1		14	*	0.031
Seascale	Sea mouse[c]	1		4.5	23		72	*	0.11
Nethertown	Winkles	4	0.042	3.3	16	170	32	*	0.043
Nethertown	Mussels	4		2.0	9.6		20	0.010	0.039
Whitriggs	Shrimps	1					<0.33		
Drigg	Winkles	1	0.018	2.1	11	130	23	*	0.029
Ravenglass	Cod	1		0.00057	0.0027		0.0059	*	0.000014
Ravenglass	Plaice	1		0.0040	0.021		0.041	*	0.000072
Ravenglass	Crabs	1		0.059	0.29	3.3	1.3	*	0.0027
Ravenglass	Lobsters	1		0.035	0.17	2.1	3.1	*	0.0080
Ravenglass	Winkles	2					26		
Ravenglass	Cockles	1		1.8	8.7	96	26	*	0.050
Ravenglass	Mussels	1		1.1	5.3	59	12	*	0.013
Tarn Bay	Winkles	1		3.3	16	170	31	*	0.058
Saltom Bay	Winkles	4					15		
Whitehaven	Cod	1		0.00054	0.0033		0.0057	0.000049	0.000019
Whitehaven	Plaice	1		0.0045	0.022		0.042	0.000055	0.000070
Whitehaven	Ray	1		0.0012	0.0063		0.011	*	*
Whitehaven	Herring	1		0.030	0.15		0.23	*	0.00034
Whitehaven	*Nephrops*	1		0.024	0.13		0.49	*	0.00084
Whitehaven	Whelks	1		0.33	1.7	18	3.7	*	0.0040
Silloth	Mussels	1		0.58	3.0		5.7	*	0.014
Parton	Cod	4					<0.09		
Parton	Crabs	4					1.3		
Parton	Lobsters	4					1.4		
Parton	Winkles	1		1.6	8.1	85	15	*	0.031
Haverigg	Cockles	1		0.99	5.5		15	*	0.029
Millom	Mussels	2					4.7		
Morecambe Bay (Flookburgh)	Flounder	1		0.00031	0.0017		0.0034	*	0.000023
Morecambe Bay (Morecambe)	Plaice	4					<0.11		
Morecambe Bay (Morecambe)	Bass	2					<0.27		
Morecambe Bay (Sunderland Point)	Whitebait	1		0.058	0.33	3.3	0.51	0.0025	0.0010
Morecambe Bay (Flookburgh)	Shrimps	1		0.0048	0.027	0.52	0.043	*	0.00011
Morecambe Bay (Morecambe)	Mussels	1		0.27	1.5		2.6	*	0.0029
Morecambe Bay (Flookburgh)	Cockles	1		0.42	2.3	22	6.1	*	0.011
Morecambe Bay (Middleton Sands)	Cockles	1		0.36	2.0		5.3	*	0.012

Table 4.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
River Calder	Brown trout	1				<0.87		
River Calder	Sea trout	1				<0.12		
Calder	Rainbow trout	2				<0.36		
River Duddon	Sea trout	1				<0.11		
River Kent	Sea trout	1				<0.35		
River Derwent	Sea trout	1				<0.34		
Fleetwood	Cod	1	0.00012	0.00068		0.0013	*	*
Fleetwood	Plaice	1	0.00075	0.0040		0.0082	*	*
Fleetwood	Lobsters	2				1.3		
Fleetwood	Squid	1				<0.07		
Fleetwood	Whelks	1	0.12	0.66	6.7	0.98	*	0.0014
Wirral	Shrimps	2				<0.49		
Wirral	Cockles	1	0.27	1.6		2.7	*	0.0040
Knott End	Cockles	1	0.40	2.2		5.8	*	0.0087
Ribble Estuary	Flounder	1				<0.62		
Ribble Estuary	Salmon	1				<0.18		
Ribble Estuary	Bass	1				<0.30		
Ribble Estuary	Sea trout	1				<0.37		
Ribble Estuary	Mullet	2				<0.24		
Ribble Estuary	Shrimps[d]	1	0.0043	0.021		0.034	*	0.000052
Ribble Estuary	Cockles	1	0.23	1.3		3.3	*	0.012
Isle of Man	Cod	1	0.00078	0.0045		0.0048	*	*
Isle of Man	Herring	1	0.00021	0.0012		0.0015	*	*
Isle of Man	Lobsters	4				<0.13		
Isle of Man	Scallops	1	0.016	0.082		0.022	*	0.00011
Inner Solway	Flounder	1	0.0032	0.0049		0.10		
Inner Solway	Salmon	1				<0.10		
Inner Solway	Sea trout	1	<0.0025	<0.0025		<0.0029		
Inner Solway	Shrimps	1	0.0038	0.019		0.032		
Southerness	Winkles	1	0.33	1.6	11	0.079		
Kirkcudbright	Plaice	1	0.0012	0.0091		0.0093		
Kirkcudbright	Scallops	2	0.021	0.12		0.066	*	0.00015
Kirkcudbright	Queens	2	0.0093	0.049		0.041	*	*
North Solway coast	Plaice	4				<0.11		
North Solway coast	Mullet	3				<0.11		
North Solway coast	Crabs	2	0.016	0.079	0.56	0.59	*	0.00080
North Solway coast	Lobsters	2	0.0093	0.051	0.39	0.33	0.00082	0.00098
North Solway coast	Winkles	2	0.33	1.6	14	3.3	0.019	0.0045
North Solway coast	Cockles	5	0.42	2.3	23	5.4	*	0.0093
North Solway coast	Mussels	2	0.43	2.2	24	4.5	*	0.0052
Conwy	Mussels	1	0.020	0.11		0.20	0.00035	0.00045
North Anglesey	Plaice	2				<0.16		
North Anglesey	Rays	1	0.00059	0.0028		0.0040	*	*
Northern Ireland	Cod	6				<0.13		
Northern Ireland	Whiting	1	0.00011	0.00058		0.00098	*	*
Northern Ireland	Herring	2				<0.30		
Northern Ireland	Spurdog	5				<0.20		
Northern Ireland	Lobsters	5				<0.40		
Northern Ireland	*Nephrops*	1	0.0045	0.027		0.14	*	0.00023
Northern Ireland	Winkles	1	0.031	0.16		0.15	*	0.00018

Table 4.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Sound of Mull	Salmon	1				<0.08		
Skye	Lobsters	1				<0.10		
Skye	Mussels	1				<0.45		
Islay	Crabs	1				<0.14		
Islay	Scallops	1				<0.50		
Minch	Cod	1	0.000067	0.00025		0.00024	*	*
Minch	Plaice	4				<0.11		
Minch	Haddock	1	0.000050	0.00021		0.00018	*	*
Minch	Herring	4				<0.18		
Minch	*Nephrops*	1	0.00025	0.0019		0.0025	*	*
Stornaway	Prawns	1				0.13		
Shetland	Fish meal[e]	1	0.00038	0.0036		0.00088	*	*
Shetland	Fish oil[e]	4				<0.14		
Northern North Sea	Cod	1	0.00029	0.0016		0.0025	*	0.000061
Northern North Sea	Plaice	3				<0.13		
Northern North Sea	Haddock	1	0.000039	0.00022		0.00021	*	*
Northern North Sea	Herring	1				<0.26		
Northern North Sea	Mackerel	1				<0.18		
Northern North Sea	*Nephrops*	1	0.00029	0.0021		0.0051	*	*
Mid North Sea	Cod	4				<0.12		
Mid North Sea	Plaice	4				<0.06		
Mid North Sea	Herring	1				<0.07		
Mid North Sea	Mussels[f]	1	0.0014	0.0085		0.013	*	0.000027
Southern North Sea	Cod	2				<0.05		
Southern North Sea	Plaice	2				<0.09		
Southern North Sea	Herring	2				<0.23		
Southern North Sea	Cockles	1	0.0017	0.012		0.0064	*	*
Southern North Sea	Cockles[g]	1	0.0023	0.0081		0.012	*	0.0024
Southern North Sea	Mussels	1	0.0018	0.012		0.0048	*	*
English Channel-East	Cod	4				<0.14		
English Channel-East	Plaice	4				<0.15		
English Channel-East	Scallops	1	0.00059	0.0028		0.0027	*	0.000034
English Channel-West	Mackerel	4				<0.18		
English Channel-West	Plaice	4				<0.15		
English Channel-West	Whiting	4				<0.14		
English Channel-West	Crabs	1	0.00027	0.0018		0.0025	*	0.000081
English Channel-West	Lobsters	3				<0.22		
English Channel-West	Scallops	1	0.00045	0.0054		0.0036	*	*
Gt. Yarmouth (retail shop)	Cod	4				<0.06		
Gt. Yarmouth (retail shop)	Plaice	4				<0.12		
Skagerrak	Cod	2				<0.05		
Skagerrak	Herring	2				<0.08		
Iceland Area	Cod	1				<0.22		
Icelandic processed	Cod	1	0.000034	0.00013		0.00023	*	*
Barents Sea	Cod	4				<0.09		
Baltic Sea	Cod	4				<0.32		
Baltic Sea	Herring	4				<0.13		
Norwegian Sea	Cod	1				<0.04		
Norwegian Sea	Mackerel	1				<0.46		
Norwegian Sea	Saithe	1				<0.12		
Celtic Sea	Cod	4				<0.05		
Celtic Sea	Haddock	2				<0.06		
Celtic Sea	Whiting	2				<0.13		

** Not detected by the method used*
[a] *Samples collected by Consumer 1060*
[b] *Samples collected by Consumer 116*
[c] *Aphrodite aculeata, an annelid worm*
[d] *The concentration of ^{237}Np was 0.00016 Bq kg^{-1}*
[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, 2000

Exposed population[b]	Foodstuffs	Exposure mSv[a]													
		Total	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{238}Pu	$^{239}Pu+$ ^{240}Pu	^{241}Pu	^{241}Am	Others	External
Sellafield fishing community	Plaice and other fish Crabs, lobsters and *Nephrops* Winkles and other molluscs	0.15[f]	0.003	0.001	0.003	0.019	0.002	0.002	0.005	0.005	0.027	0.005	0.053	<0.001	0.022
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.030	0.001			0.002			0.004	0.001	0.007	0.001	0.012	<0.002	
Dumfries and Galloway	Plaice, cod and salmon Crabs, lobster and *Nephrops* Winkles and mussels	0.033[c]	0.001			0.005		0.001	0.005		0.004		0.007	<0.003	0.007
Morecambe Bay	Flounders and plaice Shrimps Cockles and mussels	0.066[d]	0.002			0.002			0.010	0.002	0.011	0.002	0.020	<0.002	0.015
Fleetwood	Plaice and cod Shrimps Whelks	0.023	0.003						0.008		0.004		0.005	<0.004	
Isle of Man	Fish and shellfish[e]	0.008				0.003			0.003					<0.003	
Northern Ireland	Fish and shellfish[e]	0.015				0.002	0.001		0.004				0.005	<0.003	
North Wales	Fish and Shellfish[e]	0.010					0.001		0.004				0.003	<0.002	
Typical member of the fish eating public consuming fish landed at Whitehaven and Fleetwood	Plaice and cod	0.001												<0.001	

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

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2000

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria			
Rockcliffe Marsh	Salt marsh	4	0.070
Newton Arlosh	Salt marsh	4	0.11
Parton	Winkle bed	4	0.087
Whitehaven - outer harbour	Mud and sand	12	0.093
Whitehaven - outer harbour	Coal and sand	12	0.11
Saltom Bay	Winkle bed	4	0.097
St Bees	Sand	4	0.071
Nethertown	Winkle bed	4	0.092
Sellafield	Sand	4	0.074
Drigg Barn Scar	Mussel bed	4	0.087
Ravenglass - Carleton Marsh	Salt marsh	4	0.20
Ravenglass - salmon garth	Mud, sand and stones	4	0.12
Ravenglass - salmon garth	Sand and stones	4	0.089
Ravenglass - salmon garth	Mussel bed	4	0.088
Ravenglass - ford	Mud and sand	4	0.10
Ravenglass - Raven Villa	Mud	5	0.12
Ravenglass - Raven Villa	Mud and sand	7	0.12
Ravenglass - Raven Villa	Salt marsh	12	0.18
Tarn Bay	Sand	2	0.066
Tarn Bay	Winkle bed	2	0.082
Haverigg	Mud	4	0.091
Haverigg	Sand	4	0.067
Millom	Mud and sand	4	0.093
Sand Gate Marsh	Salt marsh	4	0.096
Flookburgh	Mud and sand	4	0.075
High Foulshaw	Salt marsh	4	0.089
Arnside	Salt marsh	4	0.099
Lancashire			
Colloway Marsh	Salt Marsh	4	0.15
Aldcliffe Marsh	Salt Marsh	4	0.11
Conder Green	Mud and sand	4	0.093
Conder Green	Salt Marsh	4	0.11
Cockerham Marsh	Salt Marsh	4	0.11
Heads - River Wyre	Salt Marsh	2	0.11
Height o' th' hill - River Wyre	Salt Marsh	4	0.11
Knott End	Mud and sand	2	0.079
South-west Scotland			
Piltanton Burn	Salt marsh	3	0.054
Garlieston	Mud	4	0.064
Innerwell	Mud	4	0.072
Innerwell	Mud and sand	4	0.082
Bladnoch	Mud	3	0.086
Creetown	Salt marsh	4	0.081
Carsluith	Mud	4	0.081
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.074
Cumstoun	Salt marsh	3	0.086
Kirkcudbright	Salt marsh	4	0.077
Cutters Pool	Winkle bed	7	0.076
Rascarrel Bay	Winkle bed	7	0.10
Palnackie Harbour	Mud	2	0.070
Gardenburn	Salt marsh	4	0.068
Kippford - Slipway	Mud	4	0.083
Kippford - Merse	Salt marsh	4	0.10
Carsethorn	Mud	4	0.060
Glencaple Harbour	Mud and sand	4	0.072

Table 4.6. Radioactivity in sediment from the Cumbrian coast and further afield, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria											
Newton Arlosh	Turf	4	<0.59	3.3	<1.7	<1.6	<7.8	<3.1	<0.73	590	<4.9
St Bees	Sand	4	<0.37	3.0	<1.5	<2.0	<3.9	<1.2	<0.42	91	<2.3
Sellafield	Sand	4	<0.36	5.3	<1.2	<1.5	<3.9	<1.2	<0.41	93	<2.1
Ravenglass - Carleton Marsh	Mud	4	<0.89	55	<2.9	<3.5	90	8.2	<1.0	510	13
Ravenglass - Raven Villa	Mud and sand	4	<0.71	37	<2.4	<3.2	44	<6.1	<0.79	210	<6.5
Newbiggin	Mud										
Millom	Mud and sand	4	<0.55	8.5	<2.0	<2.6	<16	<2.9	<0.64	230	<4.4
Flookburgh	Mud and sand	4	<0.41	<1.9	<1.5	<2.0	<4.2	<1.3	<0.46	110	<2.5
Sand Gate marsh	Turf	4	<0.53	1.3	<1.9	<2.6	<6.0	<2.1	<0.60	270	<4.0
Lancashire											
Conder Green	Turf	4	<0.65	3.6	<2.2	<3.0	<7.5	<2.6	<0.82	260	<5.2
Cockerham Marsh	Turf	1	<0.60	3.5	<2.0	<2.1	<7.3	<2.8	<0.74	500	<4.2
Morecambe	Mud and sand	4	<0.48	2.6	<1.5	<1.8	<4.8	<1.5	<0.57	120	<3.0
Scotland											
Bladnoch	NA	3	<0.25	4.2	<1.5	<1.4	<6.4	<1.3	<0.30	400	<2.1
Garlieston	NA	4	<0.15	0.98	<0.43	<0.65	<1.4	<0.70	<0.16	66	<0.99
Innerwell	Mud	6	<0.28	2.2	<0.77	<0.90	<3.5	<0.98	<0.32	120	<1.6
Carsluith[a]	NA	4	<0.14	3.9	<0.41	<0.44	<4.1	<1.5	<0.16	200	<1.0
Kippford Merse	Turf	4	<0.28	4.5	<0.75	<1.8	<7.5	<2.9	<0.68	1800	<4.0
Kippford Slipway	NA	4	<0.20	4.0	<0.65	<1.1	6.0	<1.7	<0.21	190	<1.4
Palnackie Harbour	NA	4	<0.17	4.9	<0.36	<0.79	7.3	<1.1	<0.21	280	<1.5
Carsethorn[b]	NA	2	<0.10	<0.12	<0.45	<0.62	<0.98	<0.29	<0.10	35	<0.60
Kirkconnel Merse	NA	3	<0.23	4.3	<0.35	<1.5	5.6	<1.6	<0.30	410	<1.9
Campbeltown	NA	1	<0.23	<0.20	<1.0	<1.8	<1.8	<0.51	<0.22	10	<1.5
Northern Ireland											
Lough Foyle	Mud	1	<0.23	<0.18	<0.78	<1.1	<2.1	<0.60	<0.26	3.7	<1.7
Lough Foyle	Sand	1	<0.29	<0.26	<0.90	<0.94	<2.8	<0.78	<0.34	2.0	<2.0
Portrush	Sand	2	<0.35	<0.31	<1.3	<1.9	<3.2	<0.81	<0.36	1.0	<1.8
Ballymacormick	Mud	2	<0.48	<0.43	<1.6	<2.1	<4.2	<1.2	<0.57	50	<2.4
Strangford Lough -Nickey's point	Mud	2	<0.38	<0.34	<1.3	<1.5	<3.3	<0.89	<0.44	33	<1.8
Dundrum Bay	Mud	1	<0.43	<0.37	<1.3	<1.4	<3.6	<1.0	<0.46	7.3	<2.8
Dundrum Bay	Sand	1	<0.42	<0.38	<1.5	<2.0	<3.7	<0.95	<0.46	5.7	<2.4
Carlingford Lough	Mud	2	<0.50	<0.41	<1.9	<2.9	<4.5	<1.3	<0.61	67	<3.5
Oldmill Bay	Mud	2	<0.70	<0.68	<2.3	<2.8	<6.2	<1.8	<0.78	66	<3.6

Table 4.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}						
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cumbria									
Newton Arlosh	Turf	4	<2.2	<2.6			290		
St Bees	Sand	4	<1.6	<1.1			180		
Sellafield	Sand	4	<1.4	<1.1			180		
Ravenglass - Carleton Marsh	Mud	4	10	5.8			1100		
Ravenglass - Raven Villa	Mud and sand	4	<4.8	<3.3			510		
Newbiggin	Mud								
Millom	Mud and sand	4	<3.5	<2.0			320		
Flookburgh	Mud and sand	4	<1.2	<1.4			63		
Sand Gate marsh	Turf	4	<1.6	<2.1			120		
Lancashire									
Conder Green	Turf	4	<2.0	<2.7			150		
Cockerham Marsh	Turf	1	3.0	<2.0			250		
Morecambe	Mud and sand	4	<1.3	<2.1			69		
Scotland									
Bladnoch	NA	3	2.8	<1.6			330		
Garlieston	NA	4	<1.1	<0.68	6.7	38	67	<0.00010	<0.00010
Innerwell	Mud	6	<1.3	<1.4			110		
Carsluith[a]	NA	4	1.9	1.7	32	170	290	<0.00010	<0.00010
Kippford Merse	Turf	4	8.4	<2.6	86	480	960	<0.00010	<0.00010
Kippford Slipway	NA	4	1.6	<1.5	29	150	280	<0.00010	<0.00010
Palnackie Harbour	NA	4	2.4	<1.5	22	120	190		
Carsethorn[b]	NA	2	<0.15	<0.31			7.2		
Kirkconnel Merse	NA	3	2.3	<1.7	14	74	130		
Campbeltown	NA	1	<1.9	<0.76			<1.4		
Northern Ireland									
Lough Foyle	Mud	1	<0.56	<0.82	0.058	0.45	0.60	*	0.0012
Lough Foyle	Sand	1	<0.73	<1.1			<1.9		
Portrush	Sand	2	<0.92	<0.86			<1.1		
Ballymacormick	Mud	2	<1.4	<1.1	3.2	17	26	*	0.041
Strangford Lough -Nickey's point	Mud	2	<1.1	<0.89	1.4	7.8	8.1	0.016	0.018
Dundrum Bay	Mud	1	<1.2	<1.5			<2.7		
Dundrum Bay	Sand	1	<1.2	<1.2			2.3		
Carlingford Lough	Mud	2	<1.3	<1.7	1.7	11	6.9	*	0.012
Oldmill Bay	Mud	2	<2.0	<1.7	3.3	18	25	*	0.027

* *not detected by the method used*

NA not available

[a] *The concentrations of alpha and beta activities were 240 and 1700 Bq kg^{-1} respectively*

[b] *The concentration of ^{3}H was <5.7 Bq kg^{-1}.*

Table 4.7. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2000

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, µSv h^{-1}
A	Nets	6	0.080
	Ropes	6	0.070
R	Nets	4	0.096
S	Gill nets	1	0.14
	Nets	1	0.042
	Pots	2	0.054
T	Gill nets	4	0.11
	Pots	2	0.27
W	Gill nets	2	0.060
	Pots	2	0.081
X	Gill nets	4	0.075
	Pots	2	0.17

Table 4.8. Radioactivity in terrestrial food and the environment near Sellafield, 2000,[a]

Material	Selection[b]	Farms/ samples	Mean radioactivity concentration (wet)[c], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Milk Near farms[d]		11	<4.8	<5.8	16	<0.87	<0.26	0.11	<0.0055	<1.8	<0.51
Milk Near farms[d]	max		<13	<14	20	<2.2	<0.29	0.27		<2.1	<0.55
Milk Far farms		4	<3.9	<4.4	13	<0.41	<0.27	0.060	<0.0050	<1.9	<0.56
Milk Far farms	max		<4.3	<5.5	15	<0.48	<0.32	0.065		<2.0	<0.63
Apples		2	<4.5	<8.5	11	0.90	<0.25	0.11	<0.033	<1.8	<0.40
Apples	max		<6.0	13	14	1.1	<0.30	0.13			
Barley		1		<6.0	94	2.6	<0.40	1.1		<1.4	<0.90
Blackberries		1	4.0	22	33	18	<0.40	3.6		<1.7	<0.60
Bovine kidney		1	4.0	7.0	14	<0.90	<0.30	0.033	<0.037	<2.1	<0.60
Bovine liver		1	<7.0	<7.0	19	<0.90	<0.20	0.11	0.053	<2.3	<0.60
Bovine muscle		1	<5.0	<5.0	15	<0.90	<0.20	0.13	0.036	<1.8	<0.60
Cabbage		1	<5.0	4.0	<2.0	0.90	<0.30	0.21		<2.3	<0.60
Carrots		1	<4.0	<4.0	3.0	0.30	<0.30	0.58	<0.041	<2.3	<0.50
Cauliflower		1									
Chicken		1	<5.0	<5.0	21	2.0	<0.30	0.036		<2.2	<0.70
Elderberries		1	5.0	27	24	6.2	<0.20	1.4		<1.9	<0.50
French beans		1	<7.0	5.0	2.0	0.60	<0.30	0.47		<2.2	<0.70
Hares		1	6.0	7.0	28	4.5	<0.30	0.084	<0.070	<2.2	<0.50
Ovine offal		2	<8.5	<9.0	30	<1.7	<0.30	0.41	<0.036	<2.3	<0.75
Ovine offal	max		10	11	37	2.3		0.54	<0.039		<0.80
Ovine muscle		2	<5.0	<6.0	74	<2.9	<0.30	0.067	<0.030	<1.8	<0.45
Ovine muscle	max		6.0	8.0	77	4.7		0.070			<0.60
Pheasants		1	4.0	8.0	47	<0.70	<0.20	0.030	<0.022	<2.4	<0.60
Pigeons		1	<5.0	<5.0	13	4.5	<0.60	0.033		<3.7	<0.80
Potatoes		2	<3.5	7.5	18	<0.45	<0.30	0.13		<1.6	<0.45
Potatoes	max		<5.0	9.0	24	<0.50		0.20		<2.2	<0.60
Runner beans		1	<7.0	6.0	11	1.3	<0.40	0.57		<2.2	<0.60
Swede		1	<4.0	4.0	6.0	<0.50	<0.40	1.2		<2.3	<0.60
Turnips		1									
Wheat		1		22	140	12	<0.40	2.6		<2.6	<0.60
Grass[e]		3							<0.043	<3.3	
Grass[e]	max								<0.048	<3.6	
Soil		2									
Soil[f]	max										

Table 4.8. continued

Material	Selection[b]	Farms/ samples	Mean radioactivity concentration (wet)[c], Bq kg^{-1}							
			^{129}I	^{137}Cs	Total Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk Near farms[d]		11	<0.012	<0.31	0.17		<0.00018	<0.00018	<0.049	<0.00025
Milk Near farms[d]	max		<0.019	<0.36	0.26		<0.00023	<0.00023	<0.054	<0.00028
Milk Far farms		4	<0.011	<0.29	0.11		<0.00025	<0.00020	<0.049	<0.00025
Milk Far farms	max		<0.012	<0.32	0.15					
Apples		2	<0.048		0.18		<0.00035	0.0018	<0.11	<0.0022
Apples	max		<0.049		0.21		<0.00040	0.0027		0.0039
Barley		1	<0.049		1.9		0.00030	0.0034	<0.084	0.0060
Blackberries		1	<0.056		5.7		0.0014	0.014	0.18	0.011
Bovine kidney		1	<0.050		3.6		<0.00020	<0.00050	<0.12	0.0013
Bovine liver		1	<0.050		2.1		<0.00040	<0.00060	<0.28	0.0011
Bovine muscle		1	<0.048		4.3		<0.00020	<0.00020	<0.084	0.00060
Cabbage		1	<0.046		0.11		<0.00030	0.00050	<0.10	<0.00060
Carrots		1	<0.045		0.34		<0.00030	0.0012	<0.086	<0.00070
Cauliflower		1				<0.031				
Chicken		1	<0.035		<0.044		0.00010	<0.00020	0.074	0.00030
Elderberries		1	<0.042		6.5		0.0029	0.020	0.19	0.033
French beans		1	<0.035		0.15		<0.00040	0.0019	<0.11	0.00060
Hares		1			0.18		<0.00030	0.00070	<0.11	0.00080
Ovine offal		2	<0.052		0.90		0.00040	0.00060	<0.060	0.00080
Ovine offal	max		<0.058		1.1					
Ovine muscle		2	<0.039		1.0		<0.00015	<0.00020	<0.072	<0.00020
Ovine muscle	max		<0.042		1.2		<0.00020	0.00020	<0.079	0.00020
Pheasants		1	<0.060		4.8		<0.00020	0.00050	<0.10	0.00030
Pigeons		1	<0.050		1.1		0.00030	0.00060	<0.075	<0.00030
Potatoes		2	<0.049		0.15		<0.00025	<0.00040	<0.093	<0.00045
Potatoes	max		<0.061		0.18		<0.00030	0.00040	<0.098	<0.00050
Runner beans		1	<0.051		0.20		0.00030	0.0022	<0.11	0.0027
Swede		1	<0.039		0.23		<0.00030	0.0024	<0.10	<0.00050
Turnips		1				<0.029				
Wheat		1	<0.051		0.59		0.0016	0.036	<0.073	0.010
Grass[e]		3								
Grass[e]	max									
Soil		2				65				
Soil[f]	max					66				

[a] *346 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.35, 1.4 and 0.79 Bq per cloth respectively*

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

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

[d] *The mean concentration of ^{131}I was <0.018 Bq l^{-1}; the maximum was <0.021 Bq l^{-1}*

[e] *The mean concentrations of ^{55}Fe, ^{63}Ni and ^{144}Ce were <2.7 (max 4.8), 0.40 and <0.19 (max < 0.26) Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 12, 0.43 and 11 Bq kg^{-1} respectively*

Table 4.9. Individual radiation exposures due to consumption of terrestrial foodstuffs near Sellafield and Drigg, 2000

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	Others
Consumers near Sellafield aged 1 y	Milk Potatoes	0.033	0.001	0.004	0.003	0.010	0.006	0.001	0.002	0.001	0.002	<0.001
Consumers near Drigg aged 1 y	Milk Potatoes	0.015		0.001	0.002	0.004	0.004	0.001	0.001			<0.002
Consumers near Ravenglass aged 1 y	Milk Fruit	0.018		0.001	0.003	0.004	0.005	0.001	0.001		0.001	<0.002
Typical adult member of the public eating food grown near Sellafield	Milk Wild fruit	0.011				0.003	0.002		0.001		0.003	<0.002

[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, 2000

Material and selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[c]	1	<4.0	17	<0.70	<0.24	0.095	<0.0065	<1.7	<0.50	<0.011
Cabbage	1	<4.0	<2.0	0.30	<0.20	0.53	<0.028	<2.1	<0.30	<0.035
Carrots	1	<4.0	8.0	0.40	<0.30	0.51		<0.90	<0.60	<0.045
Ovine offal	1	<7.0	40	3.0	<0.30	0.34	<0.023	<2.4	<0.70	
Ovine muscle	1	<5.0	34	3.6	<0.30	<0.023	<0.023	<2.1	<0.50	<0.034
Potatoes	1	5.0	17	<0.20	<0.30	0.076	<0.027	<1.8	<0.60	<0.045
Grass	2						<0.043			
Grass max							<0.050			

Material and selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
		Total Cs	^{147}Pm	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c]	1	0.20	<0.25		<0.00018	<0.00038	<0.056	<0.00028
Cabbage	1	0.41	0.10		<0.00030	<0.00040	<0.14	0.00050
Carrots	1	0.20			<0.00030	0.00060	<0.13	<0.00080
Ovine offal	1	0.94			<0.00030	0.00060	<0.086	0.00030
Ovine muscle	1	1.3			<0.00020	<0.00020	<0.078	0.00010
Potatoes	1	0.24	<0.20		<0.00030	<0.00040	0.13	0.0022
Grass	2		8.1	0.14				
Grass max			8.6	0.17				
Soil	2			38				
Soil[d] max				45				

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

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

[c] *The concentrations of ^{134}Cs and ^{137}Cs were <0.24 and <0.28 Bq l^{-1} respectively*

[d] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 8.6, 0.37 and 8.4 Bq l^{-1} respectively*

Table 4.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2000

Location	Ground type	No. of sampling observ-ations	µSv h^{-1}
Whitehaven - outer harbour	Mud and sand	2	0.22
St Bees	Sand	2	0.18
Nethertown	Winkle bed	2	0.41
Sellafield pipeline	Sand	2	0.23
Drigg Barn Scar	Mussel bed	2	0.21
Ravenglass - Raven Villa	Salt marsh	2	0.46
Ravenglass - salmon garth	Mussel bed	2	0.30
Tarn Bay	Sand	2	0.11

Table 4.12. Radioactivity in terrestrial food and the environment near Ravenglass, 2000

Material and selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[c,d,e]	3	<4.0	14	<0.59	<0.28	0.065	<0.45	<0.42	<0.0060	<1.6	<0.49	<0.011
Milk[c]	max		17	<0.70	<0.30	0.081	<0.47	<0.44	<0.0070	<1.7	<0.51	<0.012
Barley	1	<7.0	79	1.3	<0.30	0.48	<0.70	<0.40	<0.037	<2.4	<0.60	<0.051
Bovine kidney	1	13	<8.0	<0.90	<0.30	0.34	<0.60	<0.40		<2.4	<0.50	
Bovine liver	1	10	47	1.7	<0.20	0.074	<0.30	<0.20	<0.039	<1.4	<0.50	<0.048
Bovine muscle	1	8.0	30	3.0	<0.20	0.027	<0.30	<0.20	<0.026	<1.4	<0.50	<0.052
Broad beans[f]	1								<0.029			
Cabbage[g]	1	<5.0	<5.0	<0.50	<0.20	0.37	<0.50	<0.60	<0.032	<1.9	<0.30	<0.038
Carrots	1	<5.0	<4.0	<0.20	<0.20	0.20	<0.40	<0.40	<0.040	<1.4	<0.50	<0.034
Honey	1	<6.0	74	0.80	<0.20	0.036	<0.40	<0.50	<0.054	<1.9	<0.70	<0.020
Ovine offal	2	8.0	50	<0.70	<0.30	0.14	<0.50	<0.35	<0.18	<2.2	<0.80	<0.060
Ovine offal	max	9.0	51					<0.40	<0.29			<0.063
Ovine muscle	2	10	29	<1.1	<0.35	0.039	<0.50	<0.35	<0.045	<2.4	<0.75	<0.039
Ovine muscle	max	11	32	1.4	<0.40	0.050		<0.40	<0.060	<2.5	<0.80	<0.042
Pears	1	5.0	15	0.30	<0.20	0.27	<0.50	<0.40	<0.036	<1.7	<0.60	<0.039
Potatoes[h]	1	4.0	23	0.50	<0.50	0.047	<0.60	<0.30	<0.031	<1.8	<0.70	<0.046
Runner beans	1	6.0	9.0	0.60	<0.30	0.16	<0.70	<0.70	<0.027	<1.7	<0.60	<0.052
Grass[i]	2								0.16			
Grass[i]	max								0.23			

Material and selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
		Total Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c,d,e]	3	0.17	<1.1	<0.39	<0.00021	<0.00023	<0.047	<0.00026
Milk[c]	max	0.20		<0.42	<0.00023	<0.00030	<0.048	<0.00028
Barley	1	0.44	<1.2	<0.40	<0.00030	0.00060	0.16	0.0027
Bovine kidney	1	1.2	<2.3	<1.4	<0.00040	<0.00050	<0.11	<0.00020
Bovine liver	1	0.75	<0.80	<0.30	<0.00020	0.00090	<0.099	0.00030
Bovine muscle	1	0.61	<0.80	<0.40	<0.00030	<0.00040	<0.095	0.00080
Cabbage[g]	1	0.046	<0.90	<0.40	<0.00030	0.00040	<0.085	<0.00050
Carrots	1	0.13	<1.0	<0.40	<0.00030	<0.00050	0.12	0.00090
Honey	1	0.31	<1.7	<0.70	0.00040	<0.00080	0.22	0.0014
Ovine offal	2	2.8	<1.8	<1.0	<0.00030	<0.00050	<0.070	0.0013
Ovine offal	max	3.5	<2.0	<1.1				
Ovine muscle	2	5.6	<1.4	<0.45	<0.00040	<0.00035	<0.12	<0.00030
Ovine muscle	max	8.9	<1.6	<0.50		<0.00040	0.12	
Pears	1	0.30	<1.2	<0.40	0.0018	0.013	<0.077	0.016
Potatoes[h]	1	0.36	<1.0	<0.50	<0.00030	0.0011	<0.082	0.00060
Runner beans	1	0.14	<1.2	<0.40	<0.00020	0.00060	<0.087	<0.00030

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[b] *Except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*
[c] *The mean concentration of ^{137}Cs was <0.28 Bq l^{-1} and the maximum was <0.29 Bq l^{-1}*
[d] *The mean concentration of ^{134}Cs was <0.23 Bq l^{-1}*
[e] *The mean concentration of ^{147}Pm was <0.25 Bq l^{-1}*
[f] *The concentration of U was<0.033 Bq kg^{-1}*
[g] *The concentration of ^{147}Pm was 0.50 Bq kg^{-1}*
[h] *The concentration of ^{147}Pm was 0.10 Bq kg^{-1}*
[i] *The concentrations of ^{55}Fe, ^{63}Ni and ^{147}Pm were 2.9, <0.70 and 8.1 Bq kg^{-1} respectively and the maxima were 4.0, 1.0 and 8.5 Bq kg^{-1} respectively*
[j] *The concentrations of U, ^{234}U, ^{235}U and ^{238}U in soil were 54 (max 60), 13, 0.43 and 11 Bq kg^{-1} respectively*

Table 4.13. Radioactivity in aquatic plants from the Cumbrian coast and further afield, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{14}C	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
England												
St Bees	*Fucus vesiculosus*[a]	4	33	11	<0.26	<0.27	6200	<1.6	<0.41	1.1	<0.11	5.8
St Bees	*Porphyra*	4	42	1.6	<0.24	<0.26	5.8	9.0	<0.17	<1.0	<0.09	2.1
St Bees	*Rhodymenia spp.*	2		2.1	<0.40	<0.46		6.5	<0.35	<0.42	<0.14	11
Braystones south	*Porphyra*	4		2.1	<0.19	<0.23		13	<0.14	0.69	<0.07	2.0
Sellafield	*Fucus vesiculosus*	4		22	<0.30	<0.33	10000	2.5	1.0	1.4	<0.11	6.7
Seascale	*Porphyra*[b]	52		2.9	<0.49	<0.29		15	<0.53	<2.3	<0.32	2.1
Rabbit Cat How, Ravenglass	Samphire	1		0.16	<0.17	<0.24	0.8	<0.49	<0.08	<0.12	<0.05	1.2
Cockerham Marsh	Samphire	1		<0.08	<0.28	<0.42		<0.60	<0.12	<0.13	<0.07	0.57
Marshside Sands	Samphire	1		<0.03	<0.07	<0.07	<0.28	<0.05	<0.07	<0.07	<0.03	0.73
Isle of Man	*Fucus vesiculosus*	2		0.41	<0.31	<0.40	1600	<0.74	<0.16	<0.17	<0.09	1.7
Wales												
Portmadoc	*Fucus vesiculosus*	1		<0.05	<0.10	<0.08	64	<0.39	<0.08	<0.09	<0.05	0.51
Fishguard	*Fucus vesiculosus*	1		<0.05	<0.09	<0.07	60	<0.34	<0.08	<0.08	<0.05	0.21
Lavernock Point	*Fucus vesiculosus*	1		<0.05	<0.13	<0.12		<0.44	<0.09	<0.11	<0.06	0.23
Lavernock Point	*Fucus serratus*	1		<0.03	<0.10	<0.10	1.1	<0.33	<0.07	<0.08	<0.04	0.20
South Wales,												
Manufacturer A	Laverbread	4		<0.06	<0.21	<0.29		<0.60	<0.10	<0.13	<0.06	<0.08
Manufacturer C	Laverbread	3		<0.06	<0.17	<0.19		<0.58	<0.10	<0.13	<0.06	0.10
Manufacturer D	Laverbread	4		<0.06	<0.21	<0.27		<0.61	<0.11	<0.14	<0.06	<0.13
Scotland												
Port William	*Fucus vesiculosus*	8		0.38	<0.33	<0.88	1900	<0.54	<0.11	<0.17	<0.08	1.9
Garlieston	*Fucus vesiculosus*	8		1.4	<0.36	<1.0	3700	<0.57	<0.12	0.35	<0.09	4.8
Auchencairn	*Fucus vesiculosus*	8		1.7	<0.35	<0.84	4400	<0.65	<0.13	<0.54	<0.09	5.9
Knock Bay	*Porphyra*	8		<0.07	<0.27	<0.74	8.8	<0.37	<0.09	<0.09	<0.07	0.40
Campbeltown	NA	1		<0.10	<0.99	<4.2		<0.66	<0.14	<0.15	<0.10	1.4
Islay	NA	1		<0.10	<0.56	<1.5		<0.33	<0.11	<0.14	<0.10	0.87
Lewis	NA	1		<0.10	<0.56	<1.7	350	<0.57	<0.10	<0.14	<0.10	0.57
Cape Wrath	*Ascophyllum nodosum*	1		<0.05	<0.10	<0.08	320	<0.39	<0.09	<0.10	<0.05	0.59
Wick	*Fucus vesiculosus*	1		<0.05	<0.09	<0.10		<0.37	<0.08	<0.09	<0.05	0.31
Northern Ireland												
Ardglass	*Fucus vesiculosus*	4		<0.16	<0.44	<0.60	1100	<1.2	<0.22	<0.27	<0.13	0.89
Portrush	*Fucus vesiculosis*	3		<0.06	<0.20	<0.25		<0.52	<0.12	<0.12	<0.06	0.41
Portrush	*Fucus serratus*	1		<0.06	<0.14	<0.13		<0.49	<0.11	<0.12	<0.06	0.09
Strangford Lough	*Rhodymenia spp.*	4		<0.12	<0.75	<0.52	19	<1.2	<0.23	<0.26	<0.12	1.1
Carlingford Lough	*Fucus spp.*	4		<0.17	<0.79	<0.60	600	<1.5	<0.29	<0.33	<0.17	1.1
Isles of Scilly	*Fucus vesiculosus*	1		<0.05	<0.13	<0.12	1.1	<0.47	<0.10	<0.12	<0.06	0.08

Table 4.13. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{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*[a]	4	<0.42	<0.42	1.8	8.5		5.1	0.0079	0.0071	
St Bees	*Porphyra*	4	<0.37	<0.37	0.52	2.6	27	5.2	0.012	0.0096	190
St Bees	*Rhodymenia spp.*	2		<0.56	0.82	4.1		9.1	*	0.013	
Braystones south	*Porphyra*	4		<0.31	0.30	1.6	18	3.6	*	0.0073	
Sellafield	*Fucus vesiculosus*	4		<0.42	1.9	9.5		4.5	0.0054	0.0094	8800
Seascale	*Porphyra*[b]	52		<1.5				5.9			
Rabbit Cat How, Ravenglass	Samphire	1		<0.26				1.7			
Cockerham Marsh	Samphire	1		<0.26				0.32			21
Marshside Sands	Samphire	1		<0.12				0.08			
Isle of Man	*Fucus vesiculosus*	2		<0.36				<0.19			1200
Wales											
Portmadoc	*Fucus vesiculosus*	1		<0.16				<0.05			
Fishguard	*Fucus vesiculosus*	1		<0.17				<0.06			270
Lavernock Point	*Fucus vesiculosus*	1		<0.27				<0.23			220
Lavernock Point	*Fucus serratus*	1		<0.22				<0.10			140
South Wales,											
Manufacturer A	Laverbread	4		<0.28				<0.14			
Manufacturer C	Laverbread	3		<0.24				<0.07			
Manufacturer D	Laverbread	4		<0.28				<0.09			77
Scotland											
Port William	*Fucus vesiculosus*	8		<0.30				<0.37			
Garlieston	*Fucus vesiculosus*	8		<0.33				3.5			
Auchencairn	*Fucus vesiculosus*	8		<0.37				2.7			
Knock Bay	*Porphyra*	8		<0.20				0.37			
Campbeltown	NA	1		<0.44				<0.10			
Islay	NA	1		<0.38				<0.10			
Lewis	NA	1		<0.35				<0.10			
Cape Wrath	*Ascophyllum nodosum*	1		<0.20				<0.14			430
Wick	*Fucus vesiculosus*	1		<0.19				<0.13			270
Northern Ireland											
Ardglass	*Fucus vesiculosus*	4		<0.55				<0.27			
Portrush	*Fucus vesiculosis*	3		<0.27				<0.16			
Portrush	*Fucus serratus*	1		<0.25				<0.16			
Strangford Lough	*Rhodymenia spp.*	4		<0.62	0.088	0.48		0.60	*	0.00070	
Carlingford Lough	*Fucus spp.*	4		<0.65				<0.39			
Isles of Scilly	*Fucus vesiculosus*	1		<0.29				<0.25			200

** Not detected by the method used*
NA Not available
[a] *The concentration of ^{129}I was 9.8 Bq kg^{-1}*
[b] *Counted wet*

Table 4.14. Radioactivity in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				1.0								
Newton Arlosh	Washed grass	1				1.5								
Newton Arlosh	Soil	1				3.3								
Sellafield 1707[b]	Beetroot	1	<0.09	<0.26	<0.29	5.3	<0.88	<0.20	<0.09	<0.08	<0.48	<0.27	<0.20	<0.19
Sellafield 1707[b]	Leeks	1	<0.07	<0.15	<0.12	0.51	<0.70	<0.17	<0.07	<0.06	<0.35	<0.21	<0.16	<0.15
Sellafield 1707[b]	Runner Beans	1	<0.07	<0.16	<0.13	14	<0.73	<0.16	<0.07	<0.06	<0.26	<0.24	<0.11	<0.06
Sellafield 1707[b]	Swede	1	<0.06	<0.14	<0.12	2.9	<0.58	<0.14	<0.06	<0.05	<0.28	<0.19	<0.15	<0.21
Sellafield 1707[b]	Compost	1	160	<4.6	<4.6	19000	68	13	<1.8	56	8.9	4.9	2.6	250
Sellafield 1707[b]	Soil	1	<0.24	<0.98	<1.3	43	<2.4	<0.63	<0.33	29	<1.5	<0.75	0.98	1.1
Sellafield 14[b]	Onions	1	<0.05	<0.13	<0.15	2.0	<0.49	<0.12	<0.05	0.07	<0.25	<0.14	<0.11	<0.10
Sellafield 14[b]	Potatoes	1	<0.03	<0.12	<0.15	10	<0.29	<0.08	<0.03	0.29	<0.19	<0.10	<0.09	<0.09
Sellafield 14[b]	Soil	1	4.9	<0.67	<0.50	1200	<3.2	3.6	<0.41	130	<1.7	<0.98	<0.83	21
Sellafield 1674[b]	Beetroot	1	<0.11	<0.36	<0.46	65	<0.96	<0.22	<0.10	<0.09	<0.40	<0.33	<0.17	<0.20
Sellafield 1674[b]	Leaf Beet	1	<0.05	<0.15	<0.17	850	<0.49	<0.10	<0.05	0.21	<0.18	<0.17	<0.07	<0.05
Sellafield 1674[b]	Onions	1	<0.12	<0.37	<0.41	2.9	<1.3	<0.30	<0.12	<0.11	<0.65	<0.35	<0.28	<0.26
Sellafield 1674[b]	Soil	1	0.63	<1.1	<1.5	270	<3.1	<0.88	<0.40	57	<2.2	<0.88	1.1	<1.8
Sellafield 1676[b]	Rhubarb	1	<0.05	<0.27	<0.20	60	<0.47	<0.10	<0.05	0.20	<0.19	<0.17	<0.07	<0.04
Sellafield 1676[b]	Soil	1	43	<3.8	<5.3	7700	19	<2.7	<1.1	78	<6.0	<2.5	<2.9	91
Hutton Marsh	Grass	1				2.7								
Hutton Marsh	Washed grass	1				0.88								
Hutton Marsh	Soil	1				19								

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

Table 4.15(a). Radioactivity in food and the environment near Springfields, 2000[a]

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}					
			^{60}Co	^{99}Tc	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th
Aquatic samples								
Flounder	Ribble Estuary	1	<0.17		7.8			
Grey mullet	Ribble Estuary	2	<0.17		5.4			
Salmon	Ribble Estuary	1	<0.06		0.39			
Sea trout	Ribble Estuary	1	<0.14		5.4			
Bass	Ribble Estuary	1	<0.12		14			
Shrimps[d]	Ribble Estuary	2	<0.06	4.1	3.3	0.016	0.013	0.014
Cockles	Ribble Estuary	2	1.6		4.3	0.020	0.37	0.58
Samphire	Marshside Sands	1	<0.03		0.73			
Grass (washed)	Hutton Marsh	1		0.88				
Grass (unwashed)	Hutton Marsh	1		2.7				
Soil	Hutton Marsh	1		19				
Sand	Ribble Estuary	1	<0.23		9.7	5.5	2.7	3.3

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}					
			^{232}Th	^{234}Th	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples								
Flounder	Ribble Estuary	1		*			<0.62	
Grey mullet	Ribble Estuary	2		*			<0.24	
Salmon	Ribble Estuary	1		*			<0.18	
Sea trout	Ribble Estuary	1		*			<0.37	
Bass	Ribble Estuary	1		*			<0.30	
Shrimps[d]	Ribble Estuary	2	0.0054	*	0.0043	0.021	0.034	0.000052
Cockles	Ribble Estuary	2	0.23	9.7	0.23	1.3	3.3	0.012
Samphire	Marshside Sands	1		*			0.08	
Sand	Ribble Estuary	1	2.7	31			6.8	

Table 4.15(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}						
			^{3}H	^{14}C	^{60}Co	^{90}Sr	Total Cs	^{230}Th	^{232}Th
Terrestrial samples									
Milk	Near farms	6							
Cabbage[e]		2	<4.0	3.0	<0.35	0.43	0.13	0.092	0.064
Cabbage	max				<0.40				
Carrots		1	<4.0	7.0	<0.40	0.15	0.061	0.0082	0.0027
Chicken		1	<5.0	61	<0.30	0.036	0.17	0.0027	<0.00080
Duck[f]		2	<8.5	27	<0.30	<0.057	2.3	<0.0067	<0.0031
Duck	max		9.0	39		0.081	2.4	0.011	<0.0032
Elderberries		1	<4.0	23	<0.20	0.21	0.048	0.019	0.053
Potatoes[g]		2	7.0	15	<0.20	0.079	<0.026	0.019	0.018
Potatoes	max				<0.30				
Runner beans		1	<4.0	9.0	<0.30	0.11	0.11	0.054	0.026
Sprouts		1	<4.0	21	<0.30	0.18	0.043	<0.0034	<0.0053
Grass[h]		8			<0.65				
Grass[h]	max				0.80				

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}					
			^{129}I	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples								
Milk	Near farms	6		<0.0080				
Cabbage[e]		2	<0.040		<0.00040	0.0012	<0.11	0.0059
Cabbage	max							
Carrots		1	<0.038		0.00010	<0.00030	0.14	<0.0013
Chicken		1	<0.051		<0.00020	0.00030	<0.064	<0.00030
Duck[f]		2			0.0022	0.014	<0.15	0.018
Duck	max				0.0024		<0.19	0.021
Elderberries		1	<0.067		<0.00030	0.0015	<0.091	<0.00020
Potatoes[g]		2	<0.044		0.00040	<0.00030	<0.15	<0.00060
Potatoes	max				0.00050	<0.00040		<0.0010
Runner beans		1			<0.00010	0.00030	<0.12	<0.00030
Sprouts		1	<0.039		<0.00020	0.00030	<0.087	0.00050
Bovine faeces		6		2.1				
Bovine faeces	max			4.9				
Ovine faeces		4		11				
Ovine faeces	max			32				
Grass[h]		8		1.1				10
Grass[h]	max			3.3				17
Silage		3		2.0				
Silage	max			3.9				
Soil		4		82				
Soil[i]	max			100				

** not detected by the method used*

[a] *143 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.61, 1.4 and 0.43 Bq per cloth respectively*

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

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

[d] *The concentration of ^{14}C was 59 Bq kg^{-1}*

[e] *The concentrations of ^{134}Cs and ^{137}Cs were <0.30 and 0.30 Bq kg^{-1} respectively*

[f] *The concentration of organic ^{3}H was <9.0 Bq kg^{-1}*

[g] *The concentrations of ^{134}Cs and ^{137}Cs were <0.10 and <0.10 Bq kg^{-1} respectively*

[h] *The concentrations of ^{134}Cs and ^{137}Cs were <0.35 (max <0.40) and 18 (max 27) Bq kg^{-1} respectively*

[i] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 24, 1.0 and 24 Bq kg^{-1} respectively*

Table 4.15(b). Monitoring of radiation dose rates near Springfields, 2000

Location	Material or ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m			
Fairhaven	Sand and Mud	1	0.070
Lytham Boat Area	Sand and Mud	1	0.095
Marshside Sands	Sand and Mud	1	0.042
Banks Marsh, posn.1	Mud	5	0.13
Banks Marsh, posn 1	Mud[a]	4	0.13
Banks Marsh, posn 1	Salt marsh	5	0.15
Banks Marsh, posn 2	Salt marsh	1	0.11
Warton Marsh	Mud	5	0.13
Warton Marsh	Mud[a]	4	0.13
Warton Marsh	Salt marsh	5	0.11
Hesketh Bank Marsh	Salt marsh	1	0.13
Frecketon Boatyard	Mud	1	0.11
Freckleton Boat	Cabin	1	0.075
Becconsall Boatyard	Mud	3	0.094
Becconsall Boat 1	Cabin	1	0.054
Becconsall Boat 2	Main Cabin	1	0.075
Becconsall Boat 2	Rear Cabin	1	0.069
Becconsall Boat 2	Berths	1	0.076
Longton Marsh	Salt Marsh	1	0.13
Lower Penwortham Area	Mud	4	0.076
Frenchwood Area	Mud	3	0.071
Walton-le-Dale Area	Mud	3	0.063
Beta dose rates			µSv h^{-1}
Lytham - Granny's Bay	Mud and sand	2	0.19
Ribble Estuary	Gill net	2	1.6
Ribble Estuary	Shrimp net	2	0.27
Banks Marsh, posn.1	Mud	5	2.1
Banks Marsh, posn.1	Salt marsh	5	0.54
Warton Marsh	Mud	5	2.5
Warton Marsh	Salt marsh	5	0.46
Lower Penwortham Area	Mud	4	2.2
Frenchwood Area	Mud	3	0.91
Walton-le-Dale Area	Mud	2	0.22

[a] *15cm above substrate*

Table 4.16. Radioactivity in food and the environment near Capenhurst, 2000[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}											
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{155}Eu	^{233}Pa	^{234}Th	^{234}U	^{235}U+ ^{236}U	^{238}U	^{237}Np	^{241}Am
Aquatic samples														
Dabs	Liverpool Bay	1	<25											
Dabs	Mersey Estuary	1	<25											
Flounder	Liverpool Bay	1	<25											
Flounder	Mersey Estuary	1	<25											
Shrimps	Wirral	2	<25	<0.12	4.9	2.6	<0.34	*	*					<0.49
Mussels	Liverpool Bay	2	<25											
Mussels	Mersey Estuary	2	<25											
Cockles[c]	Wirral	4		0.36	33	2.1	<0.15	*	12					2.7
Elodea canadensis[d]	Rivacre Brook	1		<0.11	3.6	0.13	<0.17	*	3.9	4.9	0.25	2.5	0.10	<0.09
Mud	Rivacre Brook	2		<0.32	330	8.3	<1.7	120	270	110	6.0	74	3.6	<1.7
Freshwater	Rivacre Brook	2	4.2	<0.09	0.027	<0.10	<0.33	*	*	0.045	*	0.025	0.00013	<0.32

Material	Location or selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{3}H	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk	Near Farms	5		<0.0055				<0.0080
Milk	Far farms	6	<1.6					
Milk	max		<1.8					
Potatoes		1		<0.032				0.058
Runner beans		1		<0.034				<0.047
Strawberries		1		<0.041				<0.013
Bovine faeces		8		<0.024				1.3
Bovine faeces	max			<0.027				2.1
Grass		8						<0.59
Grass	max							1.5
Silage		4		<0.018				0.32
Silage	max			<0.020				0.70
Soil		4						49
Soil	max				8.5	0.35	8.4	51
Rainwater		75	<1.5					
Rainwater	max		3.0					

** not detected by the method used*

[a] *108 dry cloths were analysed. The alpha, beta and gamma concentrations were 0.17, 0.99 and 0.48 Bq per cloth respectively.*

[b] *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*

[c] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.27, 1.6 and 0.0040 Bq kg^{-1} respectively.*

[d] *The concentration of beta activity was 34 Bq kg^{-1}*

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

Table 4.17(a). Radioactivity in food and the environment near Chapelcross nuclear power station, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Aquatic samples										
Flounder[b]	Inner Solway	3	11	<0.12	<0.10	<0.25	<0.61	<2.0	7.9	<0.75
Plaice	North Solway	4		<0.10	<0.12	<0.19	<0.29	<0.46		<0.59
Salmon	Inner Solway	1	9.8	<0.10	<0.10	<0.12	<0.14	<0.17		<0.33
Sea trout	Inner Solway	1	37	<0.10	0.59	<0.12	<0.19	<0.26		<0.35
Mullet	North Solway	3		<0.10	<0.25	<0.20	<0.57	<0.67		<0.62
Shrimps	Inner Solway	4	8.1	<0.11	<0.11	<0.32	<0.69	<3.1	160	<0.84
Winkles[c]	Southerness	4	<6.3	<0.10	7.0	<0.15	<0.14	<0.20	400	<3.0
Cockles[d]	North Solway	8	<14	<0.08	<2.1	<0.15	<0.25	<0.68	7.6	<0.60
Mussels[e]	North Solway	7	<12	<0.07	0.73	<0.14	<0.15	<0.14	190	<0.76
Seaweed[f]	Pipeline	4		<0.10	<0.61	<0.14	<0.19	<0.25	560	<0.36
Sediment[g]	Pipeline	4	5.7	<0.20	2.2	<0.59	<0.63	<1.2		<3.3
Sediment[h]	Dornoch Brow	3		<0.12	1.9	<0.39	<0.54	<0.75		<2.3
Seawater	Pipeline	3	7.2	<0.10	<0.10	<0.10	<0.10	<0.10		<0.21
Seawater	Southerness	4	8.3	<0.10	<0.10	<0.10	<0.12	<0.13		<0.32
Seawater	North Solway	1	7.8							

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples										
Flounder[b]	Inner Solway	3	<0.14	<0.21	18	<0.11	<0.18	0.0032	0.0049	0.10
Plaice	North Solway	4	<0.11	<0.17	0.95	<0.10	<0.16			<0.11
Salmon	Inner Solway	1	<0.10	<0.10	0.28	<0.10	<0.12			<0.10
Sea trout	Inner Solway	1	<0.10	<0.10	3.0	<0.10	<0.10	<0.0025	<0.0025	<0.0029
Mullet	North Solway	3	<0.11	<0.17	1.6	<0.10	<0.16			<0.11
Shrimps	Inner Solway	4	<0.15	<0.23	4.1	<0.12	<0.21	0.0038	0.019	0.032
Winkles[c]	Southerness	4	<1.3	<0.71	2.6	<0.10	<0.11	0.33	1.6	0.079
Cockles[d]	North Solway	8	<0.10	<0.14	4.1	<0.13	<0.13	0.42	2.3	5.4
Mussels[e]	North Solway	7	<0.10	<0.18	2.8	<0.14	<0.13	0.43	2.2	4.5
Seaweed[f]	Pipeline	4	<0.10	0.37	18	<0.11	<0.15	0.42	0.89	2.6
Sediment[g]	Pipeline	4	<0.42	<0.71	190	<1.2	<1.5	4.8	28	45
Sediment[h]	Dornoch Brow	3	<0.18	<1.0	130	<0.48	<1.0	5.6	30	46
Seawater	Pipeline	3	<0.10	<0.10	<0.25	<0.10	<0.10			<0.10
Seawater	Southerness	4	<0.10	<0.10	0.21	<0.10	<0.10	<0.0015	<0.0062	<0.036
Seawater	North Solway	1								

Table 4.17(a). continued

Material	Location or selection[i]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr
Terrestrial samples										
Milk[j]		12	<62	16	<3.9		<0.10		<0.10	<0.48
Milk[j]	max		160	22	<6.9		<0.52			<0.94
Apples		3	190	25	<0.50		<0.06		<0.10	<0.41
Apples	max		340	36			<0.08			<0.52
Barley		3	550	110	<2.6	<0.14	<0.13	<0.39	<0.16	<0.47
Barley	max		570	140	3.4	<0.15	<0.14	<0.43	0.26	<0.53
Beetroot		1	28	22	<0.50	<0.05	<0.05	<0.16	0.15	<0.20
Blackberries		1	2200	28	<0.59		0.11		1.2	<0.37
Cabbage		4	70	9.3	<2.1	<0.03	<0.04	<0.10	<0.36	<0.12
Cabbage	max		110	13	4.0		<0.05		0.92	<0.16
Carrots		2	<56	15	<0.50	<0.04	<0.07	<0.12	0.30	<0.83
Carrots	max		100						0.37	<1.5
Damsons		1	290	28	<0.50		<0.07		<0.10	<0.51
Ground elder		1	500	25	<1.9		<0.20		0.19	<2.4
Maize		1	58	16	<0.50	<0.06	<0.06	<0.18	<0.10	<0.23
Mallard		1	<5.0	70	3.4		<0.09		0.11	<0.25
Nettles		1	420	20	8.1		<0.14		0.11	<2.0
Onions		2	64	18	<1.6		<0.07		<0.10	<0.52
Onions	max		89	25	<1.8		<0.09			<0.66
Pheasants		1	<5.0	43	8.6		<0.06		<0.10	<0.15
Plums		1	280	14	<0.50		<0.06		<0.10	<0.34
Potatoes		2	65	18	<0.69		<0.06		<0.13	<0.33
Potatoes	max		85	20	0.87		<0.08		0.15	<0.52
Rosehips		1	180	36	4.6		<0.05		<0.10	<0.29
Rhubarb		1	37	12	<0.50		<0.11		0.20	<0.77
Turnips		3	74	16	<1.7		<0.22		0.26	<0.26
Turnips	max		110	22	2.7		<0.72		0.33	<0.31
Widgeon		1	<5.0	28	2.1		<0.05		0.25	<0.13
Wood pigeon		1	8.0	23	4.9		<0.07		<0.10	<0.20
Grass[k]		6	100	29	<4.3	<0.08	<0.06	<0.25	<0.17	<0.22
Grass[k]	max		480	50	15	<0.09	<0.08	<0.27	0.25	<0.29
Soil[l]		6	36	17	<3.1	<0.22	<0.23	<0.66	<0.80	<0.90
Soil[l]	max		130	34	7.3	<0.24	<0.35	<0.74	1.8	<1.5

Table 4.17(a). continued

Material	Location or selection[i]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{241}Am
Terrestrial samples										
Milk[j]		12	<0.91	<0.32	<0.05		<0.05			
Milk[j]	max		<1.2	<0.35			<0.07			
Apples		3	<0.84	<0.64	<0.07		<0.07			
Apples	max		<1.1	<0.81	<0.09					
Barley		3	<0.56	<1.1	<0.13	<0.31	<0.11	<1.3	<0.39	<0.43
Barley	max		<0.64	<1.2	<0.14	<0.33	<0.12	<1.4	<0.43	<0.65
Beetroot		1	<0.26	<0.42	<0.05	<0.11	<0.04	<0.49	<0.14	<0.23
Blackberries		1	<0.78	<0.53	<0.07		<0.05			
Cabbage		4	<0.14	<0.29	<0.04	<0.06	<0.07	<0.30	<0.08	<0.15
Cabbage	max		<0.17	<0.40	<0.05		0.12			
Carrots		2	<0.57	<0.50	<0.07	<0.09	<0.07	<0.37	<0.11	<0.14
Carrots	max		<0.92	<0.66	<0.10		<0.10			<0.18
Damsons		1	<1.1	<0.73	<0.09		<0.07			
Ground elder		1	<7.5	<2.2	<0.28		<0.19			
Maize		1	<0.32	<0.48	<0.06	<0.13	<0.05	<0.55	<0.14	<0.22
Mallard		1	<0.21	<0.83	<0.13		12			
Nettles		1	<7.7	<1.6	<0.20		<0.13			
Onions		2	<1.1	<0.74	<0.09		<0.07			
Onions	max		<1.4	<0.96	<1.2		<0.09			
Pheasants		1	<0.13	<0.48	<0.07		0.61			
Plums		1	<0.60	<0.53	<0.06		<0.05			
Potatoes		2	<0.65	<0.53	<0.07		<0.06			
Potatoes	max		<1.1	<0.75	<0.09		<0.07			
Rosehips		1	<0.57	<0.44	<0.05		<0.05			
Rhubarb		1	<1.7	<1.1	<0.13		<0.09			
Turnips		3	<0.44	<0.47	<0.06		<0.21			
Turnips	max		<0.66	<0.65	<0.07		<0.69			
Widgeon		1	<0.11	<0.41	<0.07		1.2			
Wood pigeon		1	<0.20	<0.65	<0.10		2.3			
Grass[k]		6	<0.29	<0.50	<0.06	<0.17	<0.10	<0.79	<0.22	<0.38
Grass[k]	max		<0.33	<0.71	<0.09	<0.19	0.16	<0.86	<0.24	<0.45
Soil[l]		6	<1.0	<2.1	<0.37	<0.50	11	<1.75	<0.90	<0.82
Soil[l]	max		<1.6	<3.5	<0.54	<0.54	21	<1.9	1.3	<1.3

[a] *Except for seawater and milk where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentrations of ^{14}C and ^{90}Sr were 62 and <0.10 Bq kg^{-1} respectively*
[c] *The concentrations of ^{90}Sr and ^{241}Pu were 0.48 and 11 Bq kg^{-1} respectively*
[d] *The concentrations of ^{14}C, ^{90}Sr, ^{241}Pu and $^{243+244}$Cm were 68, <0.43, 23 and 0.0093 Bq kg^{-1} respectively*
[e] *The concentrations of ^{14}C, ^{241}Pu and $^{243+244}$Cm were 60, 24 and 0.0052 Bq kg^{-1} respectively*
[f] *The concentrations of alpha and beta activity were 39 and 490 Bq kg^{-1} respectively*
[g] *The concentrations of organic ^{3}H, ^{242}Cm and $^{243+244}$Cm were <5.8, <0.00010 and <0.00010 Bq kg^{-1} respectively*
[h] *The concentrations of ^{134}Cs, ^{242}Cm, $^{243+244}$Cm and alpha activities were <0.15, <0.00010, <0.00010 and 68 Bq kg^{-1} respectively*
[i] *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.*
[j] *The concentration of ^{40}K was 48 Bq l^{-1} and the maximum was 52 Bq l^{-1}*
[k] *The concentrations of alpha and beta activities were 5.5 (max 16) and 170 (max 200) Bq kg^{-1} respectively*
[l] *The concentrations of alpha and beta activities were 310 (max 420) and 910 (max 1300) Bq kg^{-1} respectively*

Table 4.17(b). Monitoring of radiation dose rates near Chapelcross, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Southerness	Winkle bed	3	0.057
Glencaple Harbour	Mud and sand	4	0.072
Priestside Bank	Salt marsh	4	0.059
Powfoot Merse	Mud	4	0.071
Pipeline	Sand	4	0.079
Pipeline	Salt marsh	4	0.085
Battlehill	Sand	4	0.077
Dornoch Brow	Mud and sand	4	0.069
Dornoch Brow	Salt marsh	4	0.082
Browhouses	NA	4	0.072
Beta dose rates			µSv h^{-1}
Powfoot	Salt marsh	3	<1.0
Pipeline 500m south	NA	3	<1.0
Pipeline 500m north	NA	3	<1.0
Pipeline	Stake nets	4	<1.0

NA not available

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. Discharges of radioactive waste are largely related to decommissioning and decontamination operations and the nuclear related research that is also undertaken. Tenants such as AEA Technology carry out some of this work. 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. Historically some solid waste was authorised for discharge in a shaft 55 metres deep at Dounreay, but no such discharges have been made since 1977. Solid and liquid waste discharges from Dounreay include a minor contribution from the adjoining reactor site (Vulcan Naval Reactor Test Establishment (NRTE)) which is operated by the Ministry of Defence (Procurement Executive) and the activities of AEA Technology at two facilities on the Dounreay site. Discharges from the Windscale site were negligible compared with Sellafield. Regular monitoring of the environment in relation to Dounreay, Harwell and Winfrith was undertaken and discharges from Windscale were monitored as part of the Sellafield programme. Monitoring around Vulcan (NRTE) and AEA Technology (Dounreay) was carried out as part of the Dounreay programme.

5.1 Dounreay, Highland

Radioactive waste discharges from this establishment are made by UKAEA under an authorisation granted by SEPA. The quantities discharged from Dounreay in 2000 were generally similar to those in 1999. This reflects the shut down of processing activities within the fuel cycle area under a formal direction issued by the Nuclear Installations Inspectorate in May 1998. Monitoring included sampling of grass and soil but the scope was extended in 2000 to include a greater range of terrestrial foods including meat, vegetables and cereals. As there were no dairy herds in the Dounreay area no milk samples were collected. Routine marine monitoring involved sampling of seafood around the Dounreay outfall in the Pentland Firth and other materials from further afield, and beta and gamma dose rate measurements. Seafood samples were also collected under consent granted by the then Scottish Office within the zone covered by the FEPA Order that prohibits the harvesting of seafoods around the pipeline. The results of SEPA's monitoring are presented in Tables 5.1(a) and (b).

During 2000 UKAEA continued vehicle based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. In 2000 six fragments were recovered from Sandside Bay and five from the Dounreay foreshore. Surveys identified 226 fragments on the offshore seabed of which 115 were recovered. The caesium-137 activity measured in the fragments recovered from Sandside Bay range between $4\ 10^4$ and $1.2\ 10^5$ Bq. SEPA and NRPB have conducted an extensive study into the likelihood of an encounter with these fragments, and the consequences that this might have on human health and the environment. Their findings were published in 1998 (SEPA, 1998). As a result SEPA advised the then Scottish Office that the current two kilometre fishing restrictions should remain in force and that greater and speedier effort should be made by UKAEA to find and quantify the extent of contamination in the local marine environment, using the best available methodology and technology. In 2000, SEPA formed an expert advisory group to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments.

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

The first potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a radiation dose to the skin, of the hands and forearms of fishermen, mainly from beta radiation. The critical group is represented by a small number of people who operate a fishery close to Dounreay. Measurements on their fishing gear in 2000 indicated that this pathway was of no radiological significance.

The second potential pathway involves the internal exposure of consumers of locally collected fish and shellfish. Crabs, mussels, winkles and lobsters from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. Concentrations of radionuclides in 2000 were generally similar to those for 1999. Technetium-99 in crabs, molluscs and seaweed remained at levels to be expected at this distance from Sellafield. The estimated dose from consumption of fish and shellfish by high-rate consumers was less than 0.005 mSv that was less than 0.5% of the principal annual dose limit for members of the public of 1 mSv.

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

The fourth potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore. Monitoring of spume at Oigin's Geo indicated similar concentrations of radionuclides to those measured in 1999. Measurements of gamma dose rates above areas of the foreshore remained similar to those for 1999. The radiation dose to the public from these rocky areas was less than 0.005 mSv which was less than 0.5% of the principal annual dose limit for members of the public of 1 mSv.

The results for terrestrial samples are given in Table 5.1(a) and generally show low levels of radioactivity. Low levels of cobalt-60 and europium-155 were found in grass and soil, respectively. The ratio of plutonium isotopes also suggests origins within the nuclear industry. Taking these results together with information on consumption rates, the dose to the most exposed group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.020 mSv which was 2% of the principal annual dose limit for members of the public of 1 mSv.

5.2 Harwell, Oxfordshire

Discharges of radioactive wastes from Harwell continued in 2000 with liquid discharges made under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere. The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish and indicator materials together with measurements of gamma dose rates around the liquid discharge point. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 5.2(a) and (b). Tritium was detected in honey collected near the site but at very low levels. No other radionuclides were found above the limit of detection. The dose to the most exposed group of terrestrial food consumers was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

A minor incident with potential foodchain implications occurred in September 2000. During routine testing of the liquid effluent pipeline, a section failed and water leaked from the pipe onto a ploughed field. No food was growing on the field. The Food Standards Agency was informed and sampling by UKAEA was undertaken. All results were less than 20 Bq kg^{-1} of caesium-137 in soil and at these low levels no contamination of foods grown at the location was expected. No unusual contamination was detected in foods as part of the routine surveillance programme.

Concentrations of some nuclides, notably cobalt-60 and caesium-137, were enhanced close to the outfall for liquid discharges of Sutton Courtenay, but the levels were small in terms of any radiological effect. The concentration of tritium determined in local pike was well above the limit of detection, and higher than the value found at the control location at Newbridge. However, there are other potential sources of tritium in this area as the results for Newbridge indicate. The concentration of caesium-137

in pike decreased in 2000 to 3.0 Bq kg^{-1} (1999: 7.4 Bq kg^{-1}) but this may not be indicative of a more general effect in the environment since concentrations in freshwater fish are known to vary significantly from sample to sample.

Habits surveys have identified anglers as the most exposed group affected by direct discharges into the river. Their occupancy of the river bank has been assessed to estimate their external exposures. Consumption of freshwater fish was not found to occur, but it is considered prudent to include a component in the assessment of the angler's exposure. A consumption rate of 1 kg $year^{-1}$ was selected. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 2000 was 0.013 mSv, which was about 1% of the principal dose limit for members of the public of 1 mSv. The tritium contribution to this dose was substantially less than 0.001 mSv.

5.3 Winfrith, Dorset

Discharges of radioactive wastes from this site continued in 2000 at the low rates typical of recent years following the shutdown of the Steam Generating Heavy Water Reactor (SGHWR) in September 1990. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. At this site the monitoring programme consisted of samples of milk, crops, fruit, seafood and indicator materials.

Data are presented in Table 5.3. Results for terrestrial samples gave little indication of an effect due to gaseous discharges. The most exposed group for gaseous discharges was the 15-year-old age group who were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. Concentrations of radionuclides in the marine environment continued at the low levels attained since closure of the SGHWR. No indication of the effect of discharges 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 2000at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public.

Table 5.1(a). Radioactivity in food and the environment near Dounreay, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Aquatic samples										
Crabs[b]	Pipeline	2	<0.14	<0.13	0.12	<0.49	<0.66	3.6	<1.1	<0.14
Crabs	Inside zone	2	<0.14	<0.12		<1.5	<7.3		<1.0	<0.16
Crabs	Outside zone	4	<0.14	<0.13		<0.95	<3.3		<1.2	<0.15
Crabs	Strathy	3	<0.09	<0.09		<0.19	<0.24		<0.39	<0.09
Crabs	Kinlochbervie	2	<0.10	<0.10		<0.27	<0.42	6.6	<0.54	<0.10
Crabs	Melvich Bay	3	<0.09	<0.09		<0.27	<0.58	<2.4	<0.48	<0.09
Winkles	Brims Ness	4	<0.13	<0.14	<0.10	<0.25	<0.25		<0.98	<0.26
Winkles	Sandside Bay	4	<0.13	<0.18	<0.10	<0.25	<0.24	27	<0.84	<0.29
Mussels	Echnaloch Bay	3	<0.10	<0.14		<0.17	<0.18	54	<0.49	<0.10
Seaweed[c]	Sandside Bay	4	<0.12	<0.13		<0.30	<0.48	280	<0.55	<0.11
Seaweed	Brims Ness	4	<0.10	<0.17		<0.36	<0.39		<0.62	<0.10
Seaweed	Kinlochbervie	3	<0.09	<0.09		<0.43	<0.99	390	<0.53	<0.11
Seaweed	Burwick Pier	3	<0.11	<0.10		<0.53	<1.4	90	<0.60	<0.11
Spume/sediment[d]	Oigins Geo	4	<0.69	12		<2.2	<16		<8.1	<0.70
Sediment[e]	Sandside Bay	4	<0.13	<0.13		<0.67	<2.0		<0.87	<0.16
Sediment	Rennibister	3	<0.14	<0.14		<0.52	<0.80		<1.0	<0.17
Seawater[f]	Sandside Bay	4	<0.10	<0.10		<0.13	<0.12		<0.31	<0.10
Water[g]	Bore hole	4		<15	<200	<15	<15		<16	<15

Material	Location	No. of sampling observ-ations	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
Aquatic samples										
Crabs[b]	Pipeline	2	<0.11	<0.18	<0.59	<0.13	<0.25	0.0055	0.022	0.030
Crabs	Inside zone	2	<0.12	<0.14	<0.66	<0.13	<0.21			<0.13
Crabs	Outside zone	4	<0.12	<0.18	<0.72	<0.14	<0.26			<0.16
Crabs	Strathy	3	<0.08	0.12	<0.25	<0.28	<0.13	0.0031	0.016	0.0068
Crabs	Kinlochbervie	2	<0.10	0.17	<0.35	<0.10	<0.12	0.0093	0.0088	0.012
Crabs	Melvich Bay	3	<0.30	<0.10	<0.31	<0.33	<0.14	0.016	0.014	0.011
Winkles	Brims Ness	4	<0.13	<0.27	<0.52	<0.14	<0.25	0.055	0.19	0.79
Winkles	Sandside Bay	4	<0.12	<0.19	<0.52	<0.14	<0.24	0.020	0.093	0.089
Mussels	Echnaloch Bay	3	<0.10	<0.10	<0.26	<0.10	<0.14	0.042	0.083	0.041
Seaweed[c]	Sandside Bay	4	<0.10	0.40	<0.33	<0.11	<0.17			<0.20
Seaweed	Brims Ness	4	<0.10	0.20	<0.35	<0.11	<0.17			<0.24
Seaweed	Kinlochbervie	3	<0.09	0.44	<0.36	<0.28	<0.16			<0.18
Seaweed	Burwick Pier	3	<0.09	0.20	<0.42	<0.37	<0.19			<0.21
Spume/sediment[d]	Oigins Geo	4	<0.58	25	<4.0	<0.94	<1.6	0.26	1.1	3.2
Sediment[e]	Sandside Bay	4	<0.12	3.3	<0.64	0.76	<0.58	2.3	10	10
Sediment	Rennibister	3	<0.14	12	<0.73	<0.16	<0.70			<0.53
Seawater[f]	Sandside Bay	4	<0.10	<0.08	<0.18	<0.10	<0.10			<0.10
Water[g]	Bore hole	4	<15	<15	<16					<0.62

Table 5.1(a). continued

Material	Location or selection[h]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{90}Sr	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce
Terrestrial samples										
Barley		1	<8.0	0.13	0.40	<1.1	<0.054	<0.11	<0.08	<0.72
Cabbage		1	<12	<0.03	0.56	<0.24	<0.050	<0.03	0.05	<0.15
Nettles		1	<5.3	<0.05	1.5	<0.19	<0.050	<0.05	0.12	<0.13
Potatoes		1	<11	<0.08	<1.0	<0.75	<0.054	<0.08	<0.07	<0.42
Swede		1	<12	<0.05	0.12	<0.35	<0.056	<0.05	0.20	<0.27
Bovine muscle		1	<5.0	<0.05	<0.10	<0.35	<0.055	<0.05	0.29	<0.21
Bovine offal		1	<5.2	<0.05	<0.10	<0.46	<0.05	<0.05	0.26	<0.28
Ovine muscle		1	<5.0	<0.05	<0.10	<0.59	<0.050	<0.05	0.28	<0.36
Grass		6	<5.5	<0.10	<0.24	<0.30	<0.10	<0.05	<0.31	<0.23
Grass	max		<7.4	0.33	0.39	<0.51	<0.19		0.85	<0.40
Soil		6	<5.4	<0.27	0.70	<2.4	<0.14	<0.39	58	<1.7
Soil	max		<6.0	<0.45	1.3	<4.2	<0.17	0.78	150	<2.8

Material	Location or selection[h]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples									
Barley		1	<0.35				0.0088	0.0038	0.0043
Cabbage		1	<0.08				0.0016	0.00091	0.0016
Nettles		1							0.011
Potatoes		1					0.0016	0.0018	0.00081
Swede		1					0.0013	0.00094	0.0015
Bovine muscle		1		<0.20	<0.20	<0.20	<0.25	<0.025	<0.037
Bovine offal		1		<0.050	<0.050	<0.050	<0.00051	<0.00051	<0.025
Ovine muscle		1		<0.31	<0.31	<0.31	<0.026	<0.026	<0.065
Grass		6		<0.12	<0.035	<0.12	0.0074	0.016	0.0067
Grass	max			0.31	<0.050	0.27	0.016	0.067	0.011
Soil		6	1.6	23	0.81	21	0.067	0.31	0.20
Soil	max		1.7	32	1.6	29	0.23	0.60	0.35

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

[b] *The concentration of ^{14}C was 32 Bq kg^{-1}*

[c] *The concentrations of alpha and beta activity were 8.5 and 310 Bq kg^{-1} respectively*

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

[e] *The concentrations of ^{242}Cm and $^{243+244}$Cm were <0.00010 Bq kg^{-1}*

[f] *The concentration of ^{3}H was <1.3 Bq l^{-1}*

[g] *The concentration of ^{14}C was <15 Bq l^{-1}*

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

Table 5.1(b). Monitoring of radiation dose rates near Dounreay, 2000

Location	Material or ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over substrate			
Strathy Park	NA	1	0.067
Strathy Sands	NA	1	0.044
Melvich Sands	NA	1	0.047
Melvich	Salt marsh	1	0.076
Sandside Bay	Winkle bed	5	0.090
Achvarasoal	NA	1	0.075
Oigin's Geo	Spume/sludge	4	0.14
Borrowston Mains	NA	1	0.077
Hallam Farm	NA	1	0.072
Achreregan Hill	NA	1	0.052
Thurso Riverbank	NA	1	0.078
Thurso Park	NA	1	0.071
Castletown Harbour	NA	1	0.063
Beta dose rates			µSv h^{-1}
Sandside Bay	Sediment	3	<1.0
Near pipeline	NA	1	<1.0
Oigin's Geo	Surface sediment	3	<1.0
Brims Ness	Surface sediment	3	<1.0

NA Not available

Table 5.2(a). Radioactivity in food and the environment near Harwell, 2000[e]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{57}Co	^{60}Co	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples									
Pike	Outfall (Sutton Courtenay)	2	150	130	<0.06	<0.09	3.0	<0.20	<0.21
Pike[b]	Newbridge	1	56	50	<0.05	<0.11	<0.09	<0.16	0.0032
Pike	Staines	1	<25	<25	<0.06	<0.11	0.30	<0.16	<0.08
Pike	Shepperton	1	<25	<25	<0.14	<0.17	<0.18	<0.48	<0.66
Pike	Teddington	1	<25	<25	<0.03	<0.06	0.23	<0.09	<0.05
Nuphar lutea	Outfall (Sutton Courtenay)	1		<25	<0.03	<0.05	0.81	<0.11	<0.10
Nuphar lutea	Newbridge	1		<25	<0.03	<0.06	<0.05	<0.08	<0.04
Nuphar lutea	Staines	1		<25	0.07	<0.07	0.12	<0.10	<0.05
Mud	Position 'E' [c]	2			<0.30	4.3	640	<1.9	<2.1

Material	Location or selection[d]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			Organic ^{3}H	^{3}H	^{60}Co	^{134}Cs	^{137}Cs
Terrestial samples							
Milk	Near farms	4	<4.1	<4.1	<0.24	<0.24	<0.26
Milk	Near farms max		<4.3	<4.3	<0.25	<0.25	<0.30
Apples		1	<5.0	5.0	<0.30	<0.20	<0.20
Blackberries		1	1.0	3.0	<0.30	<0.30	<0.30
Honey		1		<7.0	<0.30	<0.30	<0.30
Lettuce		1	<4.0	<4.0	<0.40	<0.30	<0.30
Potatoes		1	<5.0	5.0	<0.40	<0.30	<0.40
Runner beans		1	5.0	7.0	<0.40	<0.30	<0.30

[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] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00030 and 0.0014 Bq kg^{-1} respectively*

[c] *Near the outfall*

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

[e] *95 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.16, 0.99 and 0.57 Bq per cloth respectively*

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1m over river bank			
Position "E"[a]	Soil	2	0.083

[a] *near the outfall*

Table 5.3. Radioactivity in food and the environment near Winfrith, 2000[c]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Aquatic samples										
Cod	Weymouth Bay	2	<0.05	<0.15		0.32			<0.08	
Plaice	Weymouth Bay	2	<0.05	<0.15		0.10			<0.14	
Crabs	Chapman's Pool	1	0.68	<0.13		<0.05	0.00040	0.0017	0.0031	*
Pacific Oysters	Poole	1	0.06	<0.06		<0.02			<0.06	
Cockles	Poole	1	0.80	<0.12		0.08			<0.23	
Whelks	Weymouth Bay	1	0.23	<0.12		<0.04			<0.05	
Whelks	Poole	1	0.42	<0.18		<0.06	0.0029	0.010	0.0024	0.000024
Fucus serratus[d]	Kimmeridge	2	1.2	<0.13	1.7	<0.10			<0.09	
Fucus serratus	Bognor Rock	2	0.66	<0.14	5.3	0.14			<0.17	

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}			
			Organic ^{3}H	^{3}H	^{60}Co	^{137}Cs
Terrestial samples						
Milk	Near farms	4	<4.3	<4.3	<0.30	<0.29
Milk	Near farms max		<5.3	<5.3	<0.33	<0.30
Apples		1	<4.0	<4.0	<0.30	<0.20
Cabbage		1	7.0	10	<0.30	<0.30
Carrots		1	<4.0	<4.0	<0.30	<0.40
Honey		1		<7.0	<0.30	0.50
Potatoes		1	<4.0	<4.0	<0.40	<0.30
Raspberries		1	<4.0	<4.0	<0.20	<0.20

** Not detected by the method used*

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

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

[c] *60 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.12, 0.70 and 0.26 Bq per cloth respectively*

[d] *The concentration of beta activity was 220 Bq kg^{-1}*

6. NUCLEAR POWER STATIONS OPERATED BY ELECTRICITY GENERATING COMPANIES

This Section considers the effects of discharges from 12 locations where nuclear power stations were operating or undergoing decommissioning during 2000. For consistency with previous reports in this series, they are grouped here under the general description 'electricity companies'. The companies in question were British Energy Generation Ltd., British Energy Generation (UK) Ltd. and Magnox Electric (a wholly owned subsidiary of BNFL plc.) The ownership of each power station is given in Appendix 1. Other BNFL sites are considered in Section 4.

6.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley Power Station ceased electricity generation in March 1989, but radioactive wastes have been and are still generated by decommissioning operations. In addition there is a component of the discharge by operation of the adjoining Berkeley Centre. The Oldbury Power Station has continued operation and because the effects of both sites are on the same area, Berkeley and Oldbury are considered together for the purposes of environmental monitoring. Liquid radioactive wastes are discharged to the Severn estuary.

Habits surveys have established that the two potentially critical pathways for public radiation exposure in the aquatic environment are internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of fish and shellfish are analysed and gamma dose rates are monitored. Measurements of tritium in seafood were introduced in 1998 for surveillance of the local effects of discharges from a radiopharmaceutical plant in Cardiff (see Section 8). In addition, measurements of external exposure are supported by analyses of intertidal mud. The 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 2000 are presented in Tables 6.1(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were similar to those in recent years. Unfortunately shrimp samples, which are good indicators of local sources, were not available in 2000 since fishing in the estuary was poor. Most of the artificial radioactivity detected was due to radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the most exposed group of fish and shellfish consumers including external radiation was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. This dose includes an estimate of the concentrations of radionuclides that would have been present in samples of shrimps.

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

6.2 Bradwell, Essex

This power station, powered by Magnox reactors, is authorised to discharge gaseous wastes to the local environment and liquid wastes to the estuary of the River Blackwater. Magnox Electric is planning to close the station on 31 March 2002 after 40 years of operation. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples for tritium, carbon-14 and sulphur-35. Aquatic sampling was directed at consumption of locally caught fish and shellfish. External exposure of people who live on houseboats in muddy areas of the estuary is no longer studied by the Food Standards Agency. Surveillance included the commercial oyster fishery of importance in the northern part of the

estuary. *Fucus vesiculosus* was analysed as an indicator material and samphire and leaf beet were collected because they are plants which are eaten locally and grow in areas which become tidally inundated.

Measurements for 2000 are summarised in Table 6.2. Low concentrations of artificial radioactivity were detected in aquatic materials due to the combined effects of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were similar to those for 1999. The technetium-99 detected in *Fucus vesiculosus* at Waterside was due to the long distance transfer of Sellafield derived activity. The most exposed group of seafood consumers received less than 0.005 mSv, excluding the effects of external exposure, which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication that carbon-14 levels had been enhanced by the operation of the power station. Low concentrations of sulphur-35 were also detected in some samples. The most exposed group dose was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv, confirming that the radiological impact of authorised discharges 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). Discharges 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 analysis of dry cloths. Marine monitoring included gamma and beta dose rate measurements in Rye Harbour and analysis of seafood and indicator materials.

The results for 2000 are given in Tables 6.3(a) and (b). Concentrations of radiocaesium in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield. Apportionment is difficult at these low levels. Trace levels of cobalt-60 in some marine materials are likely to be due to the combined effects of disposals from the site and from other sites on the English Channel coast. The small concentrations of transuranics in whelks and mud were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma and beta dose rates were difficult to distinguish from the natural background. The most exposed group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.005 mSv which was 0.5% of the principal dose limit for members of the public of 1 mSv.

Activity concentrations in many terrestrial foods were close to the limits of detection. Levels of carbon-14 were generally within the range of activity concentrations observed for background, however some enhancements were observed particularly in field peas used for animal fodder. Low concentrations of sulphur-35 and caesium-137 were detected in some samples; the former is due to station disposals, but the latter is likely to have contributions from other sources, e.g. weapon test and Chernobyl fallout. The maximum dose due to gaseous disposals was received by adults. Their dose in 2000 was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public.

6.4 Hartlepool, Cleveland

This station is powered by twin AGRs. A 1998 habits survey examined the potential pathways for radiation exposure due to liquid effluent disposals. This established that exposures could be represented by consumption of local fish and shellfish and external radiation whilst digging for bait. The Food Standards Agency aquatic sampling and measurement programme accounts for the seafood pathway and

the Environment Agency undertakes measurements of external radiation on beaches. However, technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield. A selection of terrestrial foods including milk is sampled in surveillance of gaseous disposals.

Results of the monitoring programme carried out in 2000 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 2000 was 0.007 mSv which was 0.7% of the principal dose limit for members of the public of 1 mSv.

Although observed in the past, high levels of tritium in seawater were not observed in 2000. However, the level of tritium associated with organic material in winkles was unexpectedly high at about 100 Bq kg^{-1} (wet). This situation is not unique to the Hartlepool area and is the subject of a research project funded by Food Standards Agency*. Levels of technetium-99 in *Fucus vesiculosus* decreased further this year (44 Bq kg^{-1}: 2000; 58 Bq kg^{-1}: 1999; 110 Bq kg^{-1}: 1998). This trend is likely to continue as discharges from Sellafield are expected to decrease. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. The enhanced dose rates at Paddy's Hole may be due to waste slag from a local steel works which can be found containing enhanced levels of gamma-ray-emitting natural radionuclides. The radiation dose to the most exposed group of local fish and shellfish consumers, excluding external radiation, was low, at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

6.5 Heysham, Lancashire

This establishment comprises two separate nuclear power stations both powered by AGRs. Disposals of radioactive waste from both stations are made under authorisation via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. That for liquid disposals was also similar, including sampling of fish, shellfish and indicator materials and measurements of gamma dose rates, but for completeness the data considered in this Section includes all of that for Morecambe Bay. Parts of the programme are therefore in place in order to monitor the effects of Sellafield disposals. Samphire is also collected and analysed because of its use as a foodstuff.

The results for 2000 are given in Tables 6.5(a) and (b). In general, similar levels to those for 1999 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Levels of tritium in plaice and mussels may have been partially due to site discharges. Concentrations of technetium-99 in marine samples remained at the higher levels typical of recent years. They were caused by discharges from Sellafield. The radiation dose in 2000 to the most exposed group of fishermen including a component due to external radiation was 0.066 mSv that is well within the principal dose limit for members of the public of 1 mSv. There was little change from the estimate for 1999 of 0.071 mSv (Food Standards Agency and SEPA, 2000). Most of this exposure was due to the effects of disposals from Sellafield. Concentrations of radioactivity in samphire were of negligible radiological significance.

The effects of gaseous disposals were also difficult to detect in 2000. Small enhancements of concentrations of carbon-14 were apparent in some samples. The most exposed group dose was estimated to be 0.005 mSv which was 0.5% of the principal dose limit for members of the public of 1 mSv.

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* *Study of tritium and carbon-14 in the aquatic environment: RO3014*

6.6 Hinkley Point, Somerset

At this establishment there are two separate 'A' and 'B' nuclear power stations; the 'A' station comprises Magnox reactors and the 'B' station AGRs. Magnox Electric stopped generating electricity at Hinkley Point 'A' in May 2000 and the station is now undergoing defuelling. Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the Nycomed Amersham plant at Cardiff.

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

The environmental results for 2000 are presented in Tables 6.6 (a) and (b). The concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in 1999. Further information of tritium levels in seawater from the Bristol Channel is given in Section 11. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, weapons test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from Nycomed Amersham, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were difficult to distinguish from the natural background. The most exposed group from liquid disposals from the site was reassessed in 2000 using the results of a recent local habit survey. Consumption rates of seafood and occupancy rates over intertidal areas were updated with new information. The most exposed group of local fishermen were estimated to receive a dose of 0.012 mSv which was around 1% of the principal dose limit for members of the public of 1 mSv. This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff but excludes the effects of direct radiation from the site.

Results for 2000 indicate a small enhancement of radioactivity levels due to disposals of gaseous wastes. Activity concentrations of tritium and gamma emitters in terrestrial materials were all below or close to the limits of detection. Concentrations of sulphur-35 showed the effects of the power stations and some of the concentrations of carbon-14 were higher than the default values used to represent background levels (Appendix 6). The differences between reported discharges and actual discharges of carbon-14 in previous years were insufficient to expect significant differences in carbon-14 levels in food samples to be apparent. The estimated most exposed group dose due to radioactivity in the terrestrial environment was less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

6.7 Hunterston, North Ayrshire

At this establishment there are two separate nuclear power stations - Hunterston 'A' and Hunterston 'B'. Hunterston 'A' was powered by twin Magnox reactors and Hunterston 'B' is powered by a pair of AGRs. Hunterston 'A' ceased power production at the end of March 1990. Hunterston A was granted new authorisations by SEPA for gaseous and liquid discharges in August 2000 related to activities associated with decommissioning of the site.

Liquid discharges are made to the Firth of Clyde from Hunterston 'A' and Hunterston 'B' at a common point under the current authorisations granted by SEPA. Gaseous discharges are made separately from the Hunterston 'A' and Hunterston 'B' stations.

Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as indicator materials. The scope of the terrestrial monitoring programme was enhanced during the year and now includes the analysis of a comprehensive range of wild and locally produced foods. In addition, grass and soil are sampled to provide background information.

The results of monitoring in 2000 are shown in Tables 6.7(a) and (b). The concentrations of artificial radioactivity in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. Small concentrations of tritium and activation products such as manganese-54 that are likely to have originated from the site were detected. However, these were of negligible radiological significance. In 2000, the dose to the critical group from external radiation and consumption of fish and shellfish was 0.009 mSv, which was less than 1% of the principal dose limit for members of the public of 1 mSv.

The concentrations of radionuclides in milk, vegetables and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. The radiation dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was estimated to be 0.026 mSv which was less than 3% of the principal dose limit for members of the public of 1 mSv.

6.8 Sizewell, Suffolk

At this establishment there are two stations. The 'A' station is powered by Magnox reactors whilst the 'B' station is powered by a Pressurised Water Reactor (PWR). The 'B' station began operation in 1995. Authorised discharges 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 2000 are shown in Tables 6.8 (a) and (b).

In the aquatic programme, analysis of seafood and indicator materials and measurements of gamma dose rates in intertidal areas were undertaken. Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium levels in seafood were low. In 2000, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. Measured gamma dose rates were indistinguishable from the natural background except near the power station when direct radiation had an effect. The above assessment includes a contribution for external exposure based on a calculation using radionuclide concentrations in sediment.

Gamma spectrometry and analysis of tritium, carbon-14, sulphur-35, strontium-90 and actinides in milk, crops and fruit showed very low levels of artificial radioactivity near the power stations in 2000. Trace quantities of sulphur-35 were detected in some samples. The estimated dose to the most exposed group of consumers eating such foods was less than 0.008 mSv which was less than 0.8% of the principal dose limit for members of the public of 1 mSv.

Two non-routine surveys were undertaken in the vicinity of Sizewell in 2000. The first took place in October when the Food Standards Agency was informed that a higher than normal release of iodine-131 had taken place during routine maintenance of Sizewell 'B'. Grass and milk samples were obtained and one sample of grass was found to contain a small amount of activity, 2.2 Bq kg^{-1} (wet) iodine-131. Contemporary milk samples were at or below the limit of detection of about 1 Bq l^{-1}. An assessment showed that, based on a worse case scenario, the theoretical levels of iodine-131 in food produced close to the site would have been less than 5% of the relevant European intervention level of 500 Bq l^{-1} milk.

The second survey also took place in October following an unplanned release of water containing radioactivity into the North Sea from Sizewell 'B'. The incident occurred after water containing radioactivity entered the site's drainage system. The Food Standards Agency arranged for immediate beach surveillance to be carried out and found there was no measurable increase in the radiation levels normally found. The radioactivity released was estimated to be 2-10 GBq of 'activity other than tritium'; the annual limit is 200 GBq (Food Standards Agency, 2000b).

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 was enhanced in 2000, following SEPA's review of monitoring, to include sampling of milk, vegetables, fruit and seafood, and samples of seawater, seaweed, soil and various plants were monitored as indicator materials. Measurements are also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

The results of this monitoring in 2000 are shown in Tables 6.9(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace levels of activation products such as manganese-54 were detected which were likely to have originated from the station. The dose to fish and shellfish consumers (the most exposed group) was less than 0.005 mSv, which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

Beta radiation from fishermen's nets and pots was below the limit of detection. The effects of discharges from the power station were seen in low levels of tritium and sulphur-35 in terrestrial foods and indicator materials. The dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.018 mSv**,** which was less than 2% of the principal dose limit for members of the public of 1 mSv.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned. Low level discharges continued during 2000 under authorisations granted by the Environment Agency. Discharges of liquid radioactive waste were made to a freshwater lake making the power station unique in United Kingdom terms. Monitoring is carried out on behalf of the National Assembly for Wales and the Food Standards Agency. The aquatic monitoring programme is directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. Habits surveys have established that species of fish regularly consumed are brown trout, rainbow trout and a small amount of perch. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than those of indigenous fish.

The results of the terrestrial programme, including those for local milk, crops and indicator materials, as well as the aquatics programme, are shown in Tables 6.10 (a) and (b). Concentrations of activity in all terrestrial foods were low. Sulphur-35 was detected in potatoes and chicken but at levels similar to that in the regional diet. The most likely source of radiocaesium in hazelnuts is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. Detected activities were low, and similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was therefore no evidence of resuspension of activity in sediment from the lakeshore contributing to increased exposure from transuranic radionuclides in 2000.

The most exposed group for terrestrial foods at Trawsfynydd in 2000 received doses of less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv. This assessed dose includes a contribution from the radiocaesium activity detailed above.

In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where the possible exposure pathway to anglers is an issue were only slightly enhanced above background and were similar to those in 1999.

The concentrations of caesium-137 in lake water remained above those expected in catchment water coming into the lake. Concentrations of radiocaesium in fish in 2000 were unchanged. The sediment activities and the residual activity in the fish that result from earlier discharges predominate at this stage. The dose to the most exposed group of anglers was 0.028 mSv in 2000, which was about 3% of the principal dose limit for members of the public of 1 mSv.

6.11 Wylfa, Isle of Anglesey

This station is powered by Magnox reactors. Gaseous and liquid wastes from this station were discharged in 2000 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is carried out on behalf of the National Assembly for Wales and the Food Standards Agency. Such discharges and effects are very low.

The results of the programme in 2000 are given in Tables 6.11 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges though trace levels of activation products were likely to have been due to discharges from the station. The concentrations were generally similar to those for 1999, 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 which was 1% of the principal dose limit for members of the public of 1 mSv. Gamma dose rates, measured using portable instruments, continued to be difficult to distinguish from the natural background.

The dose received by high-rate food consumers remained low at less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public.

Table 6.1(a). Radioactivity in food and the environment near Berkeley and Oldbury nuclear power stations, 2000[d]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples								
Salmon	Beachley	1	<25	46	<0.07	0.27	<0.18	<0.17
Elvers	Littleton Warth	1	<25		<0.09	0.16	<0.15	<0.08
Mud	Hill Flats	2			0.75	25	<2.4	<1.5
Mud	1 km south of Oldbury	2			<0.51	25	<1.7	<1.3

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs
Terrestrial samples							
Milk	Near farms	7	<4.0	17	<0.62	<0.25	<0.28
Milk	Near farms max		<4.3	22	<0.80	<0.28	<0.33
Milk	Far farms	1	<4.0	18	<0.53	<0.25	<0.30
Apples		1	<4.0	18	0.70	<0.20	<0.30
Blackberries		1	<5.0	20	1.0	<0.20	<0.20
Cabbage[c]		1	4.0	<2.0	<0.40	<0.40	<0.40
Carrots		1	<4.0	4.0	<0.50	<0.40	<0.40
Honey		1	8.0	80	<0.60	<0.30	<0.30
Potatoes		1	<4.0	11	<0.60	<0.30	<0.30
Runner beans		1	<4.0	11	0.70	<0.30	<0.30
Wheat		1	<6.0	72	1.8	<0.30	<0.30

[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] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*
[d] *162 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.17, 0.90 and 0.39 Bq per cloth respectively*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
1km south of Oldbury	Mud	2	0.071
2km south west of Berkeley	Mud	2	0.067
Hills Flats	Mud	2	0.067

Table 6.2. Radioactivity in food and the environment near Bradwell nuclear power station, 2000[e]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{14}C	^{60}Co	^{65}Zn	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Aquatic samples												
Sole	Bradwell	2		<0.10	<0.28	<0.11	0.56	<0.20			<0.22	
Bass	Pipeline	1		<0.06	<0.20	0.14	0.97	<0.18			<0.25	
Mullet	Pipeline	1		<0.07	<0.21	0.31	2.2	<0.14			<0.16	
Native oysters	Tollesbury N. Channel	1	15	<0.03	0.24	0.09	0.36	<0.10	0.0018	0.0087	0.016	0.00033
Pacific oysters	Goldhanger Creek	2		<0.07	<0.25	<0.08	0.32	<0.15			<0.15	
Winkles	Pipeline	2		<0.17	<0.39	<0.16	0.97	<0.32			<0.37	
Winkles	Heybridge Basin	2		<0.18	<0.42	<0.18	1.1	<0.31			<0.23	
Fucus vesiculosus[b]	Waterside	2		<0.15	<0.16	0.41	2.5	<0.19			<0.06	
Leaf Beet	Tollesbury	1		<0.06	<0.13	<0.06	<0.05	<0.13			<0.12	
Samphire	Tollesbury	1		<0.06	<0.12	<0.06	0.35	<0.10			<0.11	

Material	Location or selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs
Terrestrial Samples								
Milk	Near farms	5	<4.0	17	<0.44	<0.29	<0.26	<0.28
Milk	Near farms max		4.0	21	<0.58	<0.33	<0.30	<0.33
Milk	Far farms	2	<4.0	20	<0.58	<0.26	<0.24	<0.29
Milk	Far farms max			24	<0.78	<0.28	<0.25	<0.30
Apples		1	<4.0	5.0	<0.20	<0.50	<0.40	<0.50
Cabbage[d]		1	<4.0	6.0	<0.40	<0.60	<0.40	<0.50
Carrots		1	<4.0	7.0	<0.20	<0.30	<0.30	<0.30
Potatoes		1	<4.0	7.0	<0.50	<0.30	<0.30	<0.30
Raspberries		1	<4.0	11	0.20	<0.30	<0.20	<0.30
Wheat		1	6.0	98	1.0	<0.20	<0.20	<0.20
Lucerne		1	6.0	35	1.4	<0.50	<0.40	<0.50

[a] *Except for milk units are Bq l^{-1} and for dry cloths where units are Bq per cloth*
[b] *The concentration of beta activity and ^{99}Tc were 210 and 13 Bq kg^{-1} respectively*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[d] *The concentration of ^{55}Fe was 1.5 Bq kg^{-1}*
[e] *114 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.18, 1.1 and 0.63 Bq per cloth respectively*

Table 6.3(a). Radioactivity in food and the environment near Dungeness nuclear power stations, 2000[g]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Aquatic samples												
Plaice	Pipeline	2	<25	<0.05		0.12	<0.11			<0.12		
Cod	Pipeline	2	<25	<0.11		0.23	<0.23			<0.28		
Bass	Pipeline	1	<25	<0.11		0.24	<0.17			<0.09		
Crabs	Hastings	1		0.12		0.06	<0.15			<0.14		
Shrimps[b]	Pipeline	2		<0.07		0.16	<0.14			<0.10		
Whelks[c]	Pipeline	2		<0.10		<0.11	<0.22	0.00065	0.0027	0.0023	0.00025	0.00017
Cuttlefish	Hastings	1		<0.03		0.02	<0.06			<0.04		
Fucus vesiculosus	Copt Point	2			4.9							
Mud & sand	Rye Harbour	2		2.0		1.6	1.8	0.17	4.5	1.1	*	0.059
Sea water	Pipeline	2	1.7									

Material	Location or selection[d]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs
Terrestrial Samples								
Milk[e]	Far Farms	2	<4.3	12	<0.50	<0.26	<0.23	<0.26
Milk[e]	Far Farms max		<4.5	14		<0.30		<0.28
Blackberries		1	<4.0	17	1.9	<0.30	<0.20	<0.30
Field beans		1	<7.0	67	1.7	<0.30	<0.30	<0.30
Honey		1	11	110	<0.40	<0.30	<0.30	<0.30
Peas		1	<6.0	83	1.6	<0.30	<0.30	<0.30
Potatoes		1	<4.0	18	0.70	<0.30	<0.30	<0.30
Sea kale[f]		1	<4.0	5.0	<0.60	<0.40	<0.30	0.50

** 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] *The concentration of ^{14}C was 33 Bq kg^{-1}*

[c] *The concentration of ^{90}Sr was <0.057 Bq kg^{-1}*

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

[e] *There are no "near" farms producing milk near this site in programme.*

[f] *The concentration of ^{55}Fe was <0.90 Bq kg^{-1}*

[g] *96 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.27, 1.3 and 0.54 Bq per cloth respectively*

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose at 1m over intertidal areas			
Rye Harbour	Mud and sand	2	0.062
Beta dose rates			µSv h^{-1}
Rye Harbour	Mud and sand	2	0.089

Table 6.4(a). Radioactivity in food and the environment near Hartlepool nuclear power station, 2000[e]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples													
Plaice	Pipeline	2	<25	<25	36	<0.05		0.35			<0.11		
Cod	Pipeline	2				<0.04		0.46			<0.17		
Crabs	Pipeline	2			40	<0.05		<0.09	0.00036	0.0023	0.0018	*	
Winkles	Paddy's Hole	2	95	110		<0.07		0.44	0.010	0.062	0.029	0.0011	
Fucus vesiculosus	Pilot Station	2				<0.05	44	0.19			<0.21		240
Sea water	Pipeline	2		3.1									

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs
Terrestrial samples							
Milk	Far Farms[c]	6	<5.2	19	<0.58	<0.31	<0.27
Milk	Far Farms[c] max		10	27	1.0	<0.60	<0.40
Apples		1	<4.0	6.0	<0.20	<0.30	<0.20
Blackberries		1	<4.0	27	<0.30	<0.30	<0.30
Cabbage[d]		1	<4.0	4.0	<0.60	<0.20	<0.30
Carrots/Swedes		1	5.0	6.0	<0.30	<0.20	<0.30
Green Beans		1	5.0	23	<0.30	<0.30	<0.30
Honey		1	<6.0	63	<0.40	<0.20	<0.30
Potatoes		1	<5.0	23	<0.30	<0.30	<0.30
Wheat		1	7.0	84	1.5	<0.30	<0.30

** not detected by the method used*

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

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

[c] *There are no "near" farms producing milk near this site in the programme*

[d] *The concentration of ^{55}Fe was <0.90 Bq kg^{-1}*

[e] *96 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.26, 1.2 and 0.77 Bq per cloth respectively*

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Paddy's Hole	Winkle bed	2	0.21

Table 6.5(a). Radioactivity in food and the environment near Heysham nuclear power stations, 2000[a]

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples													
Flounder	Flookburgh	4		57		<0.11			<1.0	<0.19	<0.27	<0.11	14
Plaice[d]	Morecambe	4	52			<0.09	0.039	12	<0.81	<0.17	<0.20	<0.08	6.3
Bass	Morecambe	2				<0.10			<1.0	<0.19	<0.28	<0.11	15
Whitebait	Sunderland Point	1				<0.07	0.17		<0.54	<0.11	<0.15	<0.06	6.9
Shrimps	Flookburgh	4		75		<0.10		4.7	<0.48	<0.09	<0.13	<0.05	6.1
Cockles[e]	Middleton Sands	2				4.4			<0.61	<0.13	<0.16	<0.07	3.9
Cockles	Flookburgh	4		87		3.8	0.31	74	<0.70	<0.13	<0.18	<0.07	4.5
Winkles	Red Nab Point	4				1.6			<1.0	<0.18	<0.38	<0.08	4.7
Mussels[f]	Morecambe	4	75	70		0.89		150	<0.94	<0.11	<0.23	<0.06	3.5
Fucus vesiculosus[g]	Half Moon Bay	4				1.3		2900	<0.58	<0.12	<0.40	<0.07	5.9
Samphire[h]	Cockerham Marsh	1				<0.08			<0.60	<0.12	<0.13	<0.07	0.57
Mud and sand	Flookburgh	4				<1.9			<4.2	<0.69	<1.3	<0.46	110
Mud and sand	Half Moon Bay	4				6.9			<5.9	<0.92	<2.6	<0.67	150
Mud and sand	Morecambe Central Pier	4				2.6			<4.8	<0.78	<1.5	<0.57	120
Turf	Conder Green	4				3.6			<7.5	<1.1	<2.6	<0.82	260
Turf	Sand Gate Marsh	4				1.3			<6.0	<0.88	<2.1	<0.60	270
Sea water	Pipeline	2	21										
Sea water	Half Moon Bay	1										0.002	0.22
Terrestrial samples													
Milk	Near farms	6	<4.0	17	<0.54	<0.27			<1.9	<0.26		<0.25	<0.27
Milk	Near farms max		<4.3	21	<0.65	<0.30			<2.1	<0.30		<0.28	<0.28
Apples		1	5.0	14	<0.50	<0.30			<2.3	<0.30		<0.30	<0.30
Barley		1	<7.0	86	1.4	<0.50			<2.8	<0.30		<0.30	<0.40
Cabbage[i]		1	<4.0	<2.0	0.30	<0.40			<2.7	<0.30		<0.30	<0.40
Damsons		1	3.0	23	1.7	<0.30			<2.5	<0.30		<0.30	<0.30
Honey		1	<7.0	86	2.5	<0.30			<2.4	<0.30		<0.30	<0.30
Potatoes		1	5.0	7.0	<0.20	<0.30			<3.3	<0.30		<0.40	<0.40
Sprouts		1	<4.0	24	<0.60	<0.40			<2.1	<0.30		<0.30	0.90
Swede		1	<5.0	9.0	<0.50	<0.40			<1.4	<0.20		<0.30	<0.30

Table 6.5(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Aquatic samples										
Flounder	Flookburgh	4	<0.32	<0.21	0.00031	0.0017		0.0034	*	0.000023
Plaice[d]	Morecambe	4	<0.26	<0.16				<0.11		
Bass	Morecambe	2	<0.32	<0.23				<0.27		
Whitebait	Sunderland Point	1	<0.18	<0.18	0.058	0.33	3.3	0.51	0.0025	0.0010
Shrimps	Flookburgh	4	<0.15	<0.13	0.0048	0.027	0.52	0.04	*	0.00011
Cockles[e]	Middleton Sands	2	<0.18	<0.14	0.36	2.0		5.3	*	0.012
Cockles	Flookburgh	4	<0.18	<0.15	0.42	2.3	22	6.1	*	0.011
Winkles	Red Nab Point	4	<0.21	<0.18	0.27	1.4		2.7	*	0.0019
Mussels[f]	Morecambe	4	<0.16	<0.14	0.27	1.5		2.6	*	0.0029
Fucus vesiculosus[g]	Half Moon Bay	4	<0.21	<0.17				0.72		
Samphire[h]	Cockerham Marsh	1	<0.18	<0.10				0.32		
Mud and sand	Flookburgh	4	<1.2	<1.4				63		
Mud and sand	Half Moon Bay	4	<1.7	<1.9	11	60		100	*	*
Mud and sand	Morecambe Central Pier	4	<1.3	<2.1				69		
Turf	Conder Green	4	<2.0	<2.7				150		
Turf	Sand Gate Marsh	4	<1.6	<2.1				120		
Sea water	Pipeline	2								
Sea water	Half Moon Bay	1								

** Not detected by the method used*

[a] *81 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.12, 0.61 and 0.27 Bq per cloth respectively*

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

[c] *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*

[d] *The concentration of organic ^{3}H was 26 Bq kg^{-1}*

[e] *The concentration of beta activity was 77 Bq kg^{-1}*

[f] *The concentration of organic ^{3}H was 56 Bq kg^{-1}*

[g] *The concentration of beta activity was 2300 Bq kg^{-1}*

[h] *The concentration of beta activity was 21 Bq kg^{-1}*

[i] *The concentration of ^{55}Fe was 0.80 Bq kg^{-1}*

Table 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Sand Gate Marsh	Salt marsh	4	0.096
High Foulshaw	Salt marsh	4	0.089
Arnside	Salt marsh	4	0.099
Morecambe Central Pier	Mussel bed	4	0.076
Morecambe Central Pier	Mud and sand	4	0.077
Half Moon Bay	Mud and sand	4	0.076
Colloway Marsh	Salt marsh	4	0.15
Aldcliffe Marsh	Salt marsh	4	0.11
Conder Green	Mud and sand	4	0.093
Conder Green	Salt marsh	4	0.11
Cockerham Marsh	Salt marsh	4	0.11

Table 6.6(a). Radioactivity in food and the environment near Hinkley Point nuclear power stations, 2000[d]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu
Aquatic samples									
Flounder	Stolford	2		99	<0.06	<0.07	<0.07	0.74	<0.11
Shrimps	Stolford	2	1300	92	<0.12	<0.11	<0.26	1.0	<0.28
Fucus vesiculosus	Pipeline	2			<0.57	<0.25	0.55	2.6	<0.16
Mud	1.6 km east of pipeline	2			<0.58	<0.52	<2.3	27	<1.5
Mud and sand	River Parrett	2			<0.49	<0.44	1.7	32	1.8
Sea water	Pipeline	2	8.2						

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples								
Flounder	Stolford	2			<0.08			
Shrimps	Stolford	2	0.00051	0.0024	0.0016	0.00014	0.000058	
Fucus vesiculosus	Pipeline	2			<0.13			210
Mud	1.6 km east of pipeline	2			<2.0			
Mud and sand	River Parrett	2			1.4			

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs
Terrestrial samples								
Milk	Near farms	6	<4.0	19	<0.52	<0.29	<0.26	<0.28
Milk	Near farms max		<4.3	21	<0.70	<0.30	<0.30	<0.30
Milk	Far Farms	1	<4.0	23	<0.43	<0.38	<0.30	<0.28
Apples		1	<5.0	12	0.40	<0.30	<0.30	<0.30
Blackberries		1	<4.0	24	<0.40	<0.20	<0.30	<0.30
Honey		1	<6.0	100	<0.40	<0.20	<0.30	0.30
Leafy green veg[c]		1	<4.0	<2.0	2.5	<0.50	<0.40	<0.40
Potatoes		1	<4.0	25	1.3	<0.40	<0.30	<0.30
Runner beans		1	<4.0	<2.0	0.60	<0.20	<0.30	<0.30
Wheat		1	<6.0	86	1.5	<0.30	<0.30	<0.30
Fodder beet		1	<4.0	9.0	0.70	<0.30	<0.30	<0.30

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

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

[d] *108 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.17, 0.96 and 0.62 Bq per cloth respectively*

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Brean Beach	Sand	1	0.053
Berrow Beach	Sand	1	0.057
Burnham Beach	Mud and sand	1	0.068
River Parrett	Mud and sand	2	0.071
Black Rock	Mud	1	0.073

Table 6.7(a). Radioactivity in food and the environment near Hunterston nuclear power station, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{54}Mn	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{110m}Ag	^{137}Cs	^{144}Ce	^{155}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples														
Cod	Millport	2	<0.10	<0.10	<0.16	<0.34		<0.11	2.0	<0.26	<0.12			<0.10
Hake	Millport	2	<0.10	<0.10	<0.21	<2.4		<0.11	3.2	<0.38	<0.15			<0.11
Crabs[b]	Millport	2	<0.10	<0.10	<0.16	<0.17	9.1	<0.10	0.44	<0.32	<0.14	0.0040	0.025	0.040
Nephrops	Millport	2	<0.10	<0.10	<0.13	<0.12	5.7	<0.10	1.4	<0.20	<0.12			<0.10
Lobsters	Largs	1	<0.09	<0.08	<0.27	<1.1	280	<0.14	0.57	<0.46	<0.20			<0.32
Squat lobsters	Largs	4	<0.10	<0.10	<0.17	<0.23	<1.6	<0.10	0.55	<0.34	<0.17	0.0092	0.037	0.016
Oysters	Fairlie	1	<0.10	<0.10	<0.22	<1.7		0.22	0.39	<0.37	<0.13			<0.10
Winkles	Pipeline	2	0.41	0.48	<0.30	<0.29		<0.41	0.78	<0.56	<0.25	0.017	0.036	0.065
Scallops	Largs	4	<0.10	<0.10	<0.13	<0.33		<0.10	0.55	<0.27	<0.13	0.0093	0.037	0.014
Seaweed	N of pipeline	2	1.5	0.53	<0.19	<0.57		<0.10	1.3	<0.29	<0.12			<0.10
Seaweed	Pipeline	2	2.5	0.63	<0.18	<0.70		<0.11	1.6	<0.29	<0.13			<0.10
Seaweed	S of pipeline	2	2.7	0.53	<0.30	<1.1		<0.18	3.0	<0.40	<0.16			<0.22
Sediment	Pipeline	2	<0.23	<0.17	<0.29	<0.36		<0.27	18	<0.73	<0.40			<0.72
Sediment	Millport	2	<0.10	<0.10	<0.23	<1.6		<0.12	7.0	<0.47	<0.21			<0.32
Sediment	Ardneil Bay	2	<0.14	<0.11	<0.44	<10		<0.24	3.2	<0.83	<0.36			<0.60
Sediment	Gulls Walk	2	<0.11	<0.11	<0.28	<0.36		<0.13	9.2	<0.56	<0.31			<0.53
Seawater[c]	Pipeline	3	<0.10	<0.10	<0.15	<1.5		<0.10	<0.08	<0.30	<0.12			<0.10

Table 6.7(a). continued

Material	Location or selection[d]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb
Terrestrial samples										
Milk		6	<10	18	<4.5		<0.06		<0.10	<0.91
Milk	max		<11	19	<6.5		<0.11			<1.1
Apples		1	<12	130	0.58	<0.15	<0.05	<0.13	<0.10	<0.15
Blackberries		1	<11	29	<0.50		<0.05		0.58	<0.47
Broccoli		1	<12	9.9	<1.8		<0.05	0.11	1.3	<0.21
Carrots		2	<8.6	19	<0.65	<0.04	<0.05	<0.14	<0.10	<0.10
Carrots	max		<12	21	0.80					<0.14
Cereal		1	5.2	140	4.3	<0.11	<0.11	<0.32	<0.10	<0.32
Ground elder		1	6.6	25	8.6		<0.21		1.5	<75
Nettles		1	<5.1	17	<4.7		<0.05		2.2	<0.17
Onions		1	<11	17	<0.50		<0.05		<0.10	<0.12
Pheasants		2	<12	39	<7.6				<0.10	
Pheasants	max		<19		14					
Potatoes		5	<10	23	<1.2	<0.06	<0.07	<0.16	<0.11	<0.41
Potatoes	max		24	28	1.6	<0.07	<0.10	<0.22	0.15	<0.84
Rowan berries		1	5.6	46	<0.50	<0.10	<0.10	<0.27	<0.10	<0.24
Turnips		1	<12	12	2.1	<0.06	<0.06	<0.18	<0.10	<0.16
Wildfowl		2					<0.07			<0.18
Wildfowl	max									<0.19
Grass		4	<9.3	28	<17		<0.06		<0.19	<0.29
Grass	max		18	34	55		<0.07		0.23	<0.38
Soil		4	<6.2	8.8	<0.94	<0.15	<0.23	<0.48	0.48	<1.2
Soil	max		<7.4	12	<1.2	<0.17	<0.37	<0.54	0.70	<2.1

Material	Location or selection[d]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{110m}Ag	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am	Total alpha	Total beta
Terrestrial samples									
Milk		6	<0.05	<0.17	<0.17				
Milk	max		<0.06	0.42	<0.21				
Apples		1	<0.05	<0.04	<0.26	<0.13	<0.21		
Blackberries		1	<0.05	<0.05	<0.26				
Broccoli		1	<0.05	0.13	<0.22				
Carrots		2	<0.04	<0.04	<0.15	<0.10	<0.15		
Carrots	max		<0.05	<0.05	<0.19				
Cereal		1	<0.11	<0.11	<0.69	<0.36	<0.59		
Ground elder		1	<0.41	0.43	<1.9		<0.25		
Nettles		1	<0.05	0.76	<0.25				
Onions		1	<0.05	<0.05	<0.12				
Pheasants		2							
Pheasants	max								
Potatoes		5	<0.07	<0.06	<0.28	<0.12	<0.18		
Potatoes	max		<0.10	<0.08	<0.50	<0.16	<0.26		
Rowan berries		1	<0.10	0.11	<0.48	<0.26	<0.40		
Turnips		1	<0.05	<0.05	<0.29	<0.17	<0.26		
Wildfowl		2	<0.09	0.81	<0.35				
Wildfowl	max		<0.10	1.1	<0.37				
Grass		4	<0.06	<0.26	<0.30		<0.13	2.9	190
Grass	max		<0.07	0.62	<0.43			5.6	260
Soil		4	<0.38	15	<1.5	<0.39	<0.64	270	780
Soil	max		<0.54	25	<2.3		<0.86	380	920

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentration of ^{14}C was 36 Bq kg^{-1}*
[c] *The concentration of ^{3}H was 5.7 Bq l^{-1}*
[d] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*

Table 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Largs Bay	NA	2	0.057
Kilchatten Bay	NA	2	<0.047
Millport	NA	2	<0.047
Gulls Walk	Mud	2	<0.047
0.5 km north of pipeline	Sand	2	<0.047
0.5 km south of pipeline	Sand and stones	2	<0.048
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	<0.047

NA Not available

Table 6.8(a). Radioactivity in food and the environment near Sizewell nuclear power stations, 2000[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples								
Cod	Sizewell	1	<25		0.61			<0.25
Sole	Sizewell	1	<25		0.33			<0.27
Crabs	Sizewell	2		33	<0.14	0.000073	0.00034	0.00067
Pacific Oyster	Blyth estuary	1			0.06			<0.08
Whelks	Dunwich	1			0.11			<0.07
Sand	Aldeburgh	2			0.27			<0.58
Sea water	Aldeburgh	2	3.4					

Material	Location or selection[c]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
				^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total Cs	^{238}Pu	$^{239+}$ ^{240}Pu	^{241}Am
Terrestrial samples												
Milk	Near farms		3	<4.0	17	<0.48		<0.28				
Milk	Near farms	max			19	<0.60						
Milk	Far farms		5	<3.8	20	<0.60		<0.30				
Milk	Far farms	max		<4.0	25	<0.90		<0.40				
Apples			1	<4.0	13	0.70		<0.30				
Bovine muscle			1	<5.0	33	<1.1	<0.029		0.26	<0.00010	0.00010	0.00030
Bovine offal			1	9.0	67	<1.1	<0.021		0.20	<0.00040	<0.00040	<0.00080
Cabbage[d]			1	<4.0	<3.0	0.60		<0.30				
Carrots			1			<0.30		<0.30				
Honey			1	<7.0	93	0.80		<0.20				
Ovine muscle			1	<5.0	30	2.7	0.042		<0.043	<0.00010	<0.00010	<0.00030
Potatoes			1	4.0	12	0.60		<0.30				
Raspberries			1	<4.0	10	<0.30		<0.30				
Runner beans			1	<4.0	19	0.40		<0.40				
Wheat			1	<7.0	110	0.90		<0.30				

[a] *114 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.18, 1.1, and 0.46 Bq per cloth respectively*
[b] *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*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[d] *The concentration of ^{55}Fe was <0.60 Bq kg^{-1}*

Table 6.8(b). Monitoring of radiation dose rates near Sizewell nuclear power stations, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Aldeburgh	Sand and gravel	2	0.048
Pipeline	Gravel	4	0.12
Pipeline	Sand	2	0.099

Table 6.9(a). Radioactivity in food and the environment near Torness nuclear power station, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples												
Cod	Pipeline	2		<0.10	<0.10		<0.10	0.74	<0.12			<0.10
Cod	White Sands	2		<0.10	<0.36		<0.12	0.53	<0.15			<0.11
Crabs[b]	Cove	2		<0.10	<0.10	5.2	<0.10	<0.13	<0.13			<0.10
Lobsters	Cove	1		<0.11	<0.10	67	<0.12	0.13	<0.20			<0.11
Nephrops	Dunbar	4		<0.11	<0.13		<0.11	0.33	<0.15	0.0012	0.0067	0.0068
Winkles[c]	Pipeline	2		<0.23	<0.28		0.18	0.18	<0.13			<0.13
Seaweed[d]	Pipeline	2		1.4	<0.44	150	<0.08	0.18	<0.14			<0.16
Porphyra	Thornton Loch Beach	2		0.32	<0.10		<0.11	<0.14	<0.17			<0.11
Seaweed	White Sands	2		<0.10	<0.10		<0.10	0.19	<0.17			<0.10
Sediment	Eyemouth	2		<0.10	<0.11		<0.13	3.1	0.59			<0.32
Sediment	Dunbar Inner Harbour	2		<0.10	<0.12		<0.15	4.5	<0.47			<0.41
Sediment	Barns Ness	2		<0.12	<0.11		<0.12	3.4	<0.31			<0.50
Sediment	Thornton Loch	2		<0.10	<0.10		<0.12	1.8	<0.32			<0.35
Sediment	Heckies Hole	2		<0.10	<0.11		<0.13	3.1	1.4			<0.36
Salt marsh	Belhaven Bay	2		<0.11	<0.10		<0.12	2.3	<0.78			<0.25
Seawater	Pipeline	7	<1.3	<0.10	<0.10		<0.10	<0.09	<0.11			<0.10

Material	Location or selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{65}Zn	^{90}Sr	^{137}Cs	^{155}Eu	Total alpha	Total beta
Terrestrial Samples											
Milk		1	<10	20	<6.6		<0.10	<0.05			
Blackberries		1	<5.0	17	<0.50		0.73	<0.06			
Broad beans		1	30	19	1.7	<0.36	0.19	<0.08			
Cauliflower		1	<5.0	11	<2.3		0.17	<0.05			
Ground elder		1	33	35	1.3	<0.19	0.39	0.07			
Kale		1	9.3	12	<0.84		<0.10	<0.05			
Nettles		1	<7.7	30	19		<0.10	0.06			
Potatoes		1	<7.2	25	6.7	<0.33		<0.08			
Rosehips		1	5.3	37	2.5		0.37	<0.05			
Grass		6	18	43	<1.0	0.19	<0.14	<0.06		<3.1	220
Grass	max		29	82	<2.0		0.28	0.11		5.3	240
Soil		6	<6.1	15	<1.1	<0.66	<0.35	16	<0.87	220	680
Soil	max		<8.1	19	1.6	<0.74	0.62	37	1.6	260	850

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentration of ^{14}C was 45 Bg kg^{-1}*
[c] *The concentrations of alpha and beta activity were 11 and 70 Bq kg^{-1} respectively*
[d] *The concentration of ^{131}I was 1.2 Bq kg^{-1}*
[e] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*

Table 6.9(b). Monitoring of radiation dose rates near Torness nuclear power station, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Heckies Hole	NA	2	0.060
Dunbar Inner Harbour	Sand	2	0.079
Belhaven Bay	Salt marsh	2	0.061
Barns Ness	Mud, sand and stones	2	0.055
Skateraw	Sand	2	0.050
Thornton Loch	Sand	2	<0.051
St Abbs	Mud	2	0.061
Eyemouth	Mud	2	0.054
Beta dose rates on fishing gear			µSv h^{-1}
Cove	Lobster pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

NA Not available

Table 6.10(a). Radioactivity in food and the environment near Trawsfynydd nuclear power station, 2000[a]

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], 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		36		<0.18	9.0	<0.67	0.58	74	
Rainbow trout	Lake	6				<0.14		<0.30	<0.15	3.2	
Perch	Lake	4				<0.20	3.6	<0.98	1.3	150	
Rudd	Lake	1				<0.18		<0.72	1.0	110	
Mud	Pipeline	1				68		37	33	4200	
Mud and sand	Pipeline	1				10		28	7.2	1000	
Water	Bailey Bridge	1	<1.4								
Water	Cold Lagoon	2							*	0.02	
Terrestrial Samples											
Milk	Near farms	1	<4.0	15		<0.33	0.069	<0.45			0.13
Milk	Far farms	1	<4.0	11		<0.23	0.054	<0.68			0.13
Blackberries		1	<4.0	16	<0.30	<0.20		<0.70	<0.30	0.50	
Carrots		1	<5.0	11	<0.20	<0.40		<0.70	<0.30	<0.40	
Chicken		1	<5.0	17	0.50	<0.40		<0.80	<0.50	<0.50	
Hazlenuts		1	<7.0	19	<0.30	<0.20		<1.1	<0.40	22	
Ovine muscle		2	<5.5	39		<0.25	<0.049	<0.50			0.29
Ovine muscle	max		6.0	40		<0.30	0.068				0.32
Ovine liver		2	<7.0	44		<0.20	0.17	<0.85			0.40
Ovine liver	max			58			0.31	<0.90			0.49
Ovine offal		2	<7.0	27		<0.30	<0.047	<0.60			0.36
Ovine offal	max		7.0	34			<0.065				0.52
Potatoes		1	<4.0	23	0.90	<0.30		<0.60	<0.20	<0.30	

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[c], Bq kg^{-1}					
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Freshwater samples								
Brown trout	Lake	6	<0.53	<0.43	0.00012	0.00047	0.00078	0.000015
Rainbow trout	Lake	6	<0.46	<0.25			<0.21	
Perch	Lake	4	<0.59	<0.61	0.000090	0.00034	0.00062	*
Rudd	Lake	1	<0.54	<0.55			<0.81	
Mud	Pipeline	1	23	15			100	
Mud and sand	Pipeline	1	4.4	5.5			19	
Water	Bailey Bridge	1						
Water	Cold Lagoon	2						
Terrestrial Samples								
Milk	Near farms	1	<0.33	<0.45				
Milk	Far farms	1	<0.43	<0.60				
Blackberries		1	<0.40	<0.40	0.00010	<0.00030	<0.00030	
Carrots		1	<0.40	<0.60	0.00010	0.00070	<0.00040	
Chicken		1	<0.50	<0.80	<0.00020	<0.00020	<0.00090	
Hazlenuts		1	<0.80	<1.4	<0.00090	<0.0013	<0.0024	
Ovine muscle		2	<0.40	<0.35	<0.00010	<0.00020	0.00095	
Ovine muscle	max			<0.40			0.0012	
Ovine liver		2	<0.55	<0.95	<0.00030	<0.00025	0.00065	
Ovine liver	max		<0.60	<1.1	<0.00050	<0.00030	0.0012	
Ovine offal		2	<0.50	<1.0	0.00010	0.00030	<0.00030	
Ovine offal	max			<1.1		0.00040	0.00030	
Potatoes		1	<0.30	<0.40	<0.00010	<0.00020	0.0014	

** not detected by the method used*

[a] *107 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.18, 0.97 and 0.29 Bq per cloth respectively*

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

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

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over areas near lake shoreline			
Footbridge	Rock	2	0.097
Nant Islyn Bay	Mud and stones	1	0.10
Nant Islyn Bay	Stones	1	0.12
West of footbridge	Stones	2	0.11

Table 6.11(a). Radioactivity in food and the environment near Wylfa nuclear power station, 2000[e]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples											
Plaice	Pipeline	2	35	<0.08		1.6			<0.16		
Crabs	Pipeline	2		<0.18	5.0	0.89	0.0047	0.026	0.065	0.000084	
Winkles[b]	Cemaes Bay	2		0.13		0.56	0.028	0.16	0.21	0.00026	
Fucus vesiculosus	Cemaes Bay	2		<0.05	740	1.2			<0.20		640

Material	Location or selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs
Terrestrial samples							
Milk	Near farms	5	<4.0	15	<0.63	<0.30	<0.28
Milk	Near farms	max		17	<0.73		<0.30
Apples		1	<4.0	14	0.30	<0.30	<0.30
Barley		1	9.0	100	1.8	<0.40	<0.40
Blackberries		1	6.0	19	0.60	<0.20	<0.20
Carrots		1	<5.0	13	<0.20	<0.20	<0.30
Honey		1	6.0	110	3.0	<0.30	<0.30
Kale[d]		1	<4.0	4.0	<0.60	<0.30	<0.30
Potatoes		1	<4.0	11	0.60	<0.30	<0.30
Runner beans		1	<5.0	<5.0	<0.20	<0.30	<0.30
Grass		2	<7.0	8.5	0.55	<0.30	<0.50
Grass		max	9.0	9.0	0.60	<0.40	<0.60

[a] *Except for milk where units are Bq l^{-1} and for dry cloths where units are Bq per cloth*
[b] *The concentration of ^{241}Pu was 1.5 Bq kg^{-1}*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[d] *The concentration of ^{55}Fe was <0.90 Bq kg^{-1}*
[e] *92 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.14, 0.98 and 0.41 Bq per cloth respectively*

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2000

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Cemaes Bay	Sand	4	0.055

7. DEFENCE ESTABLISHMENTS

Surveillance by the Food Standards Agency and SEPA is undertaken near 7 defence-related establishments in the United Kingdom. Low-level discharges also occur from Burghfield in Berkshire. Liquid effluent discharges from this site ceased on 31 March 2000 following the grant of a revised authorisation by the Environment Agency to AWE. The operator carries out environmental monitoring at Burghfield. Monitoring at nuclear submarine berths is carried out by the Ministry of Defence (DRPS, 2000). Monitoring at Greenwich by the Food Standards Agency ceased in 1999 with the closure of the JASON reactor and the associated revocation of the Authorisation to discharge. The Food Standards Agency's surveillance of Barrow is limited to grass sampling. In 2000 no activity was detected. Any significant effects of discharges from Barrow on seafood would be detected in the far-field surveillance of Sellafield (Section 4) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2000.

7.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. Revised authorisations were granted by the Environment Agency to AWE on 9 March 2000 and came into effect on 1 April 2000. Liquid discharges are made to the River Thames at Pangbourne, to the sewage works at Silchester and to Aldermaston Stream. Samples of milk, other terrestrial foodstuffs, freshwater fish and 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 except at Newbridge. The observed presence of tritium in organic form in pike from Newbridge is not due to discharges from Aldermaston. More probably it is associated with low-level discharges from research facilities in the upper parts of the Thames. Habit surveys have established that the most exposed group affected by discharges 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 discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

The concentrations of radioactivity in milk, vegetables, fruit and terrestrial indicator materials were also very low. Results for tritium, uranium and transuranic radionuclides were similar to those for 1999. The most likely source of the radionuclides detected was natural background or weapon test fallout. The dose to consumers of local food in 2000, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.2 Devonport, Devon

Discharges of liquid radioactive waste are made by Devonport Royal Dockyard Ltd. under authorisation and the Ministry of Defence under administrative agreement into the Tamar Estuary. The monitoring programme in 2000 consisted of a measurement of gamma dose rate and analysis of shellfish and indicator materials. The results given in Tables 7.2(a) and (b) were similar to those in 1999 where comparisons can be drawn. A small amount of tritium activity was detected in grass and green crabs from the River Lyner. Trace quantities of fission and activation products and actinides were detected in the marine environment. The dose to the most exposed group taking account of consumption of marine foods and occupancy times was estimated to be 0.009 mSv which was less than 1% of the principal dose limit for members of the public of 1 mSv. The radiological significance of this, in common with other defence establishments, continued to be low.

7.3 Faslane and Coulport, Argyll and Bute

Discharges of liquid radioactive waste into Gare Loch from Faslane (HMNB Clyde) and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from RNAD Coulport are made under letters of agreement between SEPA and the Ministry of Defence. A new habit survey was undertaken at Faslane in 2000 which identified fish consumption and external radiation from the shore as the major pathways of exposure. Caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield and weapons testing and Chernobyl fallout. Gamma dose rates were difficult to distinguish from natural background (Table 7.2(b)). Taking into account new occupancy and consumption rate data from the survey, the dose to the most exposed group from external radiation and the consumption of fish was less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.4 Holy Loch, Argyll and Bute

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

7.5 Rosyth, Fife

Activities at Rosyth Royal Dockyard continued to give rise to discharges of liquid radioactive waste into the Firth of Forth. No discharges of gaseous radioactive waste were reported in 2000. All discharges have remained well within the authorised limits.

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

The monitoring programme included sampling and analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 7.2(a) and 7.2(b). The radioactivity levels detected were low, and in most part due to the effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The dose to the most exposed group of local fishermen in 2000 was estimated to be less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

7.6 Vulcan NRTE, Highland

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

Table 7.1. Radioactivity in food and the environment near Aldermaston, 2000[d]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{57}Co	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Total beta
Aquatic samples										
Pike	Newbridge	1	56	50	<0.05	<0.09	0.00030	0.0014	0.0032	
Pike	Outfall (Pangbourne)	1	<25	<25	<0.02	0.44	0.00046	0.0021	0.0009	
Pike	Staines	1	<25	<25	<0.06	0.30			<0.08	
Pike	Shepperton	1	<25	<25	<0.14	<0.18			<0.66	
Pike	Teddington	1	<25	<25	<0.03	0.23			<0.05	
Nuphar lutea	Newbridge	1		<25	<0.03	<0.05			<0.04	
Nuphar lutea	Staines	1		<25	0.07	0.12			<0.05	
Clay	Outfall (Pangbourne)	1			<0.16	<0.21			<0.38	360

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{137}Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Terrestrial samples								
Milk	Near farms	4	<4.0	<0.27	<0.0080	<0.00014	<0.00014	<0.00025
Milk	Near farms max			<0.28		<0.00018	<0.00015	<0.00030
Apples		1	<4.0	<0.30	<0.041	<0.00020	<0.00020	0.00040
Carrots		1	<4.0	<0.30	0.076	<0.00010	<0.00020	0.00070
Honey		1	<6.0	<0.30	<0.0060	0.00010	<0.00020	0.00090
Lettuce		1	4.0	<0.30	<0.039	0.00020	0.00030	0.00030
Potatoes		1	<4.0	<0.30	<0.034	<0.00010	0.00030	0.00070
Rabbits		1	<5.0	<0.30	<0.032	<0.0016	<0.0032	<0.00030
Runner beans		1	<4.0	<0.30	<0.020	<0.00010	<0.00020	0.00050
Wheat		1	6.0	<0.30	<0.038	<0.00020	<0.00020	0.0013
Soil		4			52			
Soil[c]	max				75			

[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] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 9.3, 0.41 and 9.2 Bq kg^{-1} respectively*
[d] *82 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.12, 0.62 and 0.30 Bq per cloth respectively*

Table 7.2(a). Radioactivity in food and the environment near naval establishments, 2000

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}											
			Organic ^{3}H	^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{90}Sr	^{95}Nb	^{124}Sb	^{131}I	^{137}Cs	^{155}Eu	^{241}Am
Barrow														
Grass	Barrow	2		<4.5										
Grass		max		<5.0										
Devonport														
Crabs[c]	Plymouth Sound	1			<0.17	<0.33	<0.18		<0.95	<0.97	*	<0.14	<0.23	<0.12
Green crabs	River Lyner	1	48	<25	<0.06	<0.09	<0.06		<0.15	<0.18	*	<0.06	<0.17	<0.16
Green crabs	River Tamar	1	<25	<25	<0.06	<0.09	<0.07		<0.15	<0.18	*	<0.06	<0.12	<0.07
Mussels	River Lyner	1	<25	<25	<0.17	<0.26	<0.17		<0.46	<0.66	*	<0.15	<0.25	<0.13
Mussels	Mayflower Marina	1	<25	<25	<0.14	<0.21	<0.15		<0.35	<0.54	*	0.14	<0.36	<0.33
Oysters	River Lyner	1	<25	<25	<0.06	<0.09	<0.06		<0.16	<0.25	*	<0.05	<0.10	<0.05
Oysters	River Tamar	1	<25	<25										
Pacific oysters	River Lyner	1	<25	<25	<0.12	<0.20	<0.13		<0.40	<0.48	*	<0.12	<0.34	<0.49
Fucus vesiculosus[d]	Kinterbury	2			<0.04	<0.06	<0.05		<0.10	<0.09	*	0.12	<0.12	<0.15
Mud[e]	Kinterbury	2			<0.33	<0.41	<0.31		<0.81	<0.86	*	4.5	<1.8	0.17
Grass	Devonport	4		<5.5			<0.40		<0.45			<0.40		
Grass		max		7.0			<0.50		<0.60			<0.50		
Faslane														
Fish	Carnban boatyard	2			<0.10	<0.14	<0.10		<0.38			1.2	<0.14	<0.10
Sediment	Carnban boatyard	2			<0.10	<0.16	<0.32		<0.24			13	0.88	<0.33
Seawater	Carnban boatyard	1		<1.4										
Holy Loch														
Sediment	Mid Loch	1			<0.29	<0.61	1.6		<2.1			8.1	<0.61	<1.3
Rosyth														
Crabs	East of dockyard	2			<0.08	<0.18	<0.08		<0.52			<0.12	<0.17	<0.20
Seaweed	East of dockyard	2			<0.10	<0.13	<0.10		<0.35		2.0	0.23	<0.11	<0.10
Sediment	East of dockyard	2			<0.10	<0.14	<0.11		<0.24			19	0.99	<0.83
Sediment	Port Edgar	2			<0.13	<0.32	<0.25		<1.2			17	1.4	<1.1
Sediment	West of dockyard	2			<0.17	<0.36	<0.61		<1.3			7.8	<0.71	<0.66
Sediment	Blackness Castle	2			<0.13	<0.19	<0.12		<0.68			2.4	<0.33	<0.48
Sediment	Burntisland Bay	2			<0.12	<0.29	<0.11		<2.3			0.90	<0.35	<0.47
Seawater	East of dockyard	1						<1.4						

** Not detected by the method used*

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

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

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

[d] *The concentration of ^{99}Tc was 0.62 Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.25, 0.47 and 0.048 Bq kg^{-1} respectively*

Table 7.2(b). Monitoring of radiation dose rates near naval establishments, 2000

Establishment	Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas				
Devonport	Kinterbury	Mud	2	0.075
Faslane	Gareloch Head	Mud, sand and stones	2	<0.047
Faslane	Gulley Bridge Pier	Sand and stones	2	0.059
Faslane	Rhu	Gravel	2	0.048
Faslane	Rosneath	Sand and gravel	2	0.049
Faslane	Carnban boatyard	Mud and sand	2	0.056
Holy Loch	North Sandbank	Mud and sand	1	0.050
Holy Loch	Kilmun Pier	Sand and stones	1	0.065
Holy Loch	Mid-Loch	Sand	1	0.046
Rosyth	Blackness Castle	Mud and sand	2	0.055
Rosyth	Burntisland Bay	Sand	2	<0.050
Rosyth	East of Dockyard	Sand	2	0.060
Rosyth	Port Edgar	Mud	2	0.071
Rosyth	West of Dockyard	Mud and sand	2	<0.051

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 environmental effects of the Harwell facility are covered by general surveillance of the Harwell site (Section 5). From July 2001 the company will be known as Amersham plc.

8.1 Amersham, Buckinghamshire

Discharges of liquid radioactive wastes are made under authorisation to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Discharges of gaseous wastes are also authorised. The 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 in mud close to the outfall but their levels were very low. Tritium concentrations in biota in the Thames and the Grand Union Canal were close to or below the limit of detection. The organic tritium observed in pike at Newbridge would not have been due to discharges from Amersham. It is more probably associated with low-level discharges from research facilities in the upper part of the Thames.

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 discharges into the canal/river system. Their occupancy of the river bank has been assessed to estimate their external exposures. Even though there was no evidence of local consumption of fresh-water fish it is considered prudent to include a component in the assessment of the anglers' exposure. A consumption rate for fish of 1 kg year^{-1} was therefore assumed. The anglers' dose in 2000 was much less than 0.005 mSv which was less than 0.5% of the principal dose limit for members of the public of 1 mSv.

The dose to the most exposed group of terrestrial food consumers was assessed as being 0.005 mSv which was 0.5% of the principal dose limit for members of the public.

8.2 Cardiff, South Glamorgan

A second laboratory, situated near Cardiff, produces radiolabelled compounds used in research and diagnostic kits used in medicine for the testing of clinical samples and radio-pharmaceuticals. Liquid wastes are discharged into the Severn estuary via the sewer system. Discharges from the site are also made by OrthoClinical Diagnostics Ltd.

Routine monitoring, carried out on behalf of the National Assembly for Wales and the Food Standards Agency, includes consideration of consumption of locally produced 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, grass and dry cloths provide additional information. Supplementary monitoring and research was undertaken in 2000, which mainly targetted organic tritium in foodstuffs. (Swift, 2001 and Leonard *et al.,* 2001b).

The results of both routine and supplementary monitoring in 2000 are presented in Tables 8.2(a) and (b). The main effect of liquid discharges is seen in enhanced tritium and carbon-14 activities in samples above background levels. The high levels of total tritium in local fish and shellfish increased in 2000 compared

with 1999. Mean concentrations in flounder, the main species observed, increased from 23,000 Bq kg^{-1} (minimum 21,000 Bq kg^{-1}; maximum 24,000 Bq kg^{-1}) to 54,000 Bq kg^{-1} (minimum 22,000 Bq kg^{-1}; maximum 90,000 Bq kg^{-1}). This change runs counter to the trend in the overall discharge of tritium from the site (1998: 277 TBq 1999: 105 TBq; 2000: 87 TBq). However, research has suggested that the concentrations observed are strongly dependent on the relatively small amounts of organic tritium labelled compounds in the wastes (Leonard *et al.*, 2001b). There is no evidence that OBT discharges have declined in line with overall reductions of tritium discharges. It is possible that sediment could act as a store for organically bound tritium and it may take some time for activity levels to decline. The results of sample analyses show that over 90% of the total tritium was organically bound and the dose estimates for members of the public take this into account.

The data include observations for freshwater fish from the River Taff. These have also been affected by discharges from the site though there are no authorised discharges made directly to the river. The samples were collected from a non-tidal part of the river and fish migration could not account for all of the observations. However, there is evidence that the Cardiff sewage system can discharge into the Taff following surges after heavy rain (Swift, 2001). Authorised discharges into the sewage system could thus be transferred to freshwater biota after heavy rain.

Further information on tritium levels in seawater and at other nuclear sites in the Bristol Channel can be found in Sections 6 and 11.

Concentrations of other radionuclides in aquatic samples were low and can be explained by other sources such as Chernobyl and weapon test fallout and discharges from other establishments. Gamma and beta dose rates over sediment, as measured using portable instruments, were 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 0.064 mSv which was about 6% of the principal dose limit for members of the public of 1 mSv.

The main effects of gaseous discharges 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. The incidence of detection of enhanced carbon-14 and tritium activities in a wide range of terrestrial samples is relatively high in comparison with other nuclear sites. Sulphur-35 was detected at levels similar to those found in the general diet survey (see Table 11.4). All these measurements were of low radiological significance.

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

Table 8.1. Radioactivity in food and the environment near Amersham, 2000[d]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{57}Co	^{58}Co	^{65}Zn	^{137}Cs	$^{239}Pu+^{238}Pu$	^{240}Pu	^{241}Am
Aquatic samples												
Pike	Newbridge	1	56	50		<0.05	<0.25	<0.30	<0.09	0.00030	0.0014	0.0032
Pike	Outfall (Grand Union Canal)	1	<25	<25	17	<0.03	<0.13	<0.16	0.30			<0.13
Pike	Staines	1	<25	<25		<0.06	<0.26	<0.31	0.30			<0.08
Pike	Shepperton	1	<25	<25		<0.14	<0.51	<0.53	<0.18			<0.66
Pike	Teddington	1	<25	<25		<0.03	<0.15	<0.18	0.23			<0.05
Nuphar lutea	Newbridge	1		<25		<0.03	<0.09	<0.14	<0.05			<0.04
Nuphar lutea	Outfall (Grand Union Canal)	1		<25		0.17	0.12	<0.14	0.19			<0.04
Nuphar lutea	Staines	1		<25		0.07	<0.12	<0.19	0.12			<0.05
Mud[b]	Outfall (Grand Union Canal)	1				0.63	0.34	1.4	7.9			<0.33

Material	Location or selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{75}Se	^{125}I	^{131}I	^{134}Cs	^{137}Cs
Terrestrial samples									
Milk	Near farms	2	<4.0	<0.53	<0.33	<0.030	<0.021	<0.24	<0.29
Milk	Near farms max			<0.60	<0.35		<0.025	<0.25	<0.30
Beetroot		1	<4.0	<0.20	<0.30	<0.11		<0.30	<0.30
Cabbage		1	<4.0	0.40	<0.30	<0.085		<0.20	<0.20
Carrots		1	<4.0	<0.20	<0.30	0.21		<0.30	<0.30
Parsnips		1	<4.0	0.50	<0.30	<0.060		<0.30	<0.30
Peas		1	<4.0	<0.50	<0.50	<0.077		<0.30	<0.40
Plums		1	<4.0	<0.30	<0.30	<0.11		<0.30	<0.30
Potatoes		1	<4.0	<0.30	<0.30	<0.11		<0.20	<0.30
Wheat		1	<6.0	2.4	<0.30	<0.10		<0.30	<0.30

[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] *The concentration of beta activity was 310 Bq kg^{-1}*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[d] *70 dry cloths were analysed. The concentrations of alpha, beta and gamma activity were 0.17, 0.90 and 0.32 Bq per cloth respectively*

Table 8.2(a). Radioactivity in food and the environment near Cardiff, 2000[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu
Aquatic samples								
Flounder	East of new pipeline	14	51000	54000	730	<0.05	0.27	<0.09
Sole	East of new pipeline	3	28000	43000	460	<0.14	0.19	<0.20
Cod	East of new pipeline	1		4500	86	<0.13	0.71	<0.20
Mullet	East of new pipeline	1	420	450	92	<0.14	0.34	<0.32
Brown trout	River Taff	1	6200	7800	150			
Chub	River Taff	1	8100	10000	150			
Barbel	River Taff	1	30000	30000	490			
Grayling	River Taff	1	14000	17000	230			
Roach	River Taff	1	17000	15000	130			
Eel	River Taff	1	23000	30000	380			
Green crabs	East of new pipeline	1	57000	59000	620			
Shrimps	East of new pipeline	1	39000	40000	470			
Mussels	Orchard Ledges	14	24000	27000	440	<0.14	0.43	<0.28
Whelks	East of new pipeline	1	65000	74000	1100			
Fucus vesiculosus	Orchard Ledges	12	310	310	21	<0.05	0.32	<0.11
Mud	Orchard Ledges East	12	710	460	17	<0.55	16	<1.9
Sea water	Orchard Ledges	12		7.1				
Sea water	Orchard Ledges East	2		8.1				

Table 8.2(a). continued

Material	Location or selection[c]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
				Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{125}I	^{134}Cs	^{137}Cs
Terrestrial samples										
Milk	Near farms[d]		4	<22	<38	21	<0.63	<0.031	<0.24	<0.28
Milk	Near farms[d]	max		38	70	24	<0.70	<0.032	<0.28	<0.30
Milk	Far farms		2	<5.3	<7.8	20	<0.69	<0.032	<0.25	<0.30
Milk	Far farms	max		<5.8	<8.1		<0.88		<0.28	<0.33
Apples			3	<16	15.0	25	<0.43	<0.068	<0.20	<0.30
		max		39	310	40	<0.70			
Barley			1		8.0	130	1.8	<0.14	<0.30	<0.30
Beetroot			4	<11	17	15	<0.30			
Beetroot		max		<15	45	17	<0.40			
Blackberries			4	<35	190	29	<0.43			
Blackberries		max		88	470	40	<0.70			
Blackcurrants			2	<10	11	27	<0.60			
Blackcurrants		max		13	15	31				
Broad beans			2	<7.0	<88	54	<0.80			
Broad beans		max		9.0	170	88	<0.90			
Cabbage			1	230	630	51	<0.80			
Carrots			2	13	120	13	<0.40			
Carrots		max		22	190	20				
Courgettes			3	<11	120	8.7	<0.57			
Courgettes		max		<18	170	13	<0.70			
Duck Eggs			1	<5.0	5.0	35	<1.4			
French beans			1	8.0	85	14	<0.40			
Garlic			1	5.0	11	48	<0.40			
Gooseberries			1	6.0	9.0	16	<0.40			
Hen's Eggs			1	<4.0	<4.0	31	<2.0			
Honey			1		22	90	<0.20	<0.024	<0.20	<0.20
Leeks			1	4.0	11	18	<0.60			
Lettuce			1	<4.0	<4.0	4.0	<0.20			
Loganberries			1	<21	360	25	<0.20			
Marrow			1	50	210	14	<0.40			
Onions			2	20	130	28	<0.70			
Onions		max		32	220	40	<0.80			
Parsnips			2	<9.0	<23	18	<0.40			
Parsnips		max		11	41					
Peas			1	7.0	31	17	<0.40			
Plums			1	5.0	13	12	<0.40			
Potatoes			6	<17	<59	27	<0.38	<0.12	<0.25	<0.30
Potatoes		max		66	270	50	<0.60	<0.16	<0.30	
Rape oil			1		20	130	3.3	<0.13	<0.40	<0.40
Raspberries			2	<10	<81	22	<0.30			
Raspberries		max		<16	160	26	<0.40			
Red onions			1	55	190	51	<0.40			
Rhubarb			1	25	170	18	<0.40			
Runner beans			6	<24	150	14	<0.33			
Runner beans		max		110	500	31	<0.60			
Strawberries			1	39	240	22	<0.70			
Swede			1	36	39	<3.0	<0.50	<0.060	<0.20	<0.20
Sweetcorn			1	9.0	17	20	<0.40			
Tayberries			3	<12	93	20	<0.40			
Tayberries		max		<18	260	23	<0.60			
Tomatoes			2	<10	65	16	<0.20			
Tomatoes		max		16	130	18				
Grass			5	78	280	23			<0.33	<0.37
Grass		max		330	1300	25			<0.40	<0.40
Silage			2	4.5	10	52				
Silage		max		6.0	11	59				
Soil			3						<0.40	5.3
Soil		max								9.4

[a] *96 dry cloths were analysed. The concentration of alpha, beta and gamma activity was 0.28, 1.1 and 0.30 Bq per cloth respectively*

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

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

[d] *The concentration of ^{32}P was <0.55 Bq l^{-1} and the maximum was <0.73 Bq l^{-1}*

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 2000

Location	Ground type	No. of sampling observations	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Orchard Ledges East	Mud	2	0.076
Beta dose rates			
Orchard Ledges East	Mud	2	0.068

9. MINOR SITES

Four minor sites with very low levels of discharge are monitored using a small programme of sampling indicator materials. The results, given in the following Sections, show that there was no detected impact on the environment in 2000 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 2000 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 2000 were less than the limits of detection. Further data relevant to the Billingham area is given in Section 10.

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

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

9.4 Scottish Universities' Research Reactor Centre, South Lanarkshire

The small research reactor at this site has now ceased operation. The reactor has been defuelled and the fuel removed from the site for storage. Decommissioning plans are advancing, and applications have been made to SEPA under RSA 93 for authorisations relating to decommissioning waste. Discharges of liquid radioactive wastes to sewerage systems were prohibited by SEPA during 2000 after discovery of damage to an underground effluent pipe.

Table 9.1. Radioactivity in the environment near Derby, 2000

Material	No. of samples		Mean radioactivity concentration, Bq kg^{-1}			
			Total U	^{234}U	^{235}U	^{238}U
Grass[a]	4		0.73			
Grass[a]		max	1.50	0.21	0.0081	0.19
Soil[b]	4		57			
Soil[b]		max	63	24	0.96	23

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

10. INDUSTRIAL AND LANDFILL SITES

10.1 Rhodia Consumer Specialties Ltd., Whitehaven, Cumbria

In view of the radiological importance of natural radionuclides to fish and shellfish consumers (Pentreath *et al.*, 1989; Rollo *et al*., 1992; Camplin *et al*., 1996), a small programme of monitoring for these radionuclides in the United Kingdom marine environment has continued. Previous surveys (Rollo *et al.*, 1992) have established that an important man-made source was the Rhodia Consumer Specialties Ltd. (formerly Albright and Wilson) chemical plant at Whitehaven in Cumbria which has manufactured phosphoric acid from imported phosphate ore. Phosphogypsum, a waste product of this process, has been discharged as a liquid slurry by pipeline to Saltom Bay. The radioactive waste discharges 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 2000 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 routine monitoring for natural radioactivity near the site in 2000 are shown in Table 10.1. This year, the data include results from a research study to provide additional information on the background levels of natural radionuclides in seafood.

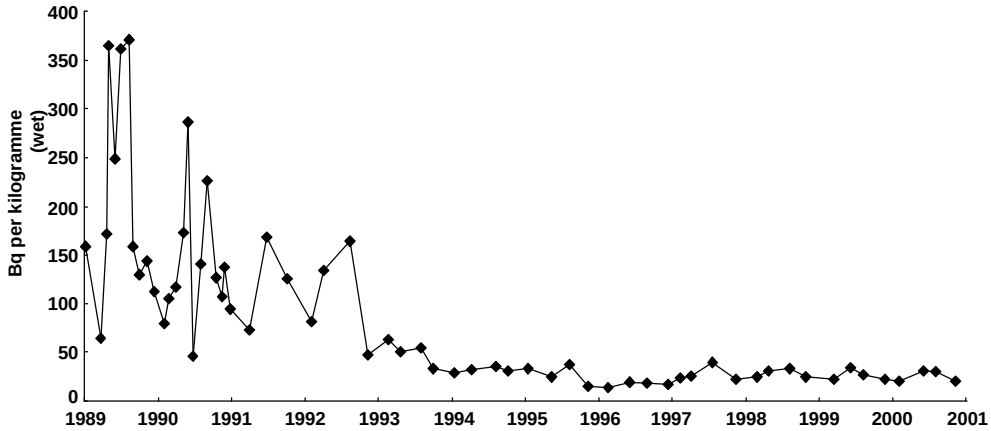

Figure 10.1 Polonium-210 in Parton winkles

Analytical effort has focused on lead-210 and polonium-210 that concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other natural radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figure 10.1 shows how concentrations of polonium-210 in winkles have decreased substantially since 1989, and more dramatically since 1992. It also demonstrates the seasonal variations in concentrations that have been previously observed (Rollo *et al*., 1992). Concentrations of lead-210 and polonium-210 were generally slightly less than those in 1999 (Food Standards Agency and SEPA, 2000). Concentrations of all natural radionuclides were difficult to distinguish from natural levels.

The critical radiation exposure pathway is internal irradiation, due to the ingestion of natural radioactivity in local fish and shellfish. In this assessment, an estimated 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 2000 but no changes to fish and shellfish data were made.

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 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 was slightly reduced from 0.47 mSv in 1999 (Food Standards Agency and SEPA, 2000) to 0.42 mSv in 2000. 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, at present, limited information on the normal background levels of natural radionuclides in seafood that is being addressed by a research study. In view of the uncertainty we have chosen low values in order to ensure that the assessment of local enhancements of these nuclides is not underestimated. It is entirely plausible that the actual dose received is an order of magnitude less than the estimate above.

The fish and shellfish consumed by the most exposed group also contains artificial radionuclides due to Sellafield discharges. The additional exposure due to artificial radionuclides has been calculated using data from Section 4. In 2000 these exposures added a further 0.049 mSv to the doses above resulting in a total dose to this group of up to 0.47 mSv. The estimated doses in 2000 are therefore well within the principal dose limit for members of the public of 1 mSv.

10.2 Other industrial sites

Levels of radionuclides in gaseous discharges from some other industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and waste incineration. Since 1991, a small rolling programme to examine the effects of these activities has been carried out. Following interest in levels of carbon-14 found in 1999 in grass samples close to a radiochemical plant in Billingham, Cleveland, sampling in 2000 was directed to the general area near this site.

The results of the sampling of vegetables, grass, soil, indicator materials and animals in 2000 are given in Table 10.2.

The enhancement of both tritium and carbon-14 concentrations in grass near Billingham continued to be observed in 2000 above those levels expected due to background sources. The mean concentration of carbon-14 in samples taken from the same field as in 1999 was 350 Bq kg^{-1} compared with 960 Bq kg^{-1} in 1999. The mean concentration of carbon-14 in grass samples both from within and surrounding the field was 260 Bq $kg^{-1.}$ Samples outside the field had a mean activity concentration of only 53 Bq kg^{-1}, roughly a seventh of the levels found in the field, with all levels outside the field being less than 100 Bq kg^{-1}. The maximum concentration was also reduced but by a smaller amount (1999: 1300 Bq kg^{-1}; 2000: 900 Bq kg^{-1}). The mean concentration of tritium in grass samples both from within and surrounding the field was 210 Bq kg^{-1} in 2000 compared with 400 Bq kg^{-1} in 1999 whilst the maximum concentration increased to 890 Bq kg^{-1} in 2000 from 510 Bq kg^{-1} in 1999. The mean activity concentrations of tritium in the field in 2000 were 290 Bq kg^{-1} compared with 150 Bq kg^{-1} outside the field. Sampling in 2000 covered a wide area and could have included the effects of several industrial sites that are authorised to dispose of gaseous radioactive wastes including tritium and carbon-14. These include: chemical & polymer plants, an analytical services centre (which has now stopped working with radioactivity), and manufacturers of radiochemicals.

No food is produced in the area where the high levels of carbon-14 have been found. However, a conservative (hypothetical) assessment of the combined effects of these sites has been made using the specific activity approach. It has been assumed that the average concentration of tritium in water in grass, and the average concentration of carbon-14 (excluding natural carbon-14) in carbon in grass, are the same as those found in food produced in the Billingham area. The assessment also assumes that high-rate consumers obtain all of their food from local sources.

On this basis, we estimate that consumers could have received a dose of up to 0.26 mSv in 2000 which was 26% of the principal dose limit for members of the public of 1 mSv had any food actually been produced in the field. Over 95% of this was due to the carbon-14 content of the food. A more realistic estimate of the increase in carbon-14 concentrations in an area that would support a significant amount of food production is 25 Bq kg^{-1}. At this level the resulting dose would be about 0.025 mSv.

Food samples were collected from other parts of the area of interest around Billingham. The results obtained for cabbage (Table 10.2) indicate that the application of the specific activity approach to activity levels in grass from outside the playing field may overestimate concentrations of tritium and carbon-14 by a significant amount.

The Environment Agency will undertake further investigation of this issue and will keep the Food Standards Agency informed of their findings.

The concentrations of other radionuclides in all other samples were all low and of negligible radiological significance. Estimated doses from consumption of rabbit and cabbage sampled near the industrial sites were all less than 0.005 mSv.

10.3 Landfill sites

Some organisations are authorised by SEPA in Scotland or the Environment Agency in England and Wales to dispose of solid wastes containing very low levels of radioactivity to approved landfill sites. In addition waste with very limited radioactivity can be disposed of in general refuse. Radioactivity in wastes can migrate into leachate, and in some cases can enter the groundwater. Monitoring of leachates in England and Wales is carried out by the Environment Agency (Environment Agency, 2000). In Scotland, monitoring is undertaken by SEPA and the results are presented in Table 10.3. The results show very low levels of carbon-14 and caesium-137 in leachate and, in common with data for sites in England and Wales, there is evidence for migration of tritium from some of the discharge sites. A detailed survey at Ness Tip in Aberdeen was repeated and the results were consistent with those previously reported. Inadvertent ingestion of leachate (2.5 l y^{-1}) at the highest concentration of tritium observed at a site would result in a dose of less than 0.001 mSv which was less than 0.1% of the principal annual dose limit for members of the public of 1 mSv.

Table 10.1. Natural radioactivity in fish, shellfish, seaweed and sediment, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Rhodia Consumer Specialities Ltd, Whitehaven											
Winkles	Saltom Bay	4	20	1.7							
Winkles	Parton	4	25	3.2	0.093	0.44	0.79	0.33	0.76	0.030	0.69
Winkles	North Harrington	1	28								
Winkles	Nethertown	4	19	2.7							
Winkles	Drigg	4				0.61	0.60	0.48			
Winkles	Tarn Bay	1	15								
Winkles	Ravenglass	1	25	2.3							
Mussels	Parton	2	51	2.3							
Mussels	Nethertown	4	50	3.0							
Limpets	St Bees	2	13								
Limpets	Tarn Bay	1	8.4	1.4							
Cockles	Ravenglass	2	18								
Crabs	Parton	4	26	0.23		0.12	0.019	0.010	0.054	0.0023	0.047
Crabs	Sellafield coastal area	4	13	0.35							
Lobsters	Parton	4	11	0.10		0.027	0.0097	0.0046	0.048	0.0024	0.046
Lobsters	Sellafield coastal area	4	13	0.080							
Cod	Parton	3	0.65	0.19		0.020	0.0043	0.0027	0.013	0.00070	0.012
Flounder	Whitehaven	1	1.6								
Other samples											
Winkles	Bradwell	1	13	1.5							
Winkles	Cemaes Bay	1	15	1.5							
Winkles	Plymouth	1	6.1	1.1							
Mussels	Bradwell	1	22	0.83							
Mussels	Carbis Bay	1	28	6.0							
Mussels	Conwy	1	48	2.0							
Mussels	Plymouth	1	19	4.0							
Mussels	The Wash	1	40	1.2							
Cockles	Southern North Sea	2				0.47	0.27	0.35			
Cockles	The Wash	1	25	1.1							
Cockles	Dee Estuary	1	17	0.59							
Cockles	Middleton Sands	1	16	0.79							
Cockles	Ribble Estuary	1			0.020	0.37	0.58	0.23			
Cockles	Poole Bay	1	36	0.72							
Cockles	Flookburgh	2	13								
Whelks	Bradwell	1	6.5	0.49							
Whelks	Dungeness	1	2.9	0.27							
Whelks	Dunwich	1	11	0.53							
Whelks	Poole Bay	1	4.0	0.34							
Whelks	Weymouth Bay	1	3.4	0.34							
Whelks	Fleetwood	1	2.1								
Limpets	Hinkley	1	6.8	1.5							
Limpets	Lavernock Point	1	5.9	1.3							
Limpets	Lowestoft	1	7.1	0.68							
Limpets	Kirkcudbright	1	7.3								
Oysters	Whitstable	1	5.4								
Crabs	Cardigan Bay	1	17	0.61							
Crabs	Chapman's Pool	1	15	0.14							
Crabs	Conwy	1	27	0.21							
Crabs	Cromer	1	6.6	0.26							
Crabs	Eastbourne	1	32	0.51							
Crabs	Padstow	1	20	0.40							
Crabs	Torness	1	9.6	0.16							
Lobsters	Portrush	1	5.5	0.33							
Lobsters	Jersey	1	1.9	0.38							
Lobsters	Kilkeel	1	5.1	0.060							
Lobsters	Kirkcudbright	1	2.7	0.050							
Shrimps	Ribble Estuary	2			0.016	0.013	0.014	0.0054			
Shrimps	Hastings	1	5.2	0.28							
Shrimps	Hinkley	1	8.5	0.43							
Shrimps	Holyhead Bay	1	9.1	2.4							
Shrimps	Mablethorpe	1	4.8	0.13							
Shrimps	Lowestoft	1	10	0.45							
Nephrops	North Sea	2	3.8	0.68							
Sand	Ribble Estuary	1				2.7	3.3	2.7			

[a] *except for sediment where dry concentrations apply*

Table 10.2 Radioactivity in food and the environment near Billingham, 2000

Material		No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			Organic ^{3}H	^{3}H	^{7}Be	^{14}C	^{40}K	^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu + ^{240}Pu
Cabbage		1	3.0	5.0		11									
Rabbits		5			<1.0		92	<0.13	<0.12	0.044	0.038	0.0073	<0.0016	<0.00040	<0.00013
Rabbits	max				<1.5		100	<0.18	<0.18	0.052	0.047	0.010	0.0022	0.0018	0.00019
Rose Bay Willow Herb		1	33	60		120									
Grass[b]		30	<54	<210	66	260	140	<0.21	<0.21	3.9	2.1	0.17	0.023	<0.00022	0.00036
Grass	max		94	890	110	900	230	<0.41	<0.50	8.3	3.9	0.42	0.11	0.00012	0.0016
Grass/nettles		1	56	110		200									
Soil		24			<3.7		420	<0.52	9.9	36	28	29	20	<0.0078	0.22
Soil	max				<6.8		610	<0.92	22	58	53	44	40	0.022	0.66

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

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

The concentration of carbon-14 in grass was omitted in error from this table in the report for 1999. The mean value in 1999 was 960 Bq kg^{-1} (wet).

Table 10.3. Radioactivity in surface water leachate from landfill sites in Scotland, 2000

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{14}C	^{40}K	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip (outfall)	1	<25	<15		<0.05	
Aberdeen City	Ness Tip (Pond)	2	180	<15	1.1	<0.05	<0.05
Aberdeen City	Ness Tip (SP1)	2	<15	<15	<0.92	<0.05	<0.06
Aberdeen City	Ness Tip (SP2)	1	2100	<15		<0.05	
Aberdeen City	Ness Tip (SP3)	1	3900	<15		<0.05	
Aberdeen City	Ness Tip (SP4)	1	<25	<15		<0.05	
Aberdeen City	Ness Tip (WM1)	1	760	<15		<0.05	
Aberdeen City	Ness Tip (WM2)	1	4100	<15		<0.05	
Aberdeen City	Ness Tip (WM5)	1	<4.9	<15	1.5	<0.05	<0.06
Aberdeen City	Ness Tip (WM6)	1	36	<15		<0.07	
Aberdeen City	Ness Tip (WM8)	2	4300	<15	3.7	<0.05	<0.05
Aberdeen City	Ness Tip (WM18)	2	14000	<15	5.7	<0.05	<0.06
Aberdeen City	Ness Tip (BH6)	1	300	<15	4.0	<0.05	<0.05
Aberdeen City	Ness Tip (BH16)	1	<4.9	<15	<0.82	<0.05	<0.05
Aberdeen City	Ness Tip (MAKRO)	1	<4.9	<15	<1.2	<0.05	<0.06
Aberdeen City	Ness Tip (Shell)	1	<4.8	<15	<0.79	<0.05	<0.05
Aberdeen City	Ness Tip (Crows Ness Sump)	1	120	<15		<0.05	
Aberdeen City	Ness Tip (Crows Ness GW4)	1	<25	<15		<0.06	
Aberdeen City	Ness Tip (Crows Ness GW7)	1	<25	<15		<0.50	
Aberdeen City	Ness Tip (Crows Ness LC3)	1	990	<15		<0.05	
City of Glasgow	Summerston Tip	1	710	<15	5.6	<0.05	<0.05
Clackmannanshire	Black Devon	1	<5.0	<15	0.96	<0.05	<0.05
Dundee City	Riverside	1	6.2	<15	2.8	<0.05	<0.05
Fife	Balbarton	1	86	<15	2.0	<0.05	<0.05
Fife	Melville Wood	1	65	<15	11	<0.05	<0.05
Highland	Longman Tip	1	51	<15	3.6	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	190	<15	12	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.21	<0.05	<0.05
Stirling	Lower Polmaise	1	460	<15	7.6	<0.05	<0.05

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 2000 with surveillance of sheep and indigenous freshwater fish. Radiocaesium is detected in sheep grazing certain upland areas in the United Kingdom which were subjected to heavy rainfall after the Chernobyl accident in 1986. Restrictions are in place on the movement, sale and slaughter of sheep from these areas in order to prevent animals from entering the food chain above the action level of 1000 Bq kg^{-1} of caesium; a level that was recommended by an EU expert committee in 1986.

In the summer of 2000, intensive monitoring surveys of parts of the post-Chernobyl restricted areas of Cumbria and Scotland were carried out. The results of the surveys did not identify any farms in Cumbria where controls could be lifted, but they confirmed that levels remained low at farms where controls were lifted in 1999. In Scotland, two farms were identified where controls could be lifted and this decision was implemented in January 2001. This will leave 386 farms or parts of farms and approximately 230,000 sheep within the restricted areas of England, Scotland and Wales. These areas are identified in Figures 11.1 to 11.3. This represents a reduction of 96% since 1986 when approximately 8900 farms were under restriction.

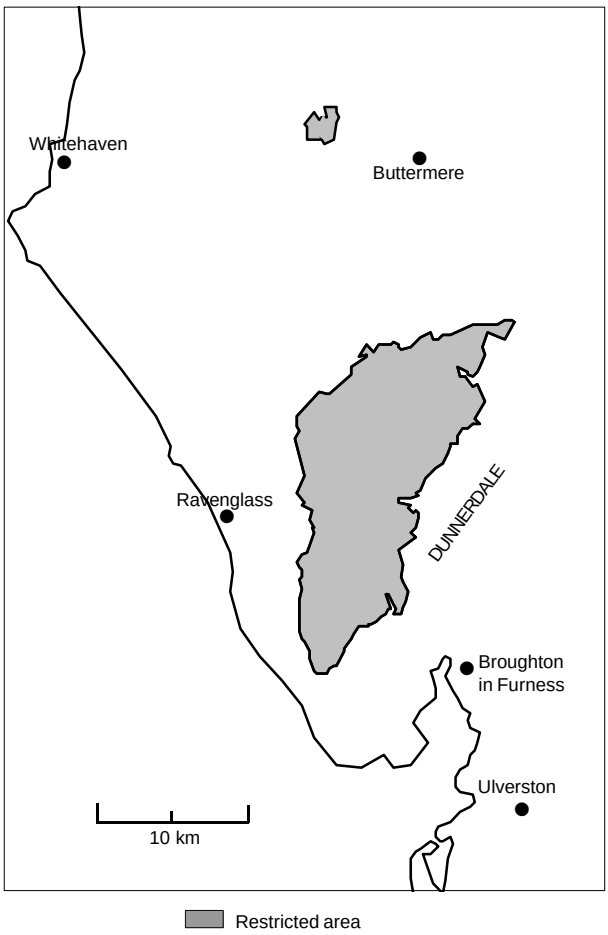

Figure 11.1. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - England

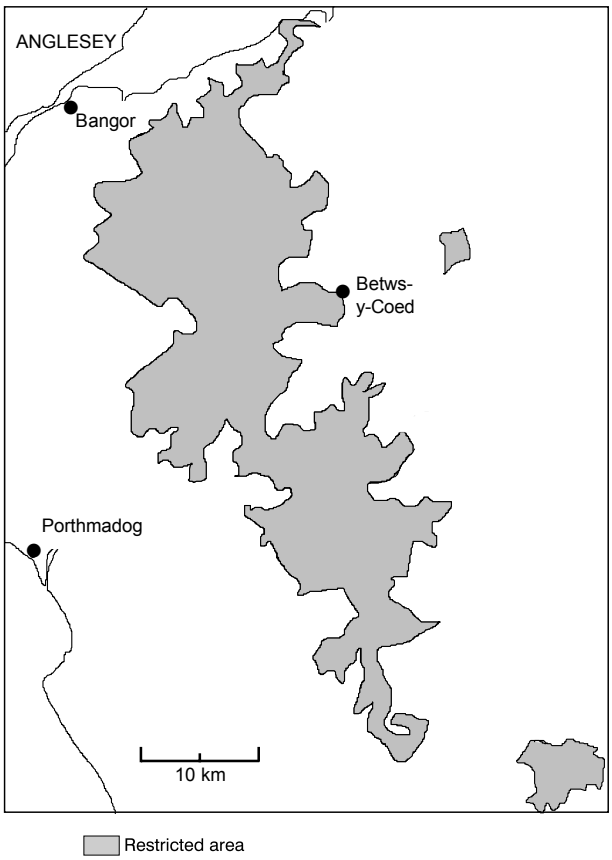

Figure 11.2. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Wales

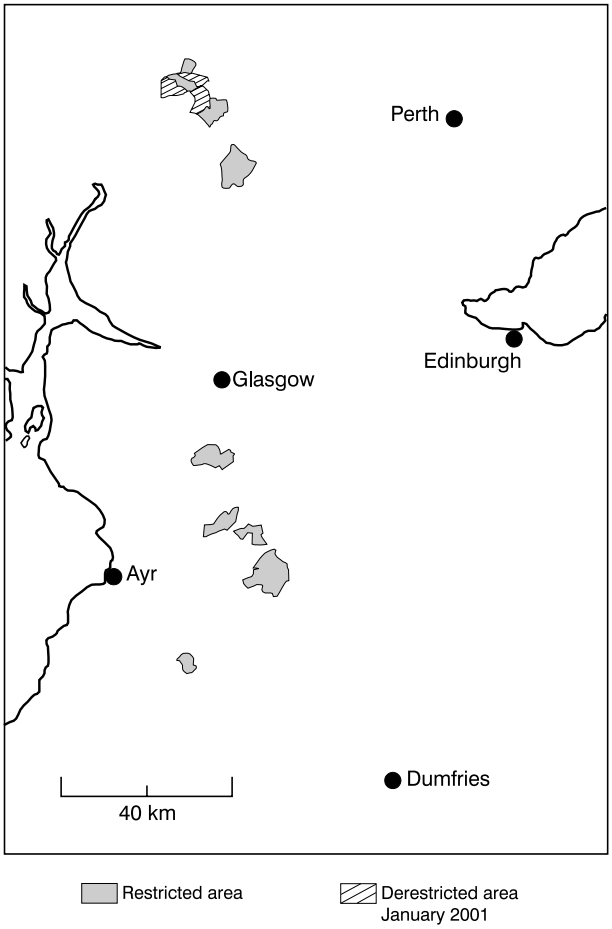

Figure 11.3. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Scotland

In addition, the radiocaesium monitoring of sheep carcasses at slaughterhouses has continued in north Wales and, to a lesser extent in England where there are fewer farms under restriction. This will ensure that continuing restrictions are adequate. The mean result of samples analysed in England in 2000 was 47 Bq kg^{-1} and the highest result was 209 Bq kg^{-1}. In Wales the mean result in 2000 was 33 Bq kg^{-1} and the highest result was 266 Bq kg^{-1}.

In Northern Ireland, concentrations of activity in sheep are well below the action level, and restrictions were removed from the remaining 45 farms in April 2000 (Department of Agriculture and Rural Development, 2000).

Sampling locations for freshwater fish are now limited to Cumbria, an area of relatively high deposition of fallout from Chernobyl. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 11.1 presents concentrations of caesium-134 and caesium-137 in fish and water. Concentrations of other artificial radionuclides from the Chernobyl accident are no longer detectable. Concentrations in perch and brown trout 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 1999 there are likely to be large statistical fluctuations because of the small sampling programme, but concentrations of radiocaesium were generally similar in 2000 to those in 1999. The long-term trend of radiocaesium in freshwater fish has been reviewed by Smith *et al.* (2000b)

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously (Food Standards Agency and SEPA, 2000). A consumption rate of fish of 37 kg $year^{-1}$, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is cautious (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish of much lower radiocaesium concentration may contribute to the diet. In 2000, estimated doses were less than 0.12 mSv.

11.2 Isle of Man

The Food Standards Agency carries out an on-going programme of radioactivity monitoring on behalf of the Department of Local Government and the Environment on the Isle of Man for a wide range of terrestrial foodstuffs. Results are reported in Isle of Man Government press releases in addition to this report. Results of monitoring of aquatic foodstuffs are presented in Section 4 and Tables 4.1-4.3.

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

The results of monitoring for 2000 are presented in Table 11.2. Most radionuclides were present below the limits of detection of the methods used. Carbon-14 was detected in local milk and crops at activity concentrations similar to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Levels of strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of United Kingdom dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. Concentrations of carbon-14 in honey were also typical of background levels in the UK. However, the observed strontium-90 and caesium-137 concentrations were unexpectedly high. Further data will be collected to establish whether these were single anomalous observations. 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 2000.

With the exception of the honey data, which have not been collected before, the results are similar to those obtained in previous years. The dose to the most exposed group from consumption of Manx foodstuffs monitored in 2000 was 0.016 mSv or less than 2% of the principal dose limit for members of the public of 1 mSv.

11.3 Channel Islands

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

The results for 2000 are given in Table 11.3. Concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. However, no evidence for release of activity from the Hurd Deep site was found.

An assessment of the most exposed group of high-rate fish and shellfish consumers gives a dose of 0.005 mSv in 2000 or 0.5% of the principal dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands therefore continued to be of negligible radiological significance. Doses due to discharges from the French reprocessing plant at La Hague and other local sources were less than 1% of the limit.

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. Most samples are derived from the Food Standards Agency's Total Diet Study (TDS). The design of the UK Total Diet Study has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (MAFF, 1994; Peattie *et al*., 1983). The relative importance of each food category within a group reflects its importance in the diet and is based on an average of three previous years of consumption data from the National Food Survey (MAFF, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (MAFF, 1994; Peattie *et al*., 1983). These samples are analysed for a range of food components including radioactivity. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both natural and man-made origins were measured in samples in 2000. 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. Most were close to the limits of detection the various analytical methods used. There was some variability from region to region, for example, the sample from Scotland (Perth) contained twice as much tritium as those from other regions, but no more than is usually detected from the programme. Within the normal variability observed, there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 11.4 and 11.5 have been assessed for adults, infants and 15 and 10-year-old children. In all cases the exposures of infants were higher than other age groups. The data are summarised in Table 11.6. The most important man-made radionuclides were strontium-90 derived from weapons test fallout, and sulphur-35. The

nationwide mean dose for all man-made radionuclides was low at 0.003 mSv. Similar doses were estimated for 1999 (Food Standards Agency and SEPA, 2000).

The mean dose due to consumption of natural radionuclides was 0.14 mSv, which is similar to the mean dose in 1999 of 0.19 mSv. As for 1999, the most important radionuclides were lead-210 and polonium-210. Significant contributions would also have been made by other members of the uranium-238 and thorium-232 decay series that were not determined in this year's analytical schedule. Further data for these nuclides is provided by MAFF (1995). The results demonstrate that natural radionuclides are by far the most important source of exposure in the average diet of consumers and man-made radionuclides only contributed about 2% of the mean dose.

11.5 Milk

The programme of milk sampling in the United Kingdom continued in 2000. Samples were collected monthly and analysed for natural and man-made radionuclides. The programme, together with that for crops presented in the following Section, provides useful information with which to compare data from farms close to nuclear sites and other establishments which may enhance concentrations above background levels. The data from this programme are supplied to the European Commission as part of the requirements under the EURATOM treaty (e.g. JRC, 1998).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2000 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 expected in rain. Raised values of 16 and 22 Bq l^{-1} were found at Tyneside and Londonderry respectively. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels. The concentration of strontium-90 was less than 0.04 Bq l^{-1}. The levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout.

The assessed doses from consumption of dairy milk at average rates were highest to the one-year-old infant age group. For the full range of radionuclides analysed, the average dose was 0.033 mSv that was dominated by the presence of the natural radionuclides lead-210 and polonium-210. Man-made radionuclides contributed less than 5% to these exposures.

11.6 Crops, bread and meat

The programme of monitoring natural and man-made radionuclides in crops continued in 2000 (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. Within the normal variability observed, the concentrations of other radionuclides in crops were similar to those observed in 1999.

Sampling of bread and meat continued in Scotland in 2000. The results, presented in Tables 11.9 and 11.10, show the presence of low levels of man-made and natural radionuclides consistent with naturally occurring sources, and from weapons testing and Chernobyl fallout. The levels observed were similar to those in 1999.

11.7 Fresh water

Sampling and analysis of fresh water throughout Scotland continued in 2000. Analyses of tritium, strontium-90, caesium-137 and total alpha and beta activity were undertaken. The results, in Table 11.11, were generally similar to those found in England and Wales (Environment Agency, 2000). Detectable amounts of tritium were observed in samples from Dumfries and Galloway, however they were of negligible radiological significance. Such levels have been detected before (MAFF and SEPA, 1998). The concentrations continued to be at the low levels of recent years. An assessment of the dose to high-rate consumers on the basis of the highest concentrations observed gave an estimated dose of less than 0.001 mSv in 2000.

11.8 Seawater surveys

Seawater surveys support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000) and provide information which can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Therefore a programme of 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, 1993a-c) and have been used to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). Data have also been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999b). The research vessel programme on radionuclide distribution currently comprises cruises in the Irish Sea, Scottish waters and the North Sea every two or three years. The results of the 2000 cruises are presented in Figures 11.4 - 11.6. Data from shoreline sampling in the Irish Sea and Scottish waters in 2000 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 l^{-1} and 2-20 mBq l^{-1} respectively. The 2000 data for the North Sea show similar levels to those observed from sampling in recent years, the general distribution throughout UK waters being one of falling concentrations as the distance from Sellafield increases. This distribution is governed by the effects of activity previously discharged which has become associated with seabed sediments but is now being remobilised into the water column, and to a lesser extent, recent discharges from the Sellafield site. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically up to 30,000 mBq l^{-1} (Baxter *et al.*, 1992), when discharges were substantially higher.

The concentrations of tritium observed in the North Sea (Figure 11.5) were lower than those observed in the Irish Sea (Food Standards Agency and SEPA, 2000) due to the influence of discharges from Sellafield. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 11.6).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed since 1994 due to increases in discharges of this nuclide from Sellafield. The results of research cruises to study this radionuclide have been published by Leonard *et al.* (1997a and b, 2001a). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*. (1999). A full review of the quality status of the north Atlantic has been published by OSPAR (2000).

Measurements of beta and potassium-40 activity in water from the Clyde in 2000 gave results of <820 and <2590 mBq kg^{-1} respectively. These concentrations are similar to those for 1999.

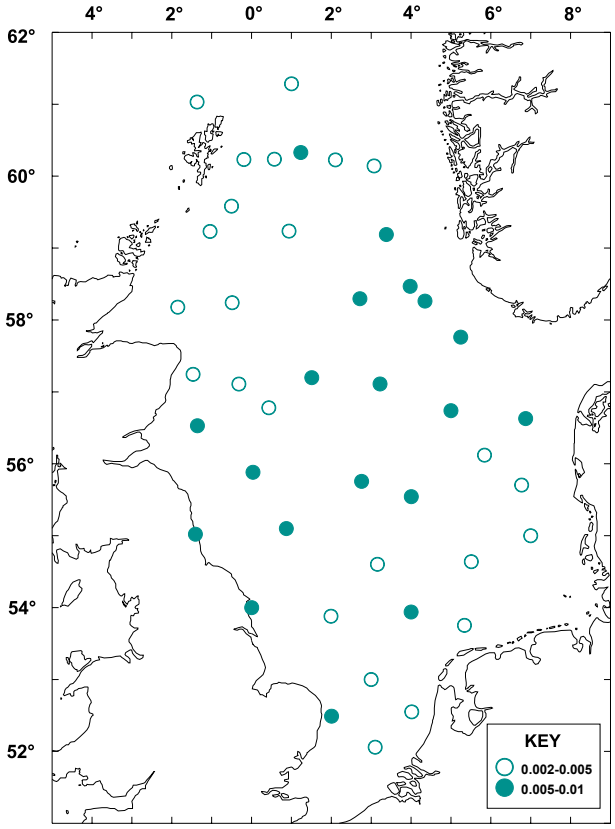

Figure 11.4. Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the North Sea, August-September 2000

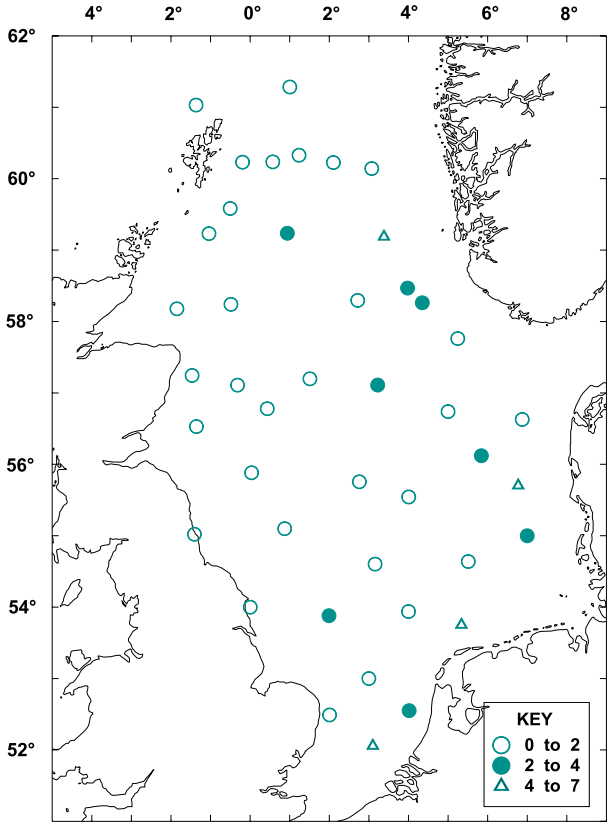

Figure 11.5. Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, August-September 2000

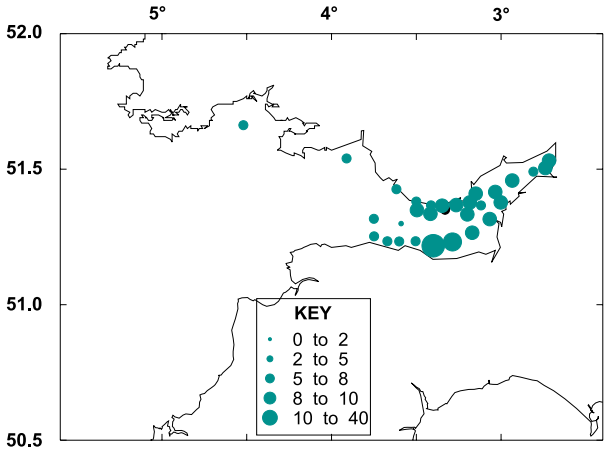

Figure 11.6. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September 2000

Table 11.1. Caesium radioactivity in the freshwater environment, 2000

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.06	0.32
Narborough[b]	Rainbow trout	1	<0.08	0.13
Ennerdale Water	Water	1	*	0.001
Devoke Water	Perch	1	1.0	240
Devoke Water	Brown trout	1	0.30	55
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.09	<0.08
Scotland				
Loch Dee	Water	3	*	0.02

** not detected by the method used*

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

[b] Concentrations of 43, 0.000050, 0.00022, 0.00031 Bq kg^{-1} (wet) of ^{14}C, ^{238}Pu, $^{239+240}$Pu and ^{241}Am were also detected in this sample

Table 11.2. Radioactivity in terrestrial food from the Isle of Man, 2000

Material or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk	2	<4.3	16	<0.60	<0.29	0.049	<0.94	<1.3	<0.0050	<1.7	<0.49
Milk max		<4.5	17		<0.30	0.055	<0.98	<1.4		<1.8	<0.55
Cabbage	1	5.0	<3.0	<0.60	<0.30	1.3	<0.60	<0.60	<0.033	<2.1	<0.70
Honey	1	13	100	<0.50	<0.20	2.0	<0.60	<0.50		<2.2	<0.90
Potatoes	1	4.0	20	1.2	<0.40	0.073	<0.60	<0.40	<0.030	<3.0	<0.60

Material or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{129}I	Total Cs	^{144}Ce	^{147}Pm	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Milk	2	<0.010	0.10	<1.4	<0.20	<0.00020	<0.00020	<0.050	<0.00020
Milk max									
Cabbage	1	<0.047	0.052	<1.4	0.30	<0.00030	0.00050	<0.058	0.00020
Honey	1		14	<2.3					
Potatoes	1	<0.053	0.030	<1.1	<0.20	<0.00030	0.00010	<0.064	0.00030

[a] *Except for milk where units are Bq l^{-1}*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima If no 'max' value is given the mean is also the maximum.*

Table 11.3. Radioactivity in seafood and the environment near the Channel Islands, 2000

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{154}Eu
Rays	Guernsey	1		<0.04			<0.42		0.28	<0.14
Mackerel	Guernsey	2		<0.13			<1.4		0.27	<0.38
Edible crabs	Guernsey	1		0.07			<0.52		<0.05	<0.16
Edible crabs	Jersey	1		0.14			<0.44		0.06	<0.14
Edible crabs[b]	Alderney	2		0.20		0.14	<1.1		<0.08	<0.30
Spiny spider crab	Jersey	1		0.73			<0.45		<0.04	<0.11
Spiny spider crab	Alderney	2		0.84			<1.2		<0.09	<0.31
Lobsters	Guernsey	1		<0.15			<1.7		<0.14	<0.46
Lobsters[c]	Jersey	1		<0.18		1.2	<1.9		<0.15	<0.48
Lobsters	Alderney	1		<0.18			<1.9		<0.16	<0.45
Oysters	Jersey	1		0.13			<0.48		<0.04	<0.14
Limpets	Guernsey	1		0.06			<0.38		<0.04	<0.12
Limpets	Jersey La Rozel	1		0.16			<0.60		<0.06	<0.19
Scallops	Guernsey	2		<0.11			<1.1		<0.09	<0.30
Scallops	Jersey	1		<0.05			<0.41		<0.04	<0.13
Ormers	Guernsey	1		<0.15			<1.5		<0.12	<0.41
Porphya	Guernsey Fermain Bay	4		<0.09			<0.94		<0.08	<0.25
Porphya	Jersey Plemont Bay	4		<0.06			<0.77		<0.08	<0.18
Fucus vesiculosus	Jersey La Rozel	4		0.32	<0.12	5.9	<0.46		<0.09	<0.18
Fucus vesiculosus	Alderney Quenard Point	2						2.5		
Fucus serratus	Guernsey Fermain Bay	4		<0.24	<0.055	2.1	<0.68		<0.07	<0.23
Fucus serratus	Alderney Quenard Point	4		0.40	<0.087	3.7	<0.41		<0.06	<0.16
Laminaria digitata	Jersey Verclut	4		<0.14			<0.51		<0.09	<0.20
Mud	Guernsey St. Sampson's Harbour	1		3.0			<2.4		2.9	<0.82
Mud	Jersey St Helier	1		11			<2.1		3.3	0.58
Sand	Alderney Lt. Crabbe Harbour	1		<0.20			<1.7		1.7	<0.54
Seawater	Guernsey	4							0.003	
Seawater	Jersey	1							0.001	
Seawater	Alderney	4	<2.6						0.002	

Table 11.3. continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total Beta
Rays	Guernsey	1	<0.13	0.00014	0.00064	0.0012	*	0.000020	100
Mackerel	Guernsey	2	<0.21	0.000027	0.00015	0.00018	*	*	140
Edible crabs	Guernsey	1	<0.18	0.00027	0.00069	0.0024	*	0.00041	49
Edible crabs	Jersey	1	<0.08	0.00085	0.0034	0.0078	*	0.00038	81
Edible crabs[b]	Alderney	2	<0.16	0.00091	0.0017	0.0032	*	0.00052	69
Spiny spider crab	Jersey	1	<0.11			<0.10			58
Spiny spider crab	Alderney	2	<0.16	0.0020	0.0044	0.0060	*	0.0013	49
Lobsters	Guernsey	1	<0.40			<0.56			73
Lobsters[c]	Jersey	1	<0.26	0.00027	0.00076	0.0027	*	0.00042	84
Lobsters	Alderney	1	<0.39	0.00034	0.0011	0.0076	*	0.00034	69
Oysters	Jersey	1	<0.14	0.0023	0.0055	0.0058	*	0.0010	70
Limpets	Guernsey	1	<0.12			<0.11			63
Limpets	Jersey La Rozel	1	<0.14	0.0040	0.0089	0.014	*	0.0019	80
Scallops	Guernsey	2	<0.26	0.0012	0.0035	0.0033	*	0.00038	110
Scallops	Jersey	1	<0.12	0.0038	0.0081	0.0076	0.000032	0.0010	86
Ormers	Guernsey	1	<0.22			<0.11			71
Porphya	Guernsey Fermain Bay	4	<0.15	0.0046	0.015	0.019	*	0.0024	140
Porphya	Jersey Plemont Bay	4	<0.10			<0.09			180
Fucus vesiculosus	Jersey La Rozel	4	<0.13	0.0050	0.011	0.0039	*	0.00074	210
Fucus vesiculosus	Alderney Quenard Point	2							
Fucus serratus	Guernsey Fermain Bay	4	<0.16	0.0064	0.019	0.010	0.000024	0.0015	230
Fucus serratus	Alderney Quenard Point	4	<0.09	0.0097	0.025	0.0090	*	0.0013	220
Laminaria digitata	Jersey Verclut	4	<0.14			<0.17			300
Mud	Guernsey St. Sampson's Harbour	1	<0.55	0.26	0.81	1.0	*	0.13	540
Mud	Jersey St Helier	1	1.4	0.79	1.9	3.5	0.0085	0.45	640
Sand	Alderney Lt. Crabbe Harbour	1	<0.39			0.24			320
Seawater	Guernsey	4							
Seawater	Jersey	1							
Seawater	Alderney	4							

** Not detected by the method used*
[a] *Except for seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *The concentration of ^{14}C was 29 Bq kg^{-1}*
[c] *The concentrations of ^{210}Pb and ^{210}Po were 0.38 and 1.9 Bq kg^{-1} respectively*

Table 11.4. Radioactivity in general diet (TDS survey), 2000

Region	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Wales	1	<6.4	50	0.29	68	0.038	0.06	0.050	0.078
East Midlands	1	<6.1	40	1.0	78	0.046	<0.08	0.0080	0.048
South West	1	<6.3	50	1.7	73	0.036	0.03	0.020	0.035
North East	1	<6.3	60	0.92	68	0.051	<0.04	0.090	0.027
South East	1	<5.7	60	<0.43	100	0.12	<0.09	0.080	0.047
West Midlands	1	<6.5	50	<0.29	68	0.036	<0.05	0.090	0.053
East	1	<6.3	50	0.48	51	0.052	<0.03	0.080	0.055
South	1	<6.3	50	<0.19	68	0.046	0.04	<0.015	0.010
North West	1	<6.3	50	0.88	64	0.045	<0.04	0.030	0.033
Scotland (Perth)[b]	1	12	49	<0.53	63	0.10	<0.06	0.070	0.040
Scotland (Glasgow)[c]	1	<6.1	71	3.2	80	0.12	0.06	0.090	0.080

Region	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
		^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Wales	1	0.024	0.001	<0.023	0.000037	0.00024	<0.00042
East Midlands	1	0.019	<0.0033	0.028	<0.000022	<0.00011	<0.00021
South West	1	0.022	0.0010	<0.022	<0.00010	<0.00020	<0.0010
North East	1	0.023	0.001	0.025	<0.00010	<0.00010	<0.00030
South East	1	0.048	<0.0021	0.025	<0.00034	<0.00020	0.00042
West Midlands	1	0.037	<0.00073	<0.023	<0.00012	<0.00011	<0.00030
East	1	0.028	<0.0011	0.023	<0.00010	<0.00020	<0.0010
South	1	0.041	0.001	<0.022	<0.000075	<0.00010	<0.00020
North West	1	0.032	<0.010	<0.023	<0.000071	<0.000071	<0.00060
Scotland (Perth)[b]	1	0.012	0.001		<0.00010	0.00017	<0.00050
Scotland (Glasgow)[c]	1	0.018	0.024		<0.00010	0.00017	<0.00020

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

[b] *Supplied by SEPA. The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.011, <0.01 and 0.012 Bq kg^{-1} respectively*

[c] *Supplied by SEPA. The concentrations of ^{234}U, ^{235}U and ^{238}U were <0.01 Bq kg^{-1}*

Table 11.5. Radioactivity in regional diet in Scotland, 2000

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{35}S	^{40}K	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	12	<12	<3.0	89	<0.10	<0.15	<0.84
East Lothian (North Berwick)	12	<13	<2.4	83	<0.10	<0.05	
Highland (Dingwall)	12	<10	<3.1	99	<0.10	<0.06	
Renfrewshire (Paisley)	12	<11	<2.3	91	<0.10	<0.15	

Table 11.6. Estimates of radiation exposure from radionuclides in regional diet, 2000

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0002
Sulphur-35	0.001
Strontium-90	0.001
Caesium-137	0.0002
Plutonium-238	0.000009
Plutonium-239+240	0.00001
Americium-241	0.00003
Sub-total	0.003
Natural radionuclides	
Carbon-14	0.02
Lead-210	0.04
Polonium-210	0.08
Radium-226	0.005
Uranium	0.0006
Thorium-232	0.0004
Sub-total	0.14
Total	0.14

[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, 2000

Location	Selection[a]	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}											
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{129}I	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	Total alpha
Co. Antrim		6	<4.0	15		0.028		0.28	<0.029	0.0060	<0.0080	<0.00010	<0.00010	
	max			22		0.031		0.42						
Co. Armagh		5	<4.0	15		0.031		0.070	0.033	0.0060	<0.0080	0.00010	<0.00010	
	max		5.0	20		0.047		0.077						
Cambridgeshire[b]		12	<2.2			0.023		<0.037	<0.039	0.0090	<0.0080	<0.00010	<0.00010	
	max		3.0			0.038		0.060						
Cheshire		12	<4.1	17		0.020		0.078	<0.036	0.0070	<0.0080	0.00010	<0.00010	
	max		5.0	26		0.027		0.23						
Clwyd		12	<4.3	13		0.027		0.051	<0.032	0.0080	<0.0080	<0.00010	<0.00010	
	max		7.0	19		0.040		0.067						
Cornwall		11	<4.2	14		0.044		0.052	<0.035	0.014	<0.0080	<0.00010	<0.00010	
	max		5.0	19		0.058		0.095						
Devon		12	<4.3	14		0.039		0.048	<0.039	0.014	<0.0080	<0.00010	<0.00010	
	max		8.0	17		0.059		0.086						
Co. Down		6	<3.8	13		0.039		0.096	<0.029	0.0070	<0.0080	0.00010	<0.00010	
	max		<4.0	17		0.052		0.20						
Dumfries and Galloway		12	<12	15	<2.1	<0.10	<0.020	<0.084[c]						<0.23
	max		<25	18	<5.0			0.20[c]						<0.30
Edinburgh		12	<11	14	<2.1	<0.10	<0.030	<0.052[c]						<0.21
	max		<25	19	<5.0		<0.040	0.070[c]						<0.25
Co. Fermanagh		5	<4.0	14		0.028		0.19	<0.044	0.0060	<0.0080	<0.00010	<0.00020	
	max			17		0.034		0.31						
Gloucestershire		21	<4.3	16		0.025		0.047	0.042	0.0070	<0.0080	<0.00010	<0.00010	
	max		10	23		0.042		0.11	0.046	0.0080				
Gwent[b]		8	<2.8			0.029		0.048	<0.032	0.0080	<0.0080	<0.00010	<0.00010	
	max		5.0			0.040		0.091						
Gwynedd		8	<3.8	12		0.042		0.052	<0.042	0.0070	<0.0080	<0.00010	0.00010	
	max		4.0	17		0.062		0.090						
Hampshire		13	<4.0	15		0.022		0.048	<0.031	0.0080	<0.0080	<0.00020	0.00010	
	max			20		0.039		0.071						
Highland		12	<10	20	<2.6	<0.10	<0.020	<0.066[c]						<0.23
	max		<25	40	<5.0			0.14[c]						<0.30
Humberside		12	<4.0	18		0.020		0.037	<0.032	0.011	<0.0080	<0.00010	<0.00010	
	max		4.0	24		0.037		0.071						
Lancashire		12	<4.3	14		0.034		0.076	<0.034	0.0060	<0.0080	0.00010	<0.00010	
	max		9.0	22		0.048		0.16						
Leeds		12	<4.3	16		0.032		0.048	<0.040	0.010	<0.0080	<0.00010	<0.00010	
	max		8.0	22		0.062		0.086						
Leicestershire		12	<3.9	17		0.018		0.033	0.049	0.0060	<0.0080	<0.00010	<0.00010	
	max		4.0	28		0.038		0.051						

Table 11.7. continued

Location	Selection[a]	No. of sampling observ-ations	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
Lincolnshire		12	<4.0	16		0.019		0.034	<0.035	0.0070	<0.0080	<0.00010	<0.00010	
	max			22		0.035		0.057						
Co. Londonderry		7	<6.6	17		0.034		0.13	<0.049	0.0030	<0.0080	<0.00010	<0.00020	
	max		22	21		0.044		0.23						
Middlesex		10	<4.0	15		0.024		<0.046	<0.038	0.0060	<0.0080	<0.00010	<0.00010	
	max			19		0.037		0.082						
Norfolk		12	<4.3	13		0.019		0.044	<0.031	0.0080	<0.0080	<0.00010	0.00010	
	max		7.0	19		0.030		0.060						
North Lanarkshire		12	<5.6	19	<1.6	<0.10		<0.078[c]						<0.10
	max		<8.2	28	3.7			0.14[c]						<0.13
North Yorkshire		12	<4.4	17		0.030		0.042	<0.044	0.0090	<0.0080	<0.00020	<0.00020	
	max		9.0	23		0.088		0.092						
Oxfordshire		12	<4.4	15		0.021		0.056	<0.033	0.0060	<0.0080	<0.00010	<0.00010	
	max		7.0	21		0.037		0.10	<0.035	0.0090				
Renfrewshire		12	<11	14	<2.3	<0.10	<0.020	<0.11[c]						<0.20
	max		<25	19	<5.0			0.20[c]						<0.25
Shropshire		12	<4.0	14		0.032		0.052	<0.043	0.011	<0.0080	0.00010	<0.00010	
	max			21		0.048		0.091						
Somerset		12	<4.0	14		0.044		0.072	0.052	0.016	<0.0080	<0.00010	<0.00010	
	max			18		0.11		0.17						
Suffolk		12	<4.0	16		0.011		0.038	<0.034	0.0070	<0.0080	<0.00010	<0.00010	
	max		4.0	26		0.019		0.070						
Co.Tyrone[b]		12	<2.6			0.033		0.13	<0.041	0.0040	<0.0080	<0.00010	<0.00010	
	max		8.0			0.053		0.18						
Tyneside		11	<7.4	14		<0.031		0.055	<0.036	0.0070	<0.0080	<0.00010	<0.00010	
	max		16	23		0.049		0.11						
West Midlands		3	<4.0	16		0.018		0.058	<0.043	0.012	<0.0080	<0.00010	0.00010	
	max			19		0.020		0.063						
Mean Values														
England			<4.3	15.2		<0.026		<0.050	<0.038	0.0088	<0.0080	<0.00011	<0.00010	
Northern Ireland			<4.2	14.7		0.032		0.15	<0.038	0.0053	<0.008	<0.00010	<0.00013	
Wales			<3.6	13		0.033		0.050	<0.035	0.0077	<0.0080	<0.00010	<0.00010	
Scotland			<9.9	16	<2.1	<0.10	<0.023	<0.078						<0.19
United Kingdom			<5.1	15		<0.039		<0.066	<0.038	0.0084	<0.0080	<0.00011	<0.00011	

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' is given then the mean is also the maximum. See section 3 for definition.*

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

[c] *^{137}Cs only*

Table 11.8. Radioactivity in crops remote from nuclear sites, 2000[b]

Location	Material	No of samples	Mean radioactivity concentration (wet), Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total Alpha
Caernarfonshire																
Bangor	Apples	1	<4.0	12		0.12	0.039	0.12	0.045	0.0060	<0.00090	<0.028	<0.00020	<0.00030	0.00090	
	Leafy Beet/ Curly Kale	1	<4.0	<2.0		0.13	0.064	1.8	0.27	0.13	0.0052	<0.046	<0.00020	0.0013	0.0034	
Devon																
Barnstaple	Kale	1	<5.0	<5.0		1.1	<0.031	0.11	0.058	0.023	0.0040	<0.038	<0.00020	<0.00030	<0.00030	
	Strawberries	1				0.14	0.90	0.032	0.020	0.017	<0.0026	<0.040	<0.00020	<0.00030	<0.00040	
Crediton	Kale	1	<5.0	19		<0.018	<0.037	0.83	0.21	0.11	<0.0014	<0.047	0.00060	<0.00030	0.0012	
	Swede	1	<4.0	<2.0		0.28	0.087	<0.037	0.025	0.0070	0.0040	<0.035	<0.00020	<0.00030	0.0012	
Dumfries and Galloway																
Dumfries	Leafy Green Veg	4	<10	5.0	<1.7	<0.10	<0.060[a]									<0.19
Durham																
Greatham	Cabbage	1				0.38	0.084	0.29	0.17	0.023	0.0075	<0.046	0.00020	<0.00020	<0.00030	
	Potatoes	1	<5.0	13		0.049	0.22	<0.033	0.026	0.010	0.0048	<0.048	<0.00010	0.00030	<0.00060	
Westgate	Leafy Green Veg	1	<4.0	<2.0		0.26	0.036	<0.030	0.028	0.010	0.0038	<0.040	<0.00020	<0.00030	<0.00080	
	Rosehips	1	10	15		1.1	0.096	1.3	0.65	0.021	0.0032	<0.046	<0.00020	<0.00040	0.00030	
East Lothian																
North Berwick	Leafy Green Veg	4	<11	5.8	<2.3	<0.10	<0.057[a]									<0.18
Herefordshire																
Hereford	Cabbage	1	<5.0	<6.0		0.18	0.042	<0.028	0.0080	0.018	<0.0018	<0.035	0.00010	<0.00020	<0.00040	
	Raspberries	1	<4.0	11		0.068	<0.037	0.069	0.021	0.0050	<0.0013	<0.017	<0.00020	0.00020	0.00020	
Kent																
Folkestone	Beetroot	1	<4.0	6.0		0.16	0.21	0.039	0.024	0.027	0.013	0.081	<0.00020	0.00040	<0.00040	
	Cabbage	1	8.0	4.0		0.23	0.082	<0.033	0.033	0.012	<0.0059	<0.039	<0.00020	0.00010	0.00070	
Whitstable	Potatoes	1	<4.0	18		0.049	0.13	<0.042	<0.0050	0.012	0.0044	0.035	<0.00020	0.00030	0.00060	
	Raspberries	1	<6.0	7.0		0.13	<0.031	<0.035	0.019	0.020	0.042	<0.020	0.00010	0.00010	<0.00040	
Lancashire																
Blackpool	Cauliflower	1	<4.0	<2.0		0.48	<0.037	0.30	0.10	0.024	<0.0011	<0.036	<0.00020	<0.00040	0.0025	
Bolton	Kale	1	<5.0	22		1.3	0.36	0.65	0.25	0.060	<0.0023	<0.041	<0.00030	<0.00030	<0.00050	
	Potatoes	1	<5.0	16		0.062	0.037	<0.029	0.014	0.012	0.0087	<0.041	<0.00020	<0.00030	0.00050	
Highlands																
Dingwall	Leafy Green Veg	4	<10	4.6	<1.6	<0.10	<0.050[a]									<0.19
Lincolnshire																
Market Rasen	Carrots	1	<5.0	8.0		0.15	<0.029	<0.039	0.020	0.077	0.0096	0.040	<0.00020	<0.00020	0.00050	
	Kale	1	<4.0	<2.0		0.95	0.082	0.61	0.28	0.11	0.054	0.37	<0.00010	0.00090	0.0032	

Table 11.8. continued

Location	Material	No of samples	Mean radioactivity concentration (wet), Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total Alpha
Merioneth																
Harlech	Cabbage/ Carrot tops	1	<4.0	8.0		3.4	0.16	3.9	1.2	0.29	0.053	0.060	0.00010	0.0022	0.0029	
	Potatoes	1	<3.0	9.0		1.7	<0.033	<0.043	0.024	0.033	0.0055	0.061	<0.00020	<0.00030	0.0014	
Norfolk																
Cromer	Blackcurrants	1	<4.0	7.0		0.13	<0.026	0.10	0.068	0.016	<0.0014	<0.024	0.00010	0.00020	<0.00050	
	Cabbage	1	<4.0	<3.0		0.14	0.046	<0.039	0.010	0.0070	<0.0011	<0.027	<0.00010	<0.00010	<0.00060	
Renfrewshire																
Paisley	Leafy Green Veg	4	<10	5.3	<1.6	<0.10	<0.050[a]									<0.24
Rutland																
Oakham	Cabbage	1	<4.0	5.0		0.077	<0.031	<0.028	0.014	0.0040	<0.0011	<0.018	<0.00020	<0.00020	<0.00030	
	Strawberries	1	<4.0	6.0		0.039	0.28	<0.028	0.023	0.0050	<0.0024	<0.032	<0.00020	0.00020	<0.00050	
Shropshire																
Telford	Cabbage/Leek	1	<4.0	<2.0		0.14	<0.034	<0.035	0.095	0.014	0.0024	<0.025	<0.00020	<0.00030	<0.00030	
	Strawberries/ Raspberries	1	<3.0	10		0.055	0.033	0.044	0.019	0.011	<0.0015	<0.032	<0.00010	0.00030	0.00020	
Somerset																
Bath	Cabbage	1	<4.0	7.0		0.12	0.055	0.080	0.021	0.0090	<0.0011	<0.034	<0.00020	<0.00030	0.00090	
	Strawberries	1	6.0	14		0.14	<0.032	0.076	0.024	0.044	<0.0010	<0.016	<0.00020	<0.00030	0.0010	
Yeovil	Cabbage	1	<4.0	<2.0		0.12	<0.028	<0.026	0.015	0.017	<0.0022	<0.024	<0.00020	<0.00030	<0.00030	
	Sugar Beet	1	<5.0	21		0.25	0.057	0.093	0.070	0.052	0.046	0.10	<0.00010	<0.00020	0.00030	
Suffolk																
Bury St Edmunds	Cabbage	1	<4.0	<3.0		0.10	<0.026	<0.040	0.016	<0.0040	<0.0014	<0.033	<0.00010	0.00020	<0.00040	
	Potatoes	1	<4.0	19		0.030	<0.025	<0.054	0.015	0.013	0.0062	<0.042	<0.00010	<0.00020	<0.00050	
Westmorland																
Ambleside	Potatoes	1	<4.0	21		0.11	0.11	0.055	0.072	0.013	0.014	<0.032	<0.00020	0.00060	0.00030	
	Rhubarb	1	7.0			0.93	0.057	0.33	0.13	0.057	<0.0017	<0.035	<0.00020	<0.00030	0.0015	
Worcestershire																
Great Malvern	Beetroot	1	3.0	<3.0		0.095	<0.031	0.047	0.026	0.058	0.033	0.074	<0.00030	0.00080	0.0011	
	Kale	1	<4.0	<2.0		0.086	0.037	0.96	0.24	0.018	0.0080	0.064	0.00060	<0.00030	0.00080	
Mean Values																
England			<4.7	<8.8		<0.28	<0.099	<0.19	<0.081	<0.027	<0.0086	<0.049	<0.00020	<0.00030	<0.00070	
Wales			<3.8	<7.8		1.3	<0.074	1.4	0.40	0.11	<0.016	<0.049	<0.00018	<0.0010	0.0022	
Scotland			<10	<5.2	<1.8	<0.10	<0.054									<0.20
Great Britian			<6.2	<7.7		<0.30	<0.12	<0.32	<0.11	<0.036	<0.0094	<0.049	<0.00020	<0.00038	<0.00085	

[a] *^{137}Cs only*

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

Table 11.9. Radioactivity in bread in Scotland, 2000

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<10	75	<2.7	<0.10	<0.06	<0.61
East Lothian (North Berwick)	4	<11	63	<4.1	<0.10	<0.06	<1.2
Highland (Dingwall)	4	<10	77	<6.6	<0.10	<0.08	<1.9
Renfrewshire (Paisley)	4	<10	73	<2.2	<0.10	<0.05	<0.65

Table 11.10. Radioactivity in meat in Scotland, 2000

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<10	40	<6.8	<0.13	<1.0	<0.27
East Lothian (North Berwick)	4	<10	42	<8.0	<0.10	<0.09	<0.31
Highland (Dingwall)	4	<10	34	<9.1	<0.10	0.14	<0.28
Renfrewshire (Paisley)	4	<10	35	<10	<0.10	0.44	<0.48

Table 11.11. Radioactivity in freshwater in Scotland, 2000

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee[a]	12	<1.5	<0.0050	<0.0093		
Argyll and Bute	Auchengaich	1	<1.2	0.0077		<0.010	0.039
Argyll and Bute	Helensburgh Reservoir	3			<0.023	<0.018	<0.030
Argyll and Bute	Loch Ascog	3			<0.010	<0.020	0.11
Argyll and Bute	Loch Eck	1	<1.2	0.0064		<0.030	0.10
Argyll and Bute	Loch Finlas	3			<0.023	<0.018	0.035
Argyll and Bute	Lochan Ghlas	3			<0.023	<0.020	0.054
Clackmannanshire	Gartmorn	1	<1.2	<0.0050		<0.020	0.21
Dumfries and Galloway	Black Esk	1	4.2	<0.005		<0.014	0.017
Dumfries and Galloway	Purdomstone	3			<0.010	<0.020	0.073
Dumfries and Galloway	Winterhope	1	19	0.0071		<0.012	0.037
East Lothian	Hopes Reservoir	1	<1.2	<0.0050		<0.020	0.032
East Lothian	Thorters Reservoir	1	<1.2	<0.0050		<0.020	0.060
East Lothian	Whiteadder	3			<0.010	<0.020	0.048
Fife	Holl Reservoir	1	<1.2	<0.0050		<0.020	0.036
Highland	Loch Baligill	1	<1.2	<0.0050		<0.020	0.051
Highland	Loch Calder	3			<0.010	<0.027	0.061
Highland	Loch Glass[b]	11	<1.4	<0.0051	<0.011		
Highland	Loch Shurrerey	1	<1.2	<0.0050		<0.020	0.044
North Ayrshire	Camphill	1	<1.2	0.0062		<0.020	0.047
North Ayrshire	Knockendon Reservoir	3			<0.010	<0.019	0.042
North Ayrshire	Munnoch Reservoir	1	<1.2	0.0072		<0.020	0.066
North Ayrshire	Outerwards	1	<1.2	0.0055		<0.020	0.035
Orkney Islands	Heldale Water	1	<1.2	<0.0050		<0.020	0.032
Perth and Kinross	Castlehill	3			<0.010	<0.018	0.026
Scottish Borders	Knowsdean[c]	12	<1.6	<0.0050	<0.0087		
Stirling	Loch Katrine[d]	11	<1.4	<0.0061	<0.0093		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.3			<0.010	0.019
West Lothian	Morton No. 2	1	<1.2	<0.0050		<0.020	0.059

[a] *The concentration of ^{40}K was 0.17 Bq l^{-1}*
[b] *The concentration of ^{40}K was <0.59 Bq l^{-1}*
[c] *The concentration of ^{40}K was <0.07 Bq l^{-1}*
[d] *The concentration of ^{40}K was <0.53 Bq l^{-1}*

Table 11.12. Radioactivity in sea water from the Irish Sea and Scottish waters, 2000

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
		^{3}H	^{99}Tc	^{134}Cs	^{137}Cs
Seascale	4			<0.0006	0.16
St. Bees	12	17	0.11	<0.004	0.19
Whitehaven	1			*	0.15
Maryport	1			0.001	0.19
Silloth	1			0.003	0.35
Silecroft	1			*	0.12
Walney- west shore	4	13		*	0.14
Isle of Whithorn	1			*	0.07
Drummore	1			*	0.05
Half Moon Bay	1			0.002	0.22
Rossal (Fleetwood)	1			0.003	0.16
Ainsdale	1			0.002	0.13
New Brighton	1			*	0.13
Ross Bay	1			*	0.10
North of Larne	12		0.018	*	0.03
Seafield	3	7.2		<0.10	<0.25
Southerness[a]	4	8.3		<0.10	0.21
Carsethorn	2	3.7			
North Solway[b]	3	6.6			
Knock Bay[c]	8	<2.0		<0.03	<0.06
Prestatyn	1			*	0.06
Llandudno	1			*	0.07
Holyhead	4	<1.9		*	0.04

** not detected by the method used*
[a] *Concentrations of <0.0015, <0.0062 and <0.036 Bq l^{-1} of ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were determined*
[b] *Concentration of 7.7 Bq l^{-1} of ^{90}Sr was determined*
[c] *Concentration of <1.4 Bq l^{-1} of ^{90}Sr was determined*

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

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

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

The contents of the research programmes are regularly reviewed and open meetings are held each year to discuss ongoing and completed projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000).

A list of related research projects completed in 2000 is presented in Table 12.1. Those sponsored by the Food Standards Agency are also listed on the internet (www.foodstandards.gov.uk). Copies of the final reports for each of those projects funded by the Food Standards Agency are available from the Radiological Safety Unit, Aviation House, 125 Kingsway, London WC2B 6NH. A charge may be made to cover photocopying and postage. Table 12.1 also provides information on projects that are currently underway. The results of these projects will be made available in due course. A short summary of the key points from specific projects that have recently been completed is given here.

Discharges to sewers – AIR (98) 10

This study considered the effects of radioactive discharges from non-nuclear sites such as hospitals, universities and research centres into public sewers (Titley *et al.*, 2000). Two case studies of large urban systems in Leeds and Central London were made, and a modelling system was set up for application to other situations. The effects of incineration of sewage were included.

On the basis of the study it was found that:

- Discharge reduction measures and further data on the radionuclide behaviour in incinerators were not needed
- Radionuclide specific limits for the more significant radionuclides should be considered.
- Discharge into sewer systems is a safe disposal option and is acceptable in the urban situation studied.

The project was undertaken jointly for EA, SEPA and the Industrial Pollution and Radiochemical Inspectorate (Northern Ireland).

Cardiff special survey – project RO3013

This survey was designed to supplement the routine surveillance programme in the vicinity of the Nycomed Amersham site at Cardiff (Swift, 2001). The results are summarised in Section 8 of this report.

Accumulation of technetium-99 in the Irish Sea – project RO1031

The research was directed at understanding the mechanisms of dispersion and bioaccumulation of technetium-99 in the Irish Sea (Leonard *et al.*, 2001a). Observational data were collected from CEFAS research cruises and the data obtained provided information on:

- distributions of technetium-99 in space and time in the water column, sediments and biota
- bioaccumulation factors
- sediment distribution coefficients
- radiation exposure of humans

Organic forms of tritium in foodchains – project RO1023

The relatively high concentrations of tritium observed in the Severn Estuary/Bristol Channel were investigated. Almost all the tritium found in sediment and biota was organically bound. It was suggested that bioaccumulation by benthic organisms and demersal fish occurred primarily via physico-chemical sorption/bacterial transformation of dissolved organic tritium labelled compounds into particulate organic matter, and subsequent transfer up a web of sediment dwelling microbes and meiofauna. The source of such labelled compounds was Nycomed Amersham at Cardiff (Leonard *et al.*, 2001b).

Computerisation of archive records – project RO3016

The formal paper archive of historic surveillance records held by CEFAS was computerised in order to secure the data for future use. The data comprised about 50000 analytical results for fish, shellfish and some seaweeds taken from England and Wales from 1959-1984. Data after this period has already been computerised. The data is now available for research purposes (Winpenny *et al.*, 2001).

Table 12.1. Extramural projects in support of the monitoring programmes

	Further details	Target completion date
RIFE Trend studies	F	Ongoing
Cardiff special survey	F	Complete
Accumulation of technetium-99 in the Irish Sea	F	Complete
Organic tritium in seafood	F	Complete
Access to CEFAS data archive	F	Complete
Computerisation of archive records	F	Complete
Discharges to sewers	S	Complete
Analysis of TDS and industrial samples 1997-2000	F	Complete
Assessment of contaminated land	S	Jun-01
Seasonal variations in radionuclides in crabs and lobsters	F	Jul-01
Methods for censored data sets	F	Sep-01
Effects of radiation on aquatic organisms	S	Oct-01
Development of TRAMS database	F	Dec-01
^{36}Cl method development	F	Dec-01
Northern Ireland and Solway Firth critical groups	S	Dec-01
Cs, Am and Pu in Northern Irish waters	S	Dec-01
U analyses in food and indicators	F	Feb-02
Dietary studies near nuclear installations	F	Mar-02
Natural radionuclides in seafood	F	Mar-02
Uncommon seafoods	F	Mar-02
Tritium and carbon-14 in seafood	F	Mar-02
Assessment of UK laboratory performance: tritium in fish and milk	F	Mar-02
Airborne survey	S	Mar-02
Surveillance of farmed fish	F	Mar-02
Natural radionuclides in wildfood	F	Jul-02
Soil and herbage survey	S	Jun-03
Dietary and occupancy surveys	S	Mar-04

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

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APPENDIX 1. DISPOSALS OF RADIOACTIVE WASTE*

Table A1.1. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2000

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Capenhurst[r]				
Rivacre Brook	Uranium	0.02	0.00116	5.8
	Uranium daughters	0.02	0.0024	12
	Non-uranic alpha	0.003	$1.22\ 10^{-4}$	4.1
	Technetium-99	0.1	0.00151	1.5
Chapelcross	Alpha	0.1	$6.29\ 10^{-4}$	<1
	Beta[e]	25	0.193	<1
	Tritium	5.5	0.546	9.9
Drigg				
Sea pipeline	Alpha	0.1	$1.05\ 10^{-4}$	<1
	Beta[e]	0.3	0.00165	<1
	Tritium	120	0.495	<1
Stream[f]	Alpha	$9.0\ 10^{4}$	193	<1
	Beta[e]	$1.2\ 10^{6}$	547	<1
	Tritium	$6.0\ 10^{8}$	$3.24\ 10^{4}$	<1
Sellafield	Alpha	1	0.12	12
Sea pipelines[v]	Beta	400	76.6	19
	Tritium	$2.5\ 10^{4}$	2260	9.0
	Carbon-14	20.8	4.61	22
	Cobalt-60	13	1.2	9.2
	Strontium-90	48	19.7	41
	Zirconium-95+Niobium-95	9	0.18	2.0
	Technetium-99	90	44.4	49
	Ruthenium-106	63	2.68	4.3
	Iodine-129	1.6	0.47	29
	Caesium-134	6.6	0.23	3.5
	Caesium-137	75	6.91	9.2
	Cerium-144	8	0.55	6.9
	Plutonium alpha	0.7	0.12	17
	Plutonium-241	27	3.2	12
	Americium-241	0.3	0.03	10
	Uranium[d]	2040	610	30
Sellafield				
Factory sewer	Alpha	0.0033	$3.5\ 10^{-5}$	1.1
	Beta	0.0135	$4.9\ 10^{-4}$	3.6
	Tritium	0.132	0.01	7.6
Springfields	Alpha	4	0.173	4.3
	Beta	240	71.3	30
	Technetium-99	0.6	0.0349	5.8
	Thorium-230	2	0.0693	3.5
	Thorium-232	0.2	0.0009	0.4
	Neptunium-237	0.04	0.0005	1.1
	Uranium	0.15	0.0587	39

* *These data are supplied by site operators to the SEPA and EA. Whilst every effort is made to ensure the data are correct at the time of publishing, the Food Standards Agency and SEPA do not guarantee their accuracy.*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq[a]	% of limit[b]
United Kingdom Atomic Energy Authority				
Dounreay	Alpha[c]	0.27	0.00156	<1
	Beta[e]	49	0.304	<1
	Tritium	30.8	0.0880	<1
	Cobalt-60	0.46	$7.12\ 10^{-4}$	<1
	Strontium-90	7.7	0.156	2.0
	Zirconium-95+Niobium-95	0.4	$7.27\ 10^{-4}$	<1
	Ruthenium-106	4.1	0.00175	<1
	Silver-110m	0.13	$2.72\ 10^{-4}$	<1
	Caesium-137	23	0.0140	<1
	Cerium-144	0.42	0.00113	<1
	Plutonium-241	2.3	0.00303	<1
	Curium-242	0.04	$2.58\ 10^{-6}$	<1
Harwell (pipeline)	Alpha	0.001	$1.27\ 10^{-5}$	1.3
	Beta[e]	0.02	0.00149	7.5
	Tritium	4	0.0651	1.6
	Cobalt-60	0.007	$7.86\ 10^{-5}$	1.1
	Caesium-137	0.007	$1.67\ 10^{-4}$	2.4
Harwell (Lydebank Brook)	Alpha	$5\ 10^{-4}$	$1.94\ 10^{-5}$	3.9
	Beta[e]	0.002	$1.22\ 10^{-4}$	6.1
	Tritium	0.1	0.0180	18
Winfrith (inner pipeline)	Alpha	0.3	0.00103	<1
	Tritium	650	4.20	<1
	Cobalt-60	10	0.0113	<1
	Zinc-65	6	$3.24\ 10^{-4}$	<1
	Other radionuclides	80	0.0739	<1
Winfrith (outer pipeline)	Alpha	0.004	$4.15\ 10^{-5}$	1.0
	Tritium	1	0.0062	<1
	Other radionuclides	0.01	$6.44\ 10^{-5}$	<1
Magnox Electric[h]				
Berkeley	Tritium	8	0.00639	<1
	Caesium-137	0.2	0.0175	8.8
	Other radionuclides	0.4	0.022	5.5
Bradwell	Tritium	30	0.649	2.2
	Caesium-137	0.75	0.487	65
	Other radionuclides	1	0.17	17
Dungeness 'A' Station	Tritium	35	1.09	3.1
	Caesium-137	1.2	0.13	11
	Other radionuclides	1.4	0.438	31
Hinkley Point 'A' Station	Tritium	25	1.27	5.1
	Caesium-137	1.5	0.3	20
	Other radionuclides	1	0.1	10
Hunterston 'A' Station	Total activity[e]	2	0.138	6.9
	Tritium	5	0.00278	<1
Oldbury	Tritium	25	0.354	1.4
	Caesium-137	0.7	0.064	9.1
	Other radionuclides	1.3	0.15	12

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq[a]	% of limit[b]
Sizewell				
'A' Station	Tritium	35	1.582	4.5
	Caesium-137	1.0	0.144	14
	Other radionuclides	0.7	0.172	25
Trawsfynydd	Total activity[e,i,j]	0.72	0.0271	3.8
	Tritium	12	0.53	4.4
	Strontium-90	0.08	0.0015	1.9
	Caesium-137	0.05	0.0018	3.6
Wylfa	Tritium	40	4.02	10
	Other radionuclides	0.15	0.029	19
British Energy Generation Ltd				
Dungeness				
'B' Station	Tritium	650	119	18
	Sulphur-35	2	0.117	5.9
	Cobalt-60	0.03	0.00154	5.1
	Other radionuclides	0.25	0.0171	6.8
Hartlepool	Tritium	1200	411	34
	Sulphur-35	3	1.22	41
	Cobalt-60	0.03	0.00327	11
	Other radionuclides	0.3	0.00193	0.64
Heysham				
Station 1	Tritium	1200	441	37
	Sulphur-35	2.8	0.121	4.3
	Cobalt-60	0.03	0.00105	3.5
	Other radionuclides	0.3	0.0142	4.7
Station 2	Tritium	1200	337	28
	Sulphur-35	2.3	0.0375	1.6
	Cobalt-60	0.03	$3.66\ 10^{-4}$	1.2
	Other radionuclides	0.3	0.0148	4.9
Hinkley Point				
'B' Station	Tritium	620	352	57
	Sulphur-35	5	0.347	6.9
	Cobalt-60	0.033	$3.00\ 10^{-4}$	<1
	Other radionuclides	0.235	0.0173	7.4
Sizewell				
'B' Station	Tritium	80	53.1	66
	Other radionuclides	0.2	0.0604	30
British Energy Generation (UK) Ltd				
Hunterston				
'B' Station	Alpha	0.001	$6.0\ 10^{-5}$	6.0
	Beta[e,g,p]	0.45	0.00361	<1
	Tritium	800	326	41
	Sulphur-35	10	1.64	16
	Cobalt-60	0.03	$4.6\ 10^{-4}$	1.5
Torness	Alpha	0.001	$1.25\ 10^{-5}$	1.3
	Beta[e,g,p]	0.45	$2.78\ 10^{-3}$	<1
	Tritium	800	234	29
	Sulphur-35	10	0.0189	<1
	Cobalt-60	0.03	$3.46\ 10^{-4}$	1.2

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq[a]	% of limit[b]
Ministry of Defence				
Aldermaston (pipeline)[k]	Alpha	$6.0\ 10^{-5}$	$1.36\ 10^{-5}$	23
	Tritium	0.05	0.00216	4.3
	Plutonium-241	$2.4\ 10^{-4}$	$5.46\ 10^{-5}$	23
	Other radionuclides	$6.0\ 10^{-5}$	$9.76\ 10^{-6}$	16
Aldermaston (Silchester)[k]	Alpha	$4.0\ 10^{-5}$	$4.04\ 10^{-6}$	10
	Beta	$1.2\ 10^{-4}$	$1.38\ 10^{-5}$	11
	Tritium	0.05	$4.8\ 10^{-4}$	<1
Aldermaston (stream)	Tritium	0.01	0.00156	16
Barrow [l]	Tritium	0.02	$4.08\ 10^{-5}$	<1
	Manganese-54	$2.5\ 10^{-7}$	$1.61\ 10^{-9}$	<1
	Cobalt-58	$7.0\ 10^{-7}$	$7.91\ 10^{-10}$	<1
	Cobalt-60	$7.0\ 10^{-8}$	$1.97\ 10^{-8}$	28
	Tin-113	$2.5\ 10^{-7}$	$2.92\ 10^{-10}$	<1
	Antimony-124	$2.0\ 10^{-6}$	$3.75\ 10^{-10}$	<1
	Other radionuclides	$3.5\ 10^{-6}$	$8.71\ 10^{-8}$	2.5
Burghfield[u]	Alpha	$2.0\ 10^{-6}$	$8.36\ 10^{-9}$	<1
	Other radionuclides	$1.2\ 10^{-5}$	$1.67\ 10^{-8}$	<1
Devonport[m,n] (sewer)	Beta		$4.23\ 10^{-6}$	
	Tritium		$7.95\ 10^{-6}$	
	Cobalt-60		$3.35\ 10^{-7}$	
Devonport[m,n] (river)	Beta		Nil	
	Tritium		“	
	Cobalt		“	
Devonport[n,o] (sewer)	Total activity		$5.24\ 10^{-4}$	
	Cobalt-60		$4.58\ 10^{-4}$	
Devonport[o] (pipeline)	Total activity[e,p]	0.001	$5.91\ 10^{-4}$	59
	Tritium	0.12	0.87	73
	Cobalt-60	0.006	$1.15\ 10^{-4}$	1.9
Faslane	Alpha activity	$2.0\ 10^{-4}$	$1.93\ 10^{-6}$	<1
	Beta activity[e,p]	$5.0\ 10^{-4}$	$8.19\ 10^{-6}$	1.6
	Tritium	1	0.0640	6.4
	Cobalt-60	$5.0\ 10^{-4}$	$1.04\ 10^{-5}$	2.1
Rosyth[q]	Alpha	10^{-6}	$6.7\ 10^{-8}$	6.7
	Beta[e,p]	$5\ 10^{-4}$	$2.26\ 10^{-4}$	45
	Tritium	0.04	0.00150	3.7
	Cobalt-60	0.005	$4.86\ 10^{-4}$	9.7
Nycomed Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$2.57\ 10^{-5}$	8.6
	Beta >0.4 MeV	0.1	0.0040	4
	Tritium	0.2	0.001	<1
	Iodine-125	0.2	$4.66\ 10^{-4}$	<1
	Caesium-137	0.005	$3.97\ 10^{-5}$	<1
	Other radionuclides	0.3	0.032	11

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq[a]	% of limit[b]
Cardiff	Tritium	900	87.2	9.7
	Carbon-14	2	0.60	30
	Phosphorus-32/33	0.01	$7.40\ 10^{-6}$	<1
	Iodine-125	0.05	0.0107	21
	Others	$5.0\ 10^{-4}$	Nil	Nil
Imperial College Reactor Centre				
Ascot	Tritium	$1.0\ 10^{-4}$	Nil	Nil
	Other radioactivity	$4.0\ 10^{-5}$	"	"
Imperial Chemical Industries plc				
Billingham	Beta/gamma	0.36	$5.95\ 10^{-5}$	<1
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha[s]	0.00666	$3.29\ 10^{-4}$	4.9
	Alpha[t]	$1.85\ 10^{-4}$	$1.26\ 10^{-8}$	<1
	Beta[t]	0.00222	$5.04\ 10^{-5}$	2.2
Scottish Universities Research and Reactor Centre				
East Kilbride	Total activity	$1.44\ 10^{-3}$	$1.01\ 10^{-7}$	<1

[a] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 3 significant figures except where fewer significant figures are provided in source documents*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Excluding curium-242*
[d] *The limit and discharge data are expressed in kg*
[e] *Excluding tritium*
[f] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3}*
[g] *Excluding sulphur-35*
[h] *Magnox Electric is a wholly owned subsidiary of BNFL plc*
[i] *Excluding caesium-137*
[j] *Excluding strontium-90*
[k] *Discharges were made by Hunting-BRAE Ltd until March 2000. From 1 April 2000 discharges have been made by AWE plc under new authorisations.*
[l] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges are made by BAE Systems Marine Ltd*
[m] *Discharges are made by the Ministry of Defence*
[n] *The current authorisation includes limits on concentrations of total activity (MoD 2 10^{-6} TBq m^{-3}; Devonport Royal Dockyard 4 10^{-6} TBq m^{-3}). At no time did the concentrations exceed the limits*
[o] *Discharges are currently made by Devonport Royal Dockyard Ltd.*
[p] *Excluding cobalt-60*
[q] *Discharges are made by Rosyth Royal Dockyard Ltd*
[r] *Discharge limits depend on operational throughput*
[s] *Discharge limit is for Nuclear Fuel Production Plant*
[t] *Discharge limit is for Neptune Reactor*
[u] *Authorisation revoked with effect from 1 April 2000. Discharges for January to March only and the percentage limit applies to the whole year.*
[v] *Discharge authorisation for ^{3}H and ^{99}Tc was revised with effect from 1 January 2000.*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2000

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq	% of limit
British Nuclear Fuels plc				
Capenhurst[d]	Tritium		0.57	
	Uranium		$4.7\ 10^{-6}$	
Chapelcross	Tritium	5000	1500	30
	Sulphur-35	0.05	0.0243	49
	Argon-41	4500	2550	57
Sellafield[a,b]	Alpha	0.0017	$7.77\ 10^{-5}$	4.6
	Beta	0.048	$7.18\ 10^{-4}$	1.5
	Tritium	1440	213	15
	Carbon-14	8.62	2.58	30
	Sulphur-35	0.21	0.1	48
	Argon-41	3700	2510	68
	Cobalt-60	$9.2\ 10^{-4}$	$3.27\ 10^{-5}$	3.6
	Krypton-85	$4.7\ 10^{5}$	$7.36\ 10^{4}$	16
	Strontium-90	0.0016	$5.38\ 10^{-5}$	3.4
	Ruthenium-106	0.046	0.00108	2.3
	Antimony-125	0.005	$1.76\ 10^{-4}$	3.5
	Iodine-129	0.063	0.0252	40
	Iodine-131	0.055	0.00279	5.1
	Caesium-137	0.0073	$5.70\ 10^{-4}$	7.8
	Plutonium (alpha)	$8.40\ 10^{-4}$	$4.40\ 10^{-5}$	5.2
	Plutonium-241	0.0051	$2.68\ 10^{-4}$	5.3
	Americium-241 and curium-242	$3.60\ 10^{-4}$	$4.48\ 10^{-5}$	12
Springfields	Uranium	0.006	$3.57\ 10^{-4}$	6.0
United Kingdom Atomic Energy Authority[h]				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$3.9\ 10^{-5}$	4.0
	Beta[k]	0.045	$1.9\ 10^{-4}$	<1
	Tritium	2	0.35	18
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$4.80\ 10^{-4}$	11
	Ruthenium-106	0.0039	$2.80\ 10^{-5}$	<1
	Iodine-129	0.0011	$5.40\ 10^{-5}$	4.9
	Iodine-131	$1.5\ 10^{-4}$	$2.70\ 10^{-5}$	18
	Caesium-134	$8.4\ 10^{-4}$	$3.60\ 10^{-6}$	<1
	Caesium-137	0.007	$5.30\ 10^{-5}$	<1
	Cerium-144	0.007	$2.00\ 10^{-5}$	<1
	Plutonium-241	0.0033	$2.00\ 10^{-4}$	6.1
	Curium-242	$2.7\ 10^{-4}$	$1.60\ 10^{-7}$	<1
	Curium-244[i]	$5.4\ 10^{-5}$	$2.10\ 10^{-7}$	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	$1.02\ 10^{-9}$	<1
	Beta	0.0015	$1.12\ 10^{-8}$	<1
	Tritium	4.5	$7.41\ 10^{-4}$	<1
	Krypton-85	$4.0\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$2.07\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$7.29\ 10^{-7}$	1.4
	Tritium	22.5	1.15	5.1
	Krypton-85	4	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq	% of limit
Dounreay (East minor sources)	Alpha[l]	$1.37\ 10^{-5}$	$1.30\ 10^{-7}$	<1
	Beta[k]	$3.71\ 10^{-4}$	$6.20\ 10^{-7}$	<1
	Krypton-85	1	$3.50\ 10^{-5}$	<1
Dounreay (West minor sources)	Alpha[l]	$3\ 10^{-7}$	$1.70\ 10^{-10}$	<1
	Beta[k]	$7.5\ 10^{-5}$	$8.00\ 10^{-8}$	<1
	Tritium	$2.25\ 10^{-5}$	Nil	Nil
Harwell	Alpha	$7.0\ 10^{-6}$	$1.29\ 10^{-7}$	1.8
	Beta	$4.5\ 10^{-4}$	$2.15\ 10^{-6}$	<1
	Tritium	150	3.63	2.4
Windscale	Alpha	$1.2\ 10^{-5}$	$2.32\ 10^{-7}$	1.9
	Beta	0.005	$3.15\ 10^{-6}$	<1
	Tritium	2.3	0.00442	<1
	Krypton-85	14	0.00260	<1
	Iodine-131	0.0012	$1.42\ 10^{-6}$	<1
Winfrith	Alpha	$2.0\ 10^{-6}$	$3.91\ 10^{-9}$	<1
	Beta	$2.5\ 10^{-5}$	$8.21\ 10^{-8}$	<1
	Tritium	5	0.157	3.1
	Carbon-14	0.3	$8.7\ 10^{-4}$	<1
	Krypton-85	150	Nil	Nil
Magnox Electric[o]				
Berkeley	Alpha and beta[m]	$2.0\ 10^{-4}$	$5.3\ 10^{-7}$	<1
	Tritium	2	$4.78\ 10^{-3}$	<1
	Carbon-14	0.2	$1.86\ 10^{-4}$	<1
	Sulphur-35	0.006	Nil	Nil
Bradwell	Beta	0.001	$1.77\ 10^{-4}$	18
	Tritium	1.5	0.558	37
	Carbon-14	0.6	0.196	33
	Sulphur-35	0.2	0.0276	14
	Argon-41	1000	241	24
Dungeness 'A' Station	Beta	0.001	$2.82\ 10^{-4}$	28
	Tritium	2	0.520	26
	Carbon-14	5	3.27	65
	Sulphur-35	0.4	0.0523	13
	Argon-41	2000	1100	55
Hinkley Point 'A' Station	Beta	0.001	$1.16\ 10^{-6}$	<1
	Tritium	25	0.0786	<1
	Carbon-14	4	0.0560	1.4
	Sulphur-35	0.2	0.00111	<1
	Argon-41	4500	Nil	Nil
Hunterston 'A' Station	Beta[j]	10^{-4}	$4.6\ 10^{-7}$	<1
	Tritium	1	Nil	Nil
	Carbon-14	0.2	"	"
Oldbury	Beta	0.001	$1.87\ 10^{-4}$	19
	Tritium	5	1.63	33
	Carbon-14	6	3.96	66
	Sulphur-35	0.75	0.329	44
	Argon-41	500	157	31

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq	% of limit
Sizewell				
'A' Station	Beta	0.001	$1.52\ 10^{-4}$	15
	Tritium	7	0.916	13
	Carbon-14	1.5	1.07	71
	Sulphur-35	0.6	0.159	27
	Argon-41	3000	1730	58
Trawsfynydd	Beta	0.002	$1.58\ 10^{-6}$	<1
	Tritium	10	0.173	1.7
	Carbon-14	5	$1.15\ 10^{-3}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta	0.001	$9.56\ 10^{-5}$	9.6
	Tritium	20	6.00	30
	Carbon-14	2.4	0.522	22
	Sulphur-35	0.5	0.075	15
	Argon-41	120	7.45	6.2
British Energy Generation Ltd				
Dungeness				
'B' Station	Beta	0.001	$6.64\ 10^{-6}$	<1
	Tritium	15	2.65	18
	Carbon-14	5	0.277	5.5
	Sulphur-35	0.45	$5.44\ 10^{-3}$	1.2
	Argon-41	150	19.3	13
	Iodine-131	0.005	$2.36\ 10^{-6}$	<1
Hartlepool	Beta	0.001	$4.31\ 10^{-6}$	<1
	Tritium	6	1.86	31
	Carbon-14	5	1.47	29
	Sulphur-35	0.16	0.0722	45
	Argon-41	60	12.4	21
	Iodine-131	0.005	$3.05\ 10^{-5}$	<1
Heysham				
Station 1	Beta	0.001	$7.66\ 10^{-6}$	<1
	Tritium	6	0.952	16
	Carbon-14	4	1.38	35
	Sulphur-35	0.12	0.0162	14
	Argon-41	60	14.2	24
	Iodine-131	0.005	$1.11\ 10^{-4}$	2.2
Heysham				
Station 2	Beta	0.001	$9.51\ 10^{-6}$	<1
	Tritium	15	1.06	7.1
	Carbon-14	3	0.940	31
	Sulphur-35	0.3	0.0196	6.5
	Argon-41	85	14.6	17
	Iodine-131	0.005	$3.67\ 10^{-5}$	<1
Hinkley Point				
'B' Station	Beta	0.001	$3.17\ 10^{-5}$	3.2
	Tritium	30	3.06	10
	Carbon-14	8	1.00	13
	Sulphur-35	0.4	0.132	33
	Argon-41	300	19.1	6.4
	Iodine-131	0.005	$1.05\ 10^{-5}$	<1
Sizewell				
'B' Station (outlets 1-3)	Noble gases	295	12.5	4.2
	Halogens	0.0027	$2.47\ 10^{-3}$	92
	Beta	0.01	$1.81\ 10^{-5}$	<1
	Tritium	7.8	0.572	7.3
	Carbon-14	0.59	0.176	30

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq	% of limit
Sizewell				
(Approved places)	Noble gases	5	Nil	Nil
	Halogens	$3.0\ 10^{-4}$	"	"
	Tritium	0.2	"	"
	Carbon-14	0.01	"	"
British Energy Generation (UK) Ltd				
Hunterston				
'B' Station	Beta[j]	0.002	$9.63\ 10^{-5}$	4.8
	Tritium	20	5.28	26
	Carbon-14	3	1.82	61
	Sulphur-35	0.8	0.276	35
	Argon-41	220	58.7	27
Torness	Beta[j]	0.002	$7.61\ 10^{-6}$	<1
	Tritium	20	1.69	8.5
	Carbon-14	3	0.575	19
	Sulphur-35	0.8	0.0185	2.3
	Argon-41	220	7.45	3.4
Ministry of Defence				
Aldermaston[a,n]	Alpha	$4.5\ 10^{-7}$	$9.86\ 10^{-8}$	22
	Other beta and gamma emitters[f]	$5.0\ 10^{-6}$	$8.6\ 10^{-8}$	1.7
	Tritium	170	8.26	4.9
	Krypton-85	1.0	$2.2\ 10^{-3}$	0.2
	Plutonium-241	$1.68\ 10^{-6}$	$3.03\ 10^{-7}$	18
Barrow[g]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.08	"	"
Burghfield[a,n]	Alpha	$2.0\ 10^{-8}$	$2.6\ 10^{-10}$	1.3
	Tritium	0.05	Nil	Nil
Coulport	Tritium	0.05	0.0025	5
Dounreay				
(Vulcan)	Alpha[j]	10^{-6}	$1.36\ 10^{-7}$	14
	Beta[j]	10^{-4}	$1.6\ 10^{-6}$	<1
	Noble gases	0.027	Nil	Nil
	Iodine-131	$3.7\ 10^{-4}$	$2.88\ 10^{-5}$	7.8
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	"	"
Nycomed Amersham plc				
Amersham	Alpha	$2.0\ 10^{-6}$	$1.4\ 10^{-7}$	7.0
	Other (penetrating)	0.05	$7.30\ 10^{-5}$	<1
	Other (non-penetrating)	0.5	0.01	2.0
	Tritium	40	Nil	Nil
	Selenium-75	0.03	$2.70\ 10^{-4}$	<1
	Iodine-125	0.1	$5.00\ 10^{-3}$	5.0
	Iodine-131	0.05	$5.10\ 10^{-4}$	1.0
	Radon-222	10	2.20	22
Cardiff	Soluble tritium	400	104	26
	Insoluble tritium	1000	399	40
	Carbon-14	6	1.59	27
	Phosphorus-32/33	$2.0\ 10^{-4}$	$3.33\ 10^{-6}$	1.7
	Iodine-125	$5.0\ 10^{-4}$	$1.19\ 10^{-4}$	24
	Other activity	0.04	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2000	
			TBq	% of limit
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$5.10\ 10^{-5}$	10
	Argon-41	2.5	0.252	10
Imperial Chemical Industries plc				
Billingham	Tritium	2	$3.53\ 10^{-6}$	<1
	Argon-41	2	Nil	Nil
Johnson and Johnson Clinical Diagnostics Ltd				
Cardiff	Iodine-125	0.015	0.0011	7.3
	Other activity	$5.0\ 10^{-4}$	Nil	Nil
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha	[d]	$1.17\ 10^{-6}$	
Scottish Universities Research and Reactor Centre				
East Kilbride	Tritium	19.2	Nil	Nil
	Argon-41	3.33	"	"
Urenco (Capenhurst) Ltd				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$9.6\ 10^{-8}$	3.8

[a] *Discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location.*
[b] *Some limits are related to the operation of the THORP plant and may thus vary from year to year*
[c] *Discharges are made by Rosyth Royal Dockyard Ltd*
[d] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[e] *Excluding curium-242 and 244*
[f] *Excluding tritium and plutonium-241*
[g] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by Marconi Marine (VSEL) Ltd until 22nd February 2000 and by BAE SYSTEMS Marine Ltd since then*
[h] *Data includes contributions from tenants*
[i] *Data includes any curium-243 present*
[j] *Particulate activity*
[k] *Excluding tritium and krypton-85*
[l] *Excluding radon and daughter products*
[m] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[n] *Discharges were made by Hunting-BRAE Ltd until 31st March 2000. From 1st April 2000 discharges were made by AWE plc under new authorisations. The limits are the annual limits contained within the new authorisations*
[o] *Magnox Electric is a wholly owned subsidiary of BNFL plc*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2000

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2000	
			TBq	% of limit
Drigg	Tritium	10	1.2	12
	Carbon-14	0.05	0.012	24
	Cobalt-60	2	0.11	6.0
	Iodine-129	0.05	$4.5\ 10^{-4}$	<1
	Radium-226 plus thorium-232	0.03	0.003	10
	Uranium	0.3	0.049	16
	Other alpha[a]	0.3	0.03	10
	Others[a,b]	15	1.9	13
Dounreay[c]	Alpha		$3.00\ 10^{-5}$	
	Beta/gamma		$1.40\ 10^{-3}$	

[a] *With half-lives greater than three months*
[b] *Other beta emitting radionuclides but including iron-55 and cobalt-60*
[c] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits.*

APPENDIX 2. MODELLING OF RADIOACTIVITY IN FOODSTUFFS

At Sellafield, Drigg, Ravenglass and the Isle of Man, a simple food chain model has been used to provide concentrations of activity in milk and livestock for selected radionuclides to supplement data obtained by direct measurements. This is done where relatively high limits of detection exist or where no measurements were made.

Activities in milk, meat and offal were calculated for ^{99}Tc, ^{106}Ru, ^{144}Ce, ^{147}Pm and ^{241}Pu using the equations:

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

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

C_m is the concentration in milk (Bq l^{-1}),

C_f is the concentration in meat or offal (Bq kg^{-1} (wet)),

F_m is the fraction of the animal's daily intake by ingestion transferred to milk (d l^{-1}),

F_f is the fraction of the animal's daily intake by ingestion transferred to meat or offal (d kg^{-1}(wet)),

Ca is the concentration in fodder (Bq kg^{-1}(dry)),

Q_f is the amount of fodder eaten per day (kg(dry) d^{-1})

No direct account is taken of radionuclide decay or the intake by the animal of soil associated activity. The concentration in fodder is assumed to be the same as the maximum observed concentration in grass, or in the absence of such data, in leafy green vegetables. The food chain data for the calculations are given in Table A2.1 (Simmonds *et al*., 1995; Brenk *et al*., unpublished) and the estimated concentrations in milk, meat and offal are presented in Table A2.2.

Table A2.1 Data for food chain model

Parameter	Nuclide	Food				
		Milk	Beef	Beef offal	Lamb	Sheep offal
Q_f		13	13	13	1.5	1.5
F_m or F_f	^{99}Tc	10^{-2}	10^{-2}	$4\ 10^{-2}$	10^{-1}	$4\ 10^{-1}$
	^{106}Ru	10^{-6}	10^{-3}	10^{-3}	10^{-2}	10^{-2}
	^{144}Ce	$2\ 10^{-5}$	10^{-3}	$2\ 10^{-1}$	10^{-2}	2
	^{147}Pm	$2\ 10^{-5}$	$5\ 10^{-3}$	$4\ 10^{-2}$	$5\ 10^{-2}$	$3\ 10^{-1}$
	^{241}Pu	10^{-6}	10^{-4}	$2\ 10^{-2}$	$4\ 10^{-4}$	$3\ 10^{-2}$

Table A2.2 Predicted concentrations 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]	$2.96\ 10^{-4}$	[b]	[b]	$8.97\ 10^{-6}$
	Ravenglass	[a]	$2.91\ 10^{-4}$	$2.75\ 10^{-3}$	[b]	$1.30\ 10^{-5}$
	Drigg	[a]	$4.55\ 10^{-4}$	[b]	$3.51\ 10^{-2}$	$3.03\ 10^{-5}$
	Isle of Man	[a]	$3.64\ 10^{-4}$	$4.85\ 10^{-3}$	$1.04\ 10^{-3}$	$1.01\ 10^{-5}$
Beef	Sellafield	[a]	$2.96\ 10^{-1}$	[b]	[b]	$8.97\ 10^{-4}$
	Ravenglass	[a]	$2.91\ 10^{-1}$	$1.38\ 10^{-1}$	[b]	$1.30\ 10^{-3}$
Lamb	Sellafield	[a]	$3.41\ 10^{-1}$	[b]	[b]	$4.14\ 10^{-4}$
	Ravenglass	[a]	$3.35\ 10^{-1}$	$1.59\ 10^{-1}$	[b]	[a]
	Drigg	[a]	$5.25\ 10^{-1}$	[b]	[b]	$1.40\ 10^{-3}$
Beef offal	Sellafield	[a]	$2.96\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	[a]	$2.91\ 10^{-1}$	[a]	[b]	[a]
Lamb offal	Sellafield	[a]	$3.41\ 10^{-1}$	[b]	[b]	$3.10\ 10^{-2}$
	Ravenglass	[a]	$3.35\ 10^{-1}$	[a]	[b]	$4.50\ 10^{-2}$
	Drigg	[a]	$5.25\ 10^{-1}$	[b]	[b]	[a]

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

APPENDIX 3. ABBREVIATIONS

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
CBC	Copeland Borough Council
CEC	Commission of the European Communities
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DoH	Department of Health
DRPS	Defence Radiological Protection Service
EA	Environment Agency
EC	European Commission
EU	European Union
FARM	Food and Agriculture Monitoring Programme
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
JRC	Joint Research Centre of the European Commission
LoD	Limit of Detection
LLW	Low level waste
MAFF	Ministry of Agriculture, Fisheries and Food
MOD(N)	Ministry of Defence (Navy)
MRL	Minimum reporting level
ND	Not detected
NDS	National Discharge Strategy
NEA	Nuclear Energy Agency
NII	Nuclear Installations Inspectorate
NRPB	National Radiological Protection Board
NRTE	Nuclear reactor test establishment
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Commission
PWR	Pressurised Water Reactor
RIFE	Radioactivity in Food and the Environment
RNAD	Royal Naval Armaments Depot
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SGHWR	Steam Generating Heavy Water Reactor
TDS	Total Diet Study
TRAMP	Terrestrial Radioactivity Monitoring Programme
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
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 based on Byrom *et al*. (1995) and are given in Table A4.1. These are based on national statistics and are taken to apply at each site. Site-specific data for aquatic pathways based on local surveys are given in Table A4.2.

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
Berkeley and Oldbury		17 kg y^{-1} flounders 4.9 kg y^{-1} shrimps 980 h y^{-1} over mud
Bradwell		44 kg y^{1} fish 3.1 kg y^{-1} crustaceans 6.5 kg y^{-1} molluscs 2900 h y^{-1} over mud[b]
Capenhurst		0.0025 kg y^{-1} sediment 2.5 l y^{-1} water
Cardiff		34 kg y^{1} fish 1.4 kg y^{1} prawns 990 h y^{1} over mud and sand
Channel Islands		62 kg y^{1} fish 30 kg y^{-1} crustaceans 30 kg y^{1} molluscs 1400 h y^{1} over mud and sand

Table A4.2. continued

Site	Group[a]	Rates
Chapelcross	A	20 kg y^{-1} salmonids (80%) and other fish (20%)
		12 kg y^{-1} shrimps
		3.0 kg y^{-1} mussels
		1000 h y^{-1} over mud and sand
	B	500 h y^{-1} over salt marsh
	C	1100 h y^{-1} handling nets
Devonport		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay	A	1800 h y^{-1} handling pots
	B	19 kg y^{-1} fish
		14 kg y^{-1} crab and lobster
		2.2 kg y^{-1} winkles
	C	430 h y^{-1} over sand and rock
	D	25 h y^{-1} in a Geo
Drinking water	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness		59 kg y^{-1} fish
		17 kg y^{-1} crustaceans
		15 kg y^{-1} molluscs
		1500 h y^{-1} over mud and sand
Faslane	A	200 h y^{-1} over mud
	B	9.9 kg y^{-1} fish
		1400 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[b]
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		43 kg y^{-1} fish
		9.8 kg y^{-1} shrimps and prawns
		1.8 kg y^{-1} whelks
		960 h y^{-1} over mud
Holy Loch		900 h y^{-1} over mud
Hunterston		82 kg y^{-1} fish
		41 kg y^{-1} Nephrops
		21 kg y^{-1} scallops
		860 h y^{-1} over sand and mud
Rosyth	A	21 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		5.6 kg y^{-1} molluscs
	B	1100 h y^{-1} over mud and sand
Sellafield	A	31 kg y^{-1} cod (40%) and other fish (60%)
		20 kg y^{-1} crab (40%), lobster (40%) and *Nephrops* (20%)
		17 kg y^{-1} winkles (50%) and other molluscs (50%)
		1000 h y^{-1} over sand and mollusc beds
	B	1200 h y^{-1} handling nets and pots

Table A4.2. continued

Site	Group[a]	Rates
Sellafield (cont.)		
	C (bait diggers)	950 h y^{-1} handling sand
	D (Whitehaven commercial)	40 kg y^{-1} plaice and cod
		9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	E (Morecambe Bay)	See Heysham
	F (Fleetwood)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	G (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
	H (Laverbread)	47 kg y^{-1} laverbread
	I (Trout)	6.8 kg y^{-1} rainbow trout
	J (typical fish consumer)	15 kg y^{-1} cod and plaice
	K (Isle of Man)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	L (Northern Ireland)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	M (North Wales)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
Sizewell		56 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		3.8 kg y^{-1} molluscs
		260 h y^{-1} over mud
Springfields	A	42 kg y^{-1} fish
		15 kg y^{-1} shrimps
		10 kg y^{-1} cockles and mussels
	B	860 h y^{-1} handling nets
Torness	A	58 kg y^{-1} fish
		11 kg y^{-1} crab and lobster
		10 kg y^{-1} Nephrops
		2.2 kg y^{-1} molluscs
	B	430 h y^{-1} over sand
	C	640 h y^{-1} over winkle beds
Trawsfynydd		1.8 kg y^{-1} brown trout
		22 kg y^{-1} rainbow trout
		0.93 kg y^{-1} perch
		1000 h y^{-1} over lake shore
Upland lake		37 kg y^{-1} fish
Whitehaven		32 kg y^{-1} fish
		17 kg y^{-1} lobsters (40%) and crab (60%)
		3.0 kg y^{-1} winkles (20%) and mussels (80%)
Winfrith		77 kg y^{-1} cod
		26 kg y^{-1} crab
		39 kg y^{-1} whelks
Wylfa		94 kg y^{-1} fish
		23 kg y^{-1} crab
		1.8 kg y^{-1} molluscs
		370 h y^{-1} over sand

[a] *Where more than one group exists at a site the groups are denoted A, B, etc.*
[b] *Not assessed in this report in 2000*

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 CEFAS. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background. Similarly, natural levels of carbon-14 are subtracted when assessing exposures due to man-made sources of this radionuclide. The natural concentrations of carbon-14 are determined by measuring the carbon concentration in each sample and applying a specific activity of 250 Bq ^{14}C natural/kg C (Collins, *et al.*, 1995). Typical values are given in table A6.1

Table A6.1 Radioactivity in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (wet))									
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	26	27			24					
Lead-210	0.025	0.08	0.3	0.08	0.69	0.69	1.1			1.2
Polonium-210	0.28	5.2	15	5.2	9.4	12	33	18	9.4	6.8
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

6.2 Terrestrial foodstuffs

The values of carbon-14 in terrestrial foodstuffs due to natural sources that are used in dose assessments are given in Table A6.2 (MAFF, 1995).

Table A6.2 Carbon-14 in terrrestrial foodstuffs due to natural sources

Food Category	% Carbon content (wet)	Concentration of carbon-14 (Bq kg^{-1} (wet))
Milk	7	18
Bovine meat	17	44
Ovine meat	21	54
Pork	21	54
Poultry	28	72
Game	15	38
Offal	12	31
Eggs	15	38
Green vegetables	3	8
Root vegetables	3	8
Legumes/other domestic vegetables	8	20
Dry beans	20	51
Potato	9	23
Cereals	41	105
Cultivated fruit	4	10
Wild fruit	4	10
Mushrooms	2	5
Honey	31	79
Nuts	58	148

APPENDIX 7. RADIOACTIVITY IN SEDIMENT TO BE DREDGED FROM THE TAMAR ESTUARY NEAR DEVONPORT, 2000

Location		Radioactivity concentration (dry)[a], Bq kg^{-1}						
and depth (m)		^{40}K	^{137}Cs	^{212}Pb	^{214}Bi	^{226}Ra	^{228}Ac	^{234}Th
D1	surface	710	6.9	39	26	31	32	100
D2	“	690	6.1	38	34	28	30	56
D3	“	680	7.2	39	34	31	29	85
D4	“	580	5.5	33	26	24	29	57
D5	“	710	7.7	39	25	30	29	37
D6	“	570	1.4	32	22	23	27	35
D7	“	710	6.7	38	23	30	32	59
D8	“	710	4.9	34	22	26	29	56
D9	“	690	6.1	38	25	30	31	61
D10	“	660	1.1	29	20	21	26	39
D11	“	680	1.1	39	22	27	36	45
D12	“	440	3.0	24	22	20	22	33
D13	0.8	680	<0.59	35	22	26	34	58
D15	2.1	630	<0.59	35	20	27	31	54
Vc8	1-1.25	650	<0.59	42	23	30	37	54
Vc67	1-1.25	540	<0.59	30	20	24	29	41
Vc88	1-1.25	700	<0.59	42	31	30	40	69
Vc95	2-2.25	540	<0.59	26	18	20	26	38

[a] *All other gamma emitting radionuclides were present at less than the limits of detection, generally ~1 Bq kg^{-1}*

ERRATUM

Erratum to Radioactivity in Food and the Environment, 1999

The second sentence of paragraph three on page 112 [Section 8.2, Cardiff, South Glamorgan] of Radioactivity in Food and the Environment 1999/RIFE 5 (Food Standards Agency and SEPA, 1999) states that "The duck and tide washed pasture pathways gave doses of 0.032 and 0.009 mSv y^{-1} respectively." Please note that the dose due to the duck pathway should in fact have read 0.042 mSv y^{-1} not 0.032 mSv y^{-1}. The value for tide washed pasture is correct.