FOOD STANDARDS AGENCY
SCOTTISH ENVIRONMENT PROTECTION AGENCY

Radioactivity in Food and the Environment, 2001

RIFE - 7

September 2002

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

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

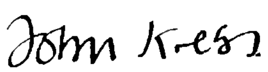
FOREWORD

We are pleased to present the 7th annual Radioactivity in Food and the Environment report from our Agencies. This is latest in a series of joint reports presenting results of measurements of radioactivity in the environment through the analysis of a diverse range of samples including foodstuffs, soil and air samples and other direct measurements of radioactivity in the environment from around nuclear sites and other locations throughout the United Kingdom. Both our Agencies are committed to ensuring that radiation doses are well below national dose limits to protect public health, the environment, consumer interests and monitoring the effects of industry. The report presents data for 2001 and shows that consumers were not exposed to unacceptable doses as a result of their diet.

The outbreak of foot and mouth disease in 2001 caused problems for sample collection, particularly limiting the availability of milk samples and access to some of the usual sampling locations. However, the dedication and professionalism of our staff overcame many of these problems to ensure that an adequate number of samples were collected to allow meaningful dose calculations to be carried out.

We would like to express our gratitude to all those involved in the management and collection of all these samples, especially those who collected the extra samples needed for the several non-routine investigations in 2001. Enclosed with this document is a CD that contains electronic copies of all seven reports in this series. The provision of such a large amount of data reinforces our commitment to ensure that our programmes remain open, accessible and transparent to the public and show that our calculations of radiological exposure from food in the UK are accurate and continue to use the best science available.

All the results, both for the routine and non-routine parts of the programme, reported here showed that the public was not exposed to unacceptable doses of radiation from food in the UK.



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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 2001.

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

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. This report assesses the doses received by consumers as a result of authorised discharges. In addition consumers also receive doses from naturally occurring radionuclides.

Both programmes demonstrate that as a result of consumption of terrestrial foodstuffs and seafood produced in and around the United Kingdom even the most exposed consumers receive small radiation doses. In 2001 exposure of consumers to artificially produced radioactivity via the food chain remained well below the statutory United Kingdom annual dose limit to members of the public of 1 mSv (millisievert) for all controlled releases of 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 0.16 mSv in 2001 compared with 0.15 mSv in 2000 (Food Standards Agency and SEPA, 2001). Concentrations, dose rates and consumption rates were largely unchanged in 2001 though there were some small increases in concentrations of technetium-99 in seafood. This group also received an estimated dose of 0.43 mSv from enhanced levels of natural radioactivity due to past operations at the Rhodia Consumer Specialties Ltd. works at Whitehaven. By definition, other groups will have received lower doses.

In Scotland, the highest exposures were in the south west. They relate to an actual group of consumers of seafood, spending time over inter-tidal areas, who were estimated to receive annual doses of 0.044 mSv, mainly as a result of the distant effect of Sellafield. In 2000, this group was estimated to have received an annual dose of 0.032 mSv. The increase in dose reflects increases in the gamma dose rates.

Doses due to gaseous discharges from Sellafield were 0.037 mSv, a small increase on the dose in 2000 of 0.033 mSv. The assessment included the 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 15% 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 0.059 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 Amersham in Cardiff where radiochemicals for research, medicine and industry are produced. Doses to high-rate seafood consumers at Cardiff were estimated to be 0.036 mSv in 2001. 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 major changes in radioactive contamination of food or external dose rates were observed in 2001. 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* and there were some increases in particular foodstuffs. However, the assessed dose to the most exposed group of seafood consumers from technetium-99 discharges was less than 3% of the 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 10,000 Bq kg^{-1} (fresh weight) though some reductions were observed compared with 2000. Small increases of tritium above an expected background of less than 1 Bq kg^{-1} in freshwater fish 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

Earlier fires at a Royal Ordnance munitions factory at Featherstone near Wolverhampton might have given rise to concern that depleted uranium had been released from the site and had been incorporated into the foodchain. Atmospheric modelling established where the possible deposition had taken place and grass and soil samples were taken and analysed in 2001. The results showed that there was no indication of any release of depleted uranium from the site.

An incident involving an overflow of Amersham`s sewage discharges into the River Misbourne occurred in winter 2000/2001 commencing on 8 December 2000. A desk based assessment on the likely impact on (i) milk and beef consumers via cattle drinking water from the river and (ii) fish consumers was undertaken. The highest estimated dose using pessimistic assumptions was less than 5% of the dose limit of 1mSv. Grass samples were taken and analysed to establish whether any significant local enhancement of radionuclide concentrations on pasture was evident. None was found.

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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.*

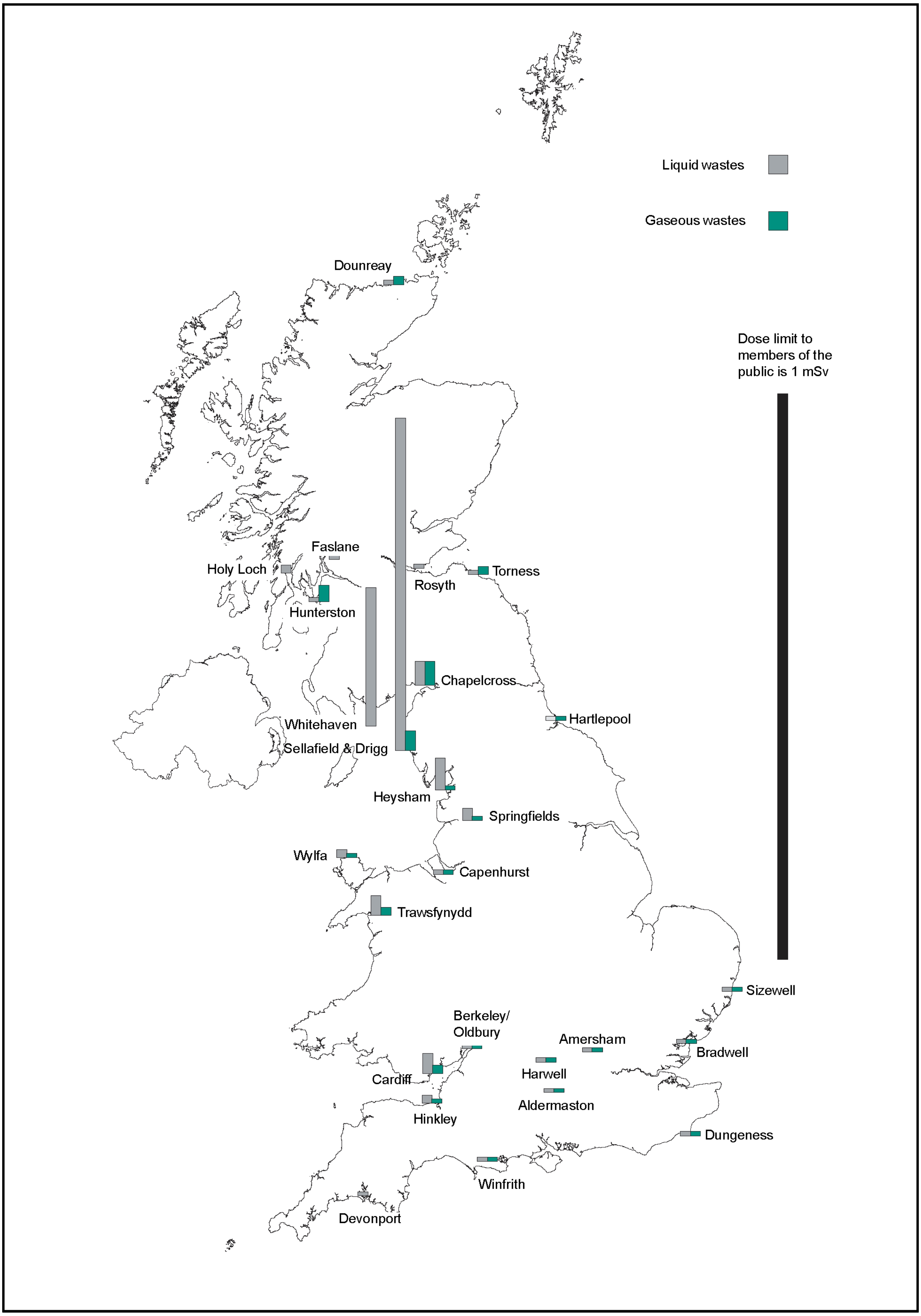

Figure S. Radiation exposures in the UK due to radioactive waste discharges, 2001 - Food Standards Agency and SEPA surveillance

(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, 2001[a]

Establishment	Radiation exposure pathways	Exposure, mSv[b]	Contributors[c]
British Nuclear Fuels plc			
Sellafield and Drigg[e]	Fish and shellfish consumption	0.16	$^{239/240}Pu$ ^{241}Am
	and external in intertidal areas (2001 habits)		
	Fish and shellfish consumption	0.15	$^{239/240}Pu$ ^{241}Am
	and external in intertidal areas (1997-2001 habits)		
	Terrestrial foods at Sellafield	0.036	^{90}Sr ^{106}Ru
	Terrestrial foods at Drigg	0.016	^{90}Sr ^{106}Ru
	Terrestrial foods at Ravenglass	0.017	^{90}Sr ^{106}Ru
	External (skin) to anglers	0.20[f]	Beta
	Handling of fishing gear	0.13[f]	Beta
	Porphyra/laverbread consumption in South Wales	<0.005	^{106}Ru ^{241}Am
	Trout consumption at Sellafield[g]	0.004	^{137}Cs ^{241}Am
	Seaweed/crops at Sellafield	0.019	^{99}Tc ^{137}Cs
Springfields	External (skin) to fishermen	0.51[f]	Beta
	Fish and shellfish consumption	0.018	^{137}Cs ^{241}Am
	Terrestrial foods[j]	0.006[i]	^{129}I ^{232}Th
Capenhurst	Inadvertent ingestion of water and sediment	<0.005	U ^{241}Am
	Terrestrial foods[h]	<0.005	^{3}H U
Chapelcross	Fish and shellfish consumption	0.044	Ext ^{241}Am
	and external in intertidal areas		
	Terrestrial foods	0.041	^{35}S ^{90}Sr
United Kingdom Atomic Energy Authority			
Dounreay	Fish and shellfish consumption	<0.005	^{90}Sr $^{239/240}Pu$
	External in intertidal areas	<0.005	Ext
	Terrestrial foods[h]	0.014	^{238}Pu $^{239/240}Pu$
Harwell	Fish consumption and external to anglers	0.009	Ext ^{137}Cs
	Terrestrial foods[h]	<0.005	^{3}H ^{137}Cs
Winfrith	Fish and shellfish consumption	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	<0.005	^{3}H ^{137}Cs
Electricity Companies[d]			
Berkeley and Oldbury	Fish and shellfish consumption	<0.005	Ext ^{3}H
	and external in intertidal areas		
	Terrestrial foods	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	0.005	^{14}C ^{35}S
Dungeness	Fish and shellfish consumption	0.007	Ext ^{241}Am
	and external in intertidal areas		
	Terrestrial foods[j]	<0.005	^{14}C ^{137}Cs
Hartlepool	Fish and shellfish consumption	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods	0.008	^{14}C ^{137}Cs
Heysham	Fish and shellfish consumption	0.059	Ext ^{241}Am
	and external in intertidal areas		
	Terrestrial foods	0.008	^{14}C ^{35}S
Hinkley Point	Fish and shellfish consumption	0.014	Ext ^{3}H
	and external in intertidal areas		
	Terrestrial foods	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption	<0.005	^{99}Tc ^{137}Cs
	and external in intertidal areas		
	Terrestrial foods	0.028	^{35}S ^{241}Am
Sizewell	Fish and shellfish consumption	<0.005	^{137}Cs ^{241}Am
	and external in intertidal areas		
	Terrestrial foods	<0.005	^{14}C ^{35}S

Summary Table: continued

Establishment	Radiation exposure pathways	Exposure, mSv[b]	Contributors[c]
Electricity Companies *continued*			
Torness	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{241}Am
	Terrestrial foods	0.017	^{90}Sr ^{241}Am
Trawsfynydd	Fish consumption and external in intertidal areas	0.034	Ext ^{137}Cs
	Terrestrial foods[j]	0.014	^{14}C ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	0.011	^{137}Cs ^{241}Am
	Terrestrial foods	<0.005	^{14}C ^{35}S
Defence Establishments			
Aldermaston	Fish consumption and external to anglers	<0.005	Ext ^{137}Cs
	Terrestrial foods	<0.005[i]	^{3}H U
Devonport	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{241}Am
Faslane	Fish and shellfish consumption and external in intertidal areas	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	0.016	Ext
Rosyth	External in intertidal areas	<0.005	Ext
Amersham plc			
Amersham	Fish consumption and external to anglers	<0.005	Ext ^{241}Am
	Terrestrial foods	0.005	^{75}Se ^{131}I
Cardiff	Fish and shellfish consumption and external in intertidal areas	0.036	^{3}H ^{14}C
	Terrestrial foods	0.014	^{3}H ^{14}C
Rhodia Consumer Specialties Ltd			
Whitehaven[k]	Fish and shellfish consumption at Whitehaven	0.19	^{210}Po ^{210}Pb
	Fish and shellfish consumption at Sellafield	0.43	^{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 2001 was 0.43 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 2001*

h *15 y old*

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

j *Adults*

k *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 2001 was 0.057 mSv at Whitehaven and 0.16 mSv at Sellafield*

Minor incidents and/or investigations occurred at other nuclear sites in 2001

- Sellafield – Solvent Treatment Plant gaseous trigger level exceeded in May and June.
- Oldbury – quarterly notification level for carbon-14 exceeded in May.
- Berkeley – a fire occurred in July in a tiled enclosure in a laboratory facility involving small amounts of uranium.
- Hinkley Point – anomalous concentrations of caesium-137 were found on a deposition collector in September.
- Derby – investigation of cobalt-60 at a low level solid waste disposal site.

Each of these issues was investigated by modifying or adding to the normal sampling and analytical schedule of surveillance. None required action to be taken using the powers available for intervention in the Food and Environment Protection Act 1985 (United Kingdom – Parliament, 1985).

During 2001, further radioactive fragments* were recovered near Dounreay. Three radioactive fragments were recovered from Sandside Bay, three from the site foreshore and 122 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.

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.

There was evidence that concentrations of natural radionuclides in fish and shellfish near Whitehaven Works (Rhodia Consumer Specialties Ltd.) continued to be slightly enhanced above normal levels. Making maximising assumptions about the effects of enhancement, doses to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, were estimated to be 0.58 mSv for the most exposed group. The contributions from artificial and enhanced natural radionuclides were 0.16 and 0.43 mSv respectively rounded to two significant figures. The most exposed group in 2001 comprised consumers near the Sellafield site. The dose to the group nearer to the Whitehaven Works from natural and artificial radionuclides was 0.25 mSv in 2001.

The programme of monitoring the effects of discharging gaseous wastes at other non-nuclear industrial sites continued. The sites included a pharmaceutical manufacturer, a biological research centre, an oil refinery, a veterinary research institute, a tritium lighting manufacturer and a waste services supplier. There was no evidence for enhancement of radionuclides near these sites.

Tritium was found in leachate from some landfill sites in Scotland at levels that were of very low radiological significance.

The programme of surveillance of the effects of the Chernobyl accident was restricted in 2001 because of the effects of the Foot and Mouth Disease outbreak. Restrictions on the movement, sale and slaughter of sheep remain in some upland areas of the UK.

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

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

The surveillance programmes

These surveillance programmes involved the collaboration of five 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 Welsh Assembly Government. In 2001, approximately 1700 food samples and 900 other samples were collected to determine levels of radioactivity in the environment. About 14000 analyses or dose rate measurements were completed. The reduction in sampling and analysis in 2001 was due to two main factors. The Foot and Mouth Disease restrictions reduced access and sample availability in parts of the UK. The effect was not permanent and the remaining programme was sufficient to maintain adequate surveillance of nuclear and other installations. The Food Standards Agency's air particulate sampling programme near nuclear sites ceased in 2001. Designed as a back-up to provide additional information on the deposition of radioactive particles, the usefulness and relevance to food consumption was reviewed and a decision taken to stop the programme.

Results of the analysis of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries on the Agency's website (www.food.gov.uk). Further details of all programmes described in this report can be obtained by telephoning the Food Standards Agency on 020 7276 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.

1. INTRODUCTION

1.1 Background

This report contains the results of the monitoring of food and other samples and dose rate undertaken in 2001 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 Welsh Assembly Government in relation to food safety. In Scotland, the Scottish Environment Protection Agency (SEPA) 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 2001. 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 Welsh Assembly Government, 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. 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 monitoring 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 2001 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. In general the doses reported around each nuclear establishment are for the most exposed group of consumers from artificially produced radionuclides and exclude natural background [see Section 3.6.6] and direct radiation. The doses are compared to the EU limit of 1 mSv applicable for controlled releases of radioactivity from artificial sources [see Section 3.5] and would be in addition to the dose of 0.15 mSv received by the general public due to the consumption of naturally produced radionuclides [see Section 11.4].

A glossary of abbreviations is provided in Appendix 3.

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

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/statistics/des/radioact/alltext.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 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 discharges in 2001 from nuclear sites 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 from other sites such as hospitals, chemical works and research establishments are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). 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 environmental legacy at 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. Discharges of radioactive substances by the non-nuclear industry into the sea have recently been reviewed (OSPAR, 2002).

Appendix 1 presents the principal discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the United Kingdom during 2001. 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 2001 are also stated in the tables.

Where changes in the rates of discharge in 2001 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"

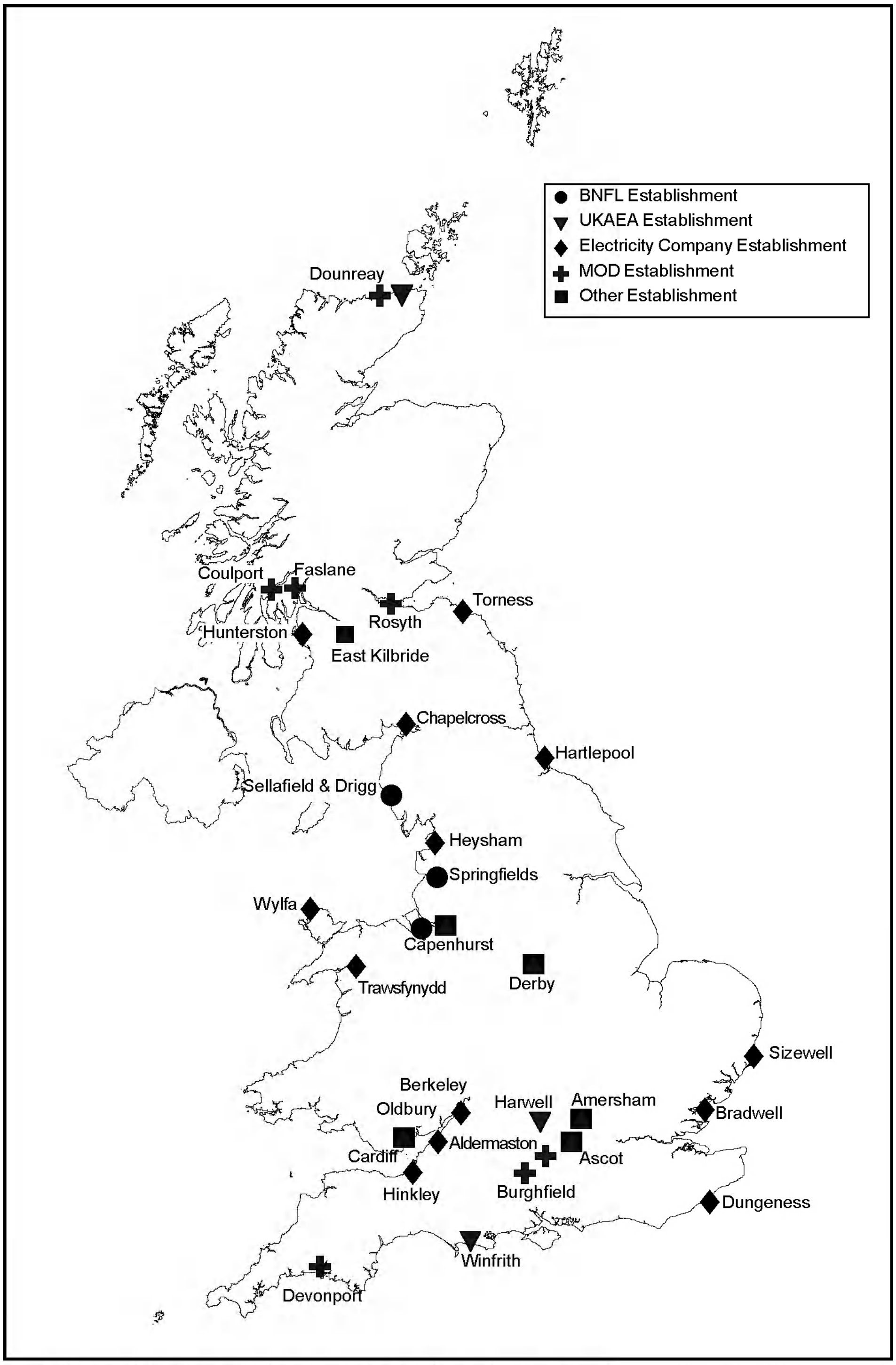

Figure 1.1 Principal sources of radioactive waste disposal in the UK

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). A UK technical report has assessed key marine indicators for study within the OSPAR context (Smith, 2002a).

During 2000, the UK Government consulted upon the draft UK Discharge Strategy (DS) (DETR, 2000b). The DS 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 DS is expected in 2002.

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

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 2001 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. No such assessments were required in 2001. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA, 1999a).

1.2.3 Other sources of radioactivity

There are several other possible sources of radioactivity that may affect the marine food chain and the environment. These include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas installations and the operation of nuclear powered submarines. Submarine berths in the United Kingdom are monitored by the Ministry of Defence (DSTL, 2002). 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 2001. 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.

1.2.4 Food irradiation

The irradiation of food by intense sources of radioactivity to limit spoilage and microbial contamination is not considered in this report. Details of a recent survey of herbs and spices, dietary supplements and prawns and shrimps undertaken by the Food Standards Agency as part of its food authenticity programme is available (Food Standards Agency, 2002a). This survey was conducted to investigate whether irradiated food is on sale in the UK, but not labelled as such.

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). Further revisions are in progress (Food Standards Agency, 2001a).

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 programmes also serve 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 are 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.

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 they are responsible for the largest individual 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.

2. Sampling and measurement

The frequency and type of measurement and the materials sampled vary from site to site. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring when necessary, for example, in response to incidents or reports of unusual or high levels of radioactivity with the potential to get into the food chain. 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, 2002). 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, 2002). 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 European Commission operates a verification system under Article 35 of the Euratom Treaty to check on the operation and efficiency of the facilities and arrangements for monitoring the levels of radioactivity in the environment. In 2000, the Commission selected the nuclear power plants at Dungeness and the surrounding area for verification. The results have been published at (http://europa.eu.int/comm/environment/radprot/art35/dungeness_main.en.pdf and http://europa.eu.int/comm/environment/radprot/art35/dungeness_techrep_en.pdf). The Commission found high standards of quality assurance were in place regarding the Food Standards Agency's surveillance programme. They only made one recommendation: to consider implementing sampling for herbage, which is harvested as a feedstuff for sheep. This recommendation has been acted on and the results of sampling of grass have been included in this report (Section 6.3).

The aquatic programme

The general scope of the aquatic programme in 2001 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 varying between 1 week and 1 year.

The types of material sampled and the locations from which samples are taken are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from local habits surveys and other sources. As a consequence the programme varies from site to site and 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 2001 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of a diverse range of samples, which includes foodstuffs. Samples are selected that may be affected by disposals to atmosphere, although in some cases where food availability is limited, environmental indicator materials such as grass and soil are monitored.

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

Grass is a useful indicator of radioactivity as it is an efficient collector of atmospheric contaminants. Milking cows graze significant areas of grass and many important radionuclides are passed from grass into milk. It is therefore important for monitoring purposes to ensure milk samples are collected and analysed. Milk is also a convenient product to sample regularly and analyse and is an important part of the diet, especially for young children and infants. For most analyses of milk, weekly or monthly collections are combined (bulked) to provide four quarterly samples for analysis each year, although some analyses are carried out more frequently, e.g. weekly iodine-131 analysis. 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 dependent upon its availability so some foodstuffs are generally annually collected. Samples are often 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 were positioned around the nuclear sites and analysed for airborne radionuclides up until 2001. This part of the programme has now ceased as the more direct measurements of foodstuffs are considered to provide a more effective method for the surveillance of gaseous releases. Air monitoring continues to be undertaken on behalf of DEFRA by the Environment Agency. In Scotland, SEPA collected direct concentrations in air data around the nuclear sites using air samplers.

2.1.2 Industrial and landfill sites

Whilst the main focus of the programme is the nuclear industry, a watching brief is kept on other activities which may have a radiological impact on 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 2001 are shown in Figure 2.1.

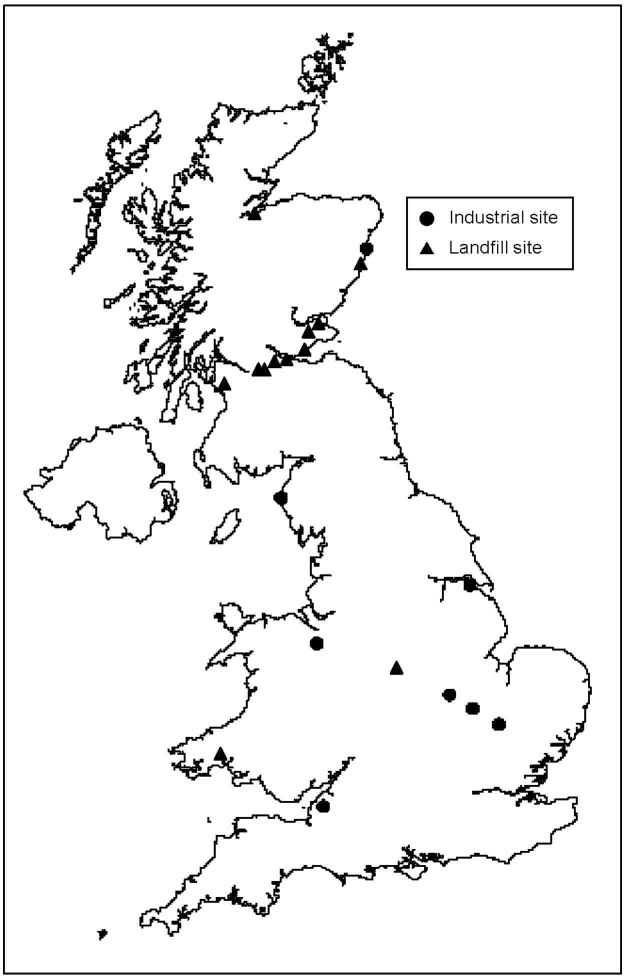

Figure 2.1 Industrial and landfill sites studied in 2001 (landfill sites in England and Wales are monitored by the Environment Agency and are therefore not generally covered in this report)

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 2001, the industrial sites studied were:

- Whitehaven, Cumbria (chemical manufacturer)
- Aberdeen, Grampian (gas and oil industry)
- Cambridge, Cambridgeshire (pharmaceuticals)
- Alconbury, Cambridgeshire (biological research)
- Immingham, North Lincolnshire (oil refinery)
- Langford, North Somerset (veterinary research)
- Weldon, Northamptonshire (tritium lighting manufacture)
- Wrexham, Wrexham County Borough (waste incineration services)

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

Ten landfill sites were monitored in Scotland. They were 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. However, a former site in Wales was additionally studied in 2001 by the Food Standards Agency in view of concerns regarding the foodchain.

2.1.3 Chernobyl fallout

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

2.1.4 Additional monitoring

In addition to the previous programmes which address specific sources of contamination in the 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. As part of the Food Standards Agency's Total Diet Study representative mixed diet samples are collected from regions throughout the United Kingdom [see Section 11.4]. 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. The EC compile data into a report of results from all Member States. At the time of writing the last report covered data for 1995 (JRC, 2001).

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 2001. Samples were taken monthly and some of the results are reported to the EC to allow comparison with those from other member states (JRC, 2001).

Other food sampling complements the regional dairy programme described above. Crop samples were taken from locations 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 11.12. The results of monitoring of drinking water in England and Wales are summarised in the Environment Agency`s surveillance report (Environment Agency, 2002). SEPA samples airborne particulates using medium volume air samplers (Table 11.11).

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.

2.1.5 Foot and mouth disease

The outbreak of Foot and Mouth Disease (FMD) in 2001 did not have any direct effect on food safety, however, the outbreak did affect the collection of samples for the RIFE programme from around the UK.

In England and Wales, very few samples of milk were collected for part of March and all of April. However, over 70% of samples were collected in May and this increased to over 97% by June and remained at this level for the remainder of the year. The farmer often had to hand a sample to the collector over the farm gate in order to ensure a continuation of supply. The supply of milk from the dairies was unaffected by FMD as the milk would have been pasteurized thereby inactivating the virus.

As the Veterinary Laboratory Agency, a contracting laboratory, had several farms on site, potentially FMD contaminated animal products from the RIFE programmes were not permitted on site. For milk samples, a new system was introduced whereby the collector (National Milk Records) stored the milk for a fortnight. At the end of this period, if the farm providing the sample was still FMD free, the sample would be forwarded to VLA for analysis. In the early stages of the FMD outbreak, the samples were analysed whilst still in the sample bottle. The outsides of the bottles were disinfected and then the whole bottle was place on a gamma-spectrometer. The altered geometry led to some increases in the limit of detection and also meant some radiochemical analysis could not be undertaken. From early May, the milk samples were acidified to inactivate the virus and to allow safe analysis of a wider range of radionuclides.

As there was no way of introducing a similar system for non-milk samples, some samples were not collected in 2001. No animal faeces and a reduced number of grass samples (potentially contaminated with animal faeces) were collected as part of the TRAMP and FARM programmes. However, most of the food samples were collected. For the crops collected from the remote sites module of the FARM programme, some town markets were targetted in addition to the usual direct method of collecting from farms or market gardens. This additional method of sampling proved effective and it will now be used routinely by the Food Standards Agency, in conjunction with previous sampling methods.

Following the confirmation of FMD outbreaks in Scotland, SEPA ceased the collection of all samples in areas that were affected by the disease. This resulted in a disruption in the collection of food and environmental samples throughout Scotland. The effect of the FMD outbreak was largely confined to a disruption of the monitoring programme from March until June 2001. Following the lifting of restrictions imposed during the FMD outbreak collection of samples and direct measurements of radioactivity in the environment resumed. The FMD outbreak prevented 152 samples or direct measurements of radioactivity in the environment being taken which was less than 15% of the annual SEPA programme.

Despite the shortfall in samples and dose rates due to FMD, it was generally the case that sufficient data was collected to allow meaningful dose calculations for comparison with dose limits. Adding best-estimate data in place of missing monitoring data was considered for the purpose of calculating doses. However, this was found to be unnecessary, with one exception. There was sufficient data for dose assessments within the overall uncertainty of these calculations in all but one case. This exception was at Dounreay, where the absence of any animal data due to FMD would have resulted in an underestimate of exposures. This case is considered in Section 5.1.

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 measured directly in the environment.

2.2.1 Sample analysis

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

Five 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 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 Total 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
- WELL Winfrith Environmental Level Laboratory (NNC Ltd.)
  gamma-ray spectrometry and radiochemistry of air and rain samples in Scotland

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

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

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

Air particulate is collected by drawing air through particle collectors using a medium volume air sampler at a continuous rate of approximately 0.36 m^3 per hour.

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 or Mini 5.10/EP 15* contamination monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all others. In this report we have presented the total gamma dose rate. NRPB reports terrestrial gamma dose rates to SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 $\mu Gy\ h^{-1}$ which is an approximation of the contribution made by cosmic radiation (HMIP, 1995).

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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, 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 2001

Measurement	Routine frequency of measurement	Analyses or measurements	Types of material	Detailed species/materials
Aquatic programme				
Analysis of foods	Annually to weekly	Total alpha, beta and gamma-ray spectrometry, ^{3}H, organic ^{3}H, ^{14}C, ^{226}Ra, ^{90}Sr, ^{99}Tc, ^{147}Pm, Th, ^{210}Po, U, ^{210}Pb, transuranics	Fish, crustaceans, molluscs and edible aquatic plants	Angler fish, bass, beadlet anemone, brill, brown trout, cockles, cod, conger eel, crabs, cuttlefish, dab, dog whelks, eels, elvers, *Enteromorpha*, fish, fish oil, flounder, green crabs, green sea urchins, grey mullet, haddock, hake, herring, John Dory, *Laminaria ssp*., laverbread, lesser spotted dogfish, leaf beet, limpets, lobsters, mackerel, molluscs, mullet, mussels, native oysters, *Nephrops*, ormers, oysters, pacific oysters, perch, pike, plaice, pollack, poor cod, *Porphyra*, queens, rainbow trout, ray, red gurnard, rough winkles, saithe, salmon, samphire, sandeels, scallops, sea lettuce, sea trout, sea urchin, seafood, shrimps, slipper limpets, sole, spiny spider crabs, sprats, spurdog, squat lobsters, squid, toothed winkle, trigger fish, tub gurnard, twaite shad, whelks, whitebait, whiting, winkles and wrasse
Analysis of indicator materials	Annually to monthly	Total alpha, beta and gamma-ray spectrometry, ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, Th,U, transuranics	Water, sediments, salt marsh, seaweeds, aquatic plants and coarse fish	*Ascophyllum nodosum,* clay, *Cladophra, Elodea canadensis,* fish meal, freshwater, *Fucus spp.,* mud *Nuphar lutea, Rhodymenia spp.,* rudd, salt marsh, sand, seawater, seaweed, sediment, soil, sludge and turf
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 weekly	Total alpha and gamma-ray spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{33}P, ^{35}S, ^{90}Sr, ^{99}Tc, ^{125}I, ^{129}I, ^{131}I, ^{147}Pm, Cs, ^{210}Po, ^{210}Pb, U, Th and transuranics	Milk, crops and animals	Apples, asparagus, barley, beef meat, kidney and liver, beetroot, blackberries, blackcurrants, broad beans, broccoli, cabbage, carrots, cereal, chickens, courgettes, cows' milk, damsons, duck, eggs, elderberries, gooseberries, hazelnuts, honey, kale, leaf beet, leafy green veg, leeks, lettuce, maize, mallard, marrow, mint, oats, onions, parsnips, pears, peas, pheasant, pigeons, plums, potatoes, rabbit, rape oil, raspberries, rhubarb, rowan berries, runner beans, sea kale, sheep meat and offal, sloe berries, spinach, sprouts, strawberries, swede, turnips, wheat, wild greens and widgeon
Analysis of indicator materials	Annually to monthly	Total alpha, beta and gamma-ray spectrometry ^{3}H, organic ^{3}H, ^{14}C, ^{32}P, ^{33}P, ^{35}S, ^{90}Sr, ^{99}Tc, ^{99m}Tc, ^{125}I, ^{131}I, ^{147}Pm, Cs, ^{210}Po, ^{210}Pb, U, Th and transuranics	Air[s], grass, soil and animal food	Air particulate, comfrey, compost, grass, ground elder, hawthorn berries, herbage, lucerne, nettles, rainwater, rape, rosebay willow herb and soil

[s] *Scotland*

Table 2.3. Analytical methods

Radionuclides	Sample type	Method of measurement
^{3}H ^{3}H (organic) ^{14}C ^{32}P ^{33}P ^{35}S ^{147}Pm ^{241}Pu	All	Beta counting by liquid scintillation
^{90}Sr	High-level aquatic samples	Cerenkov counting by liquid scintillation
^{90}Sr	Terrestrial and low-level aquatic samples	Beta counting using gas proportional detectors
^{99}Tc ^{210}Pb beta	All	Beta counting using gas proportional detectors
^{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
^{40}K ^{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 ^{154}Eu ^{155}Eu ^{241}Am ^{233}Pa ^{234}Th	All except seawater	Gamma-ray spectrometry using germanium detectors
^{129}I	Terrestrial samples^{S}	Gamma-ray spectrometry using germanium detectors
^{129}I ^{131}I ^{144}Ce	Aquatic samples	Gamma-ray spectrometry using germanium detectors
U	Terrestrial samples	Activation and delayed neutron counting
^{210}Po ^{226}Ra* ^{234}U ^{235}U $^{235+236}U$ ^{238}U ^{237}Np ^{228}Th ^{230}Th ^{238}Pu $^{239+240}Pu$ ^{241}Am ^{242}Cm $^{243+244}Cm$	All	Alpha spectrometry
^{226}Ra	Terrestrial samples	Alpha counting using thin window proportional detectors
Alpha	All^{s}	Alpha counting using gas proportional detectors

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

3. PRESENTATION AND ASSESSMENT

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 concentration is observed. This is labelled 'max' in the tables of results to distinguish it from the values that are averaged over a range of farms. For other terrestrial foods an alternative approach is adopted, since it is recognised that the possible storage of foods harvested during a particular time of the year has to be taken into account. Greater public exposures would be observed when foods are harvested at times when levels of contamination are high. For such foods, we have presented the maximum concentration observed of each radionuclide at any time in 2001 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 in an environment of changing concentrations in seawater, sediments and lower trophic levels. The resulting level of contamination therefore represents an average over a large area. Similarly cows providing milk at a farm may feed on grass and other fodder collected over a distance of a few kilometres of the farm. In the case of dose rate measurements, the position where the measurement is carried out is within a few metres of other measurements made within a year. Each observation consists of the mean of a number of instrument readings at a given location.

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

The number of sampling observations does not necessarily indicate the number of individual analyses carried out for a specific radionuclide. In particular, determinations by radiochemical methods are sometimes carried out less frequently than those by gamma-ray spectrometry. However, the results are 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 2001.

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 that 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. Provisional results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries through the Internet (www.food.gov.uk).

The main categories of additional data are:

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

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

3.5 Radiation protection standards

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

Current 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 Directions.

The relevant dose limits for members of the public are 1 mSv (millisievert) per year for whole-body (more formally 'committed effective dose') and 50 mSv per year specifically for skin. The latter limit exists to ensure that specific effects on skin due to external exposure are prevented. It is applicable, for example, in the case of handling of fishing gear. The 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 publicly consulted (Food Standards Agency, 2001b) on the EC's intention to introduce legislation setting Maximum Permitted Levels for radioactivity in foodstuffs offered for sale on the common market. The findings of the consultation are available (Food Standards Agency, 2002b) and the European Commission is considering how best to take the matter forward.

The main focus of this report and radiological regulation and surveillance more generally is towards protection of man. Radiological protection of the environment is also of concern and is considered by, for example, UNSCEAR (1996), IAEA (1999b) and Copplestone *et al.*, (2001).

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 2001. 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.

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

3.6.1 Radionuclide concentrations in foodstuffs

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 the farm with the highest individual result is used in the dose assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers. For other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

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

3.6.2 Consumption 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. Estimates of dose 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 (MAFF, 1996). Locally grown cereals are not considered in the assessment of exposures as it is considered highly unlikely that a significant proportion of cereals will be made into locally consumed (as opposed to nationally consumed) foodstuffs, notably bread.

3.6.3 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 is re-examining its methods of dose assessment, where necessary, in light of the final report (Food Standards Agency, 2001c) and has published a response document in its website (http://archive.food.gov.uk/pdf_files/consultations/dose_assess_sum.pdf). This is being undertaken within the framework of a new group of stakeholders chaired by the National Radiological Protection Board. The group is called the National Dose Assessment Working Group (NDAWG). NDAWG has representatives from CEFAS, Dept Environment (NI), DEFRA, DTI, EA, Food Standards Agency, National Assembly for Wales, NII, RWMAC, SEPA as well as from the nuclear industry and NGOs. The Food Standards Agency is also on a sub-group considering assessment of surveillance data.

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 press).

3.6.4 Dose coefficients

Dose calculations for intakes of radionuclides by ingestion 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.

The dose assessments include the use of appropriate gut uptake factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut uptake factors for a radionuclide, we have generally chosen the one that results in the highest predicted exposure. In particular where results for tritium are available, we have assumed that the total tritium content is wholly in an organic form. However, we have also taken into account specific research work of relevance to the foods considered in this report. This affects the assessments for polonium, plutonium and americium radionuclides for the 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 and this is consistent with NRPB advice. For other foods and for winkles outside Cumbria the factor of 0.0005 is used for these radioelements. This choice is supported by recent studies of cockle consumption (Hunt, 1998).

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

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

3.6.5 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} 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 estimates of dose 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 radionuclide 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 have 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.

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

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 the 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 uncertainties due to counting statistics, etc. Analytical counting statistics may vary due to factors such as the sample size, the time the sample is counted for, the detection efficiency which varies with different types of radiation, the sample geometry within the counting detector and background noise from radionuclides with emissions in the same energy range.

Although not reported in the tables for reasons of brevity, analytical uncertainties are recorded at the 95% confidence limit. Provisional quarterly data are published on the Food Standards Agency's website and uncertainties are reported with this data.

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.

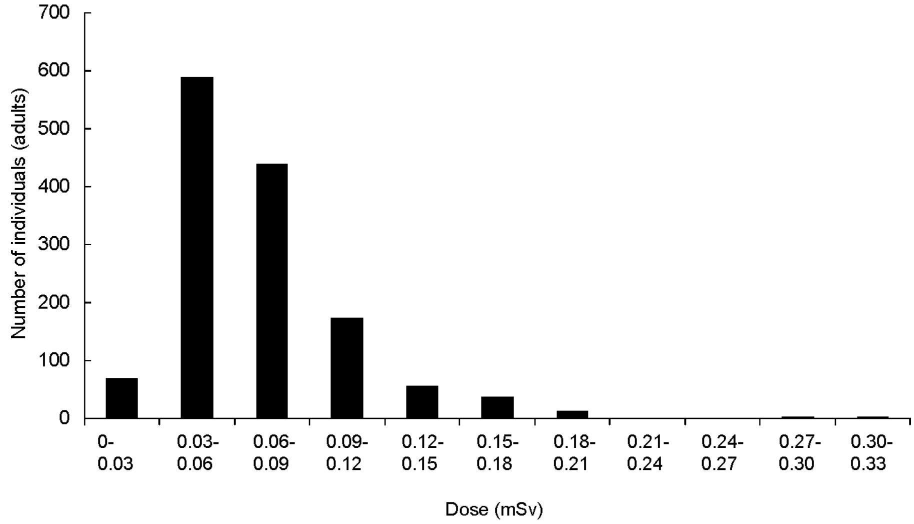

Figure 3.1 Distribution of food dose

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. No changes to the authorisation to discharge radioactivity were made in 2001 but the Environment Agency have consulted on changes for the future (Environment Agency, 2001). DEFRA and DoH Ministers announced that the manufacture of mixed oxide fuel (MOX) was justified in October 2001 (Department for Environment, Food and Rural Affairs and Department of Health, 2001). The MOX plant discharges relatively small amounts of waste. 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 2001 are summarised in Appendix 1. Total alpha and beta discharges were 0.196 and 123 TBq respectively (2000: 0.119 and 77 TBq respectively). Most discharges of individual radionuclides increased in 2001 but there were small decreases for uranium. Technetium-99 discharges increased to 79.4 TBq in 2001 (2000: 44.4 TBq) but are now much lower than the peak reached in 1995 of 192 TBq. No discharges were noted to have exceeded 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 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 2001 above those due to Sellafield. Regulatory monitoring of the Drigg Stream is carried out by the Environment Agency.

4. British Nuclear Fuels plc (BNFL)

Regular monitoring of the marine environment near Sellafield continued during 2001. Important radiation exposure pathways were consumption of fish and shellfish and external exposure to gamma rays and beta particles from human occupancy over sediments. Other pathways were kept under review. In 2001, as in previous recent years, there was no harvesting of *Porphyra* seaweed in west Cumbria for manufacture of laverbread, but monitoring continued because the pathway remains potentially important. A review of changes in discharges and effects from the site is given by Smith *et al*. (2000a). This year some uncommon non-commercial seafoods were sampled and analysed as part of a research project (Swift, 2002). The results are included in the following tables.

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 2001 were generally similar to those in 2000. 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 Sea are similar. Data for cod from the 'Offshore Area' have been used to give a general indication of trends in fish (Figure 4.4) though substantial variability between species can be found. This year both plaice and sole, sampled as common seafoods, showed relatively high concentrations of technetium-99, approximately 65 Bq kg^{-1}. Common dragonet (*Callionymus lyra*), a commonplace fish which is rarely eaten gave 250 Bq kg^{-1} (Swift, 2002). However, these levels are small compared to those found in some shellfish.

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

A sample of rainbow trout from a small lake near Sellafield was again collected this year. The caesium-137 concentration in the sample, at 33 Bq kg^{-1}, was much lower than in 2000 (390 Bq kg^{-1}); however, the variability in activities in samples of freshwater fish is known to be high (Camplin *et al*., 1989). Although the evidence is not conclusive, the source of activity in this lake is likely to be Sellafield. No samples of brown or sea trout were obtained from the River Calder which runs through the Sellafield site this year because of the FMD outbreak.

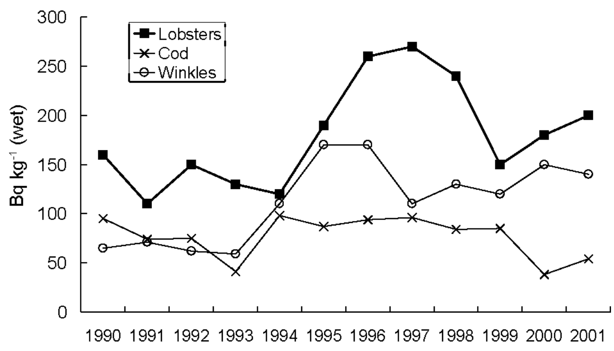

Figure 4.1 Carbon-14 concentrations in cod, lobsters and winkles from Sellafield

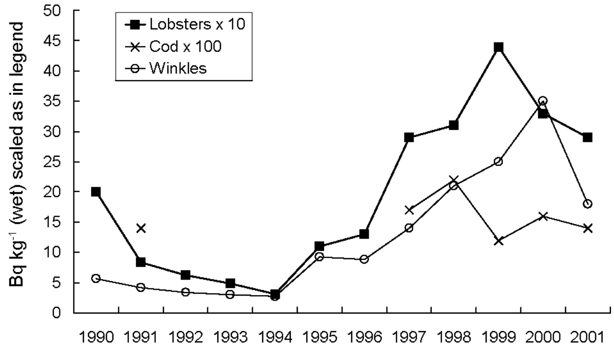

Figure 4.2 Cobalt-60 concentrations in cod, lobsters and winkles from Sellafield

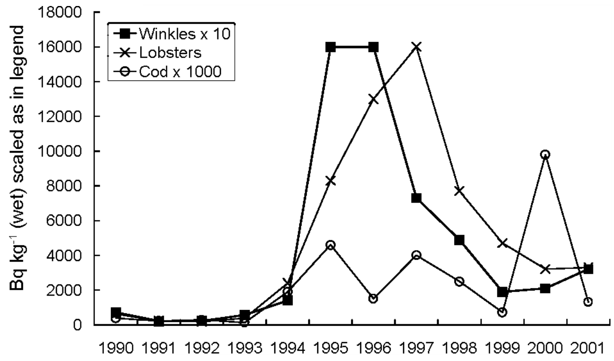

Figure 4.3 Technetium-99 concentrations in cod, lobsters and winkles from Sellafield

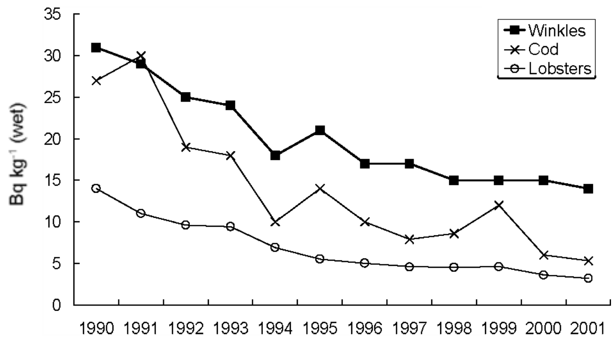

Figure 4.4 Caesium-137 concentrations in cod, lobsters and winkles from Sellafield

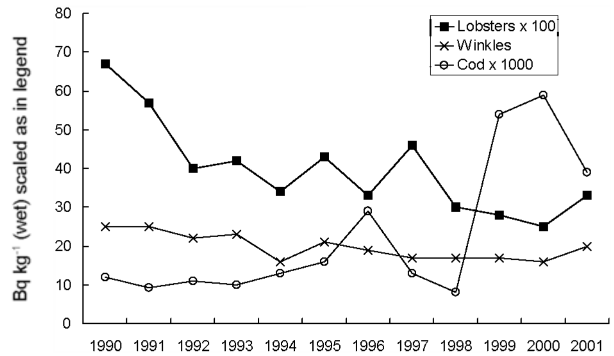

Figure 4.5 Plutonium-239/240 concentrations in cod, lobsters and winkles from Sellafield

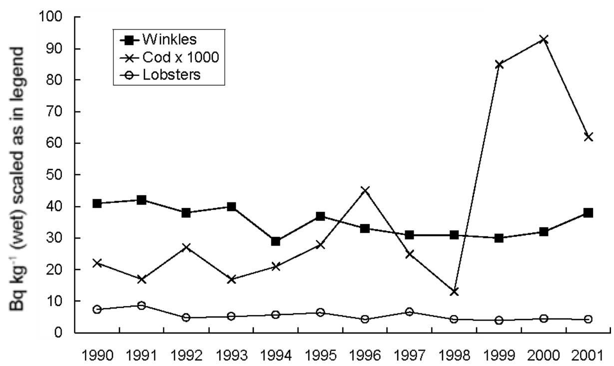

Figure 4.6 Americium-241 concentrations in cod, lobsters and winkles from Sellafield

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 11.13). Taken with data for other sites around the UK, it now seems clear that some degree of bioaccumulation of tritium is taking place. However, the extent of bioaccumulation is much smaller than at Cardiff , 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 2000 and 2001 data across a wide range of sampling locations and shellfish species, few significant changes in concentrations were found. Technetium-99 levels generally increased in local samples but by small amounts. Further information about technetium-99 trends is given for seaweeds around the UK in Section 4.1.4.

Analyses for transuranic radionuclides are costly and labour-intensive; as in previous years, a selection of samples of fish and shellfish, chosen mainly on the basis of potential radiological significance, were analysed for transuranic nuclides. The data for 2001 are presented in Table 4.3. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Concentrations in shellfish in 2001 were generally similar to those in 2000 (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 reduced in 2001, but remained at levels which are higher than those typical of the 1990s. 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 2001 from artificial radionuclides in fish and shellfish. The dose to the local most exposed group of consumers was 0.16 mSv. This dose includes a contribution due to external exposure of radiation. The increase in dose from 0.15 mSv reported for 2000 (Food Standards Agency and SEPA, 2001) is largely due to small increases in technetium-99 in seafood. The consumption and occupancy rates of the local critical group were reviewed in 2001. No changes to the rates representative of this group were made. Most of the dose from the ingestion of seafood and external irradiation due to

Sellafield was from historic discharges. Recent and current discharges of technetium-99 contributed about 15% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose were plutonium-239/240 and americium-241.

In order to provide a more direct measure of the effects of changing concentrations and dose rates in the environment, as opposed to changes in the habits of consumers, a dose calculation is presented based on a 5y average of critical group habits. The period of averaging chosen for assessment of 2001 concentration and dose rate data was 1997-2001 and the data are provided in Appendix 4. For comparison, surveillance data for 2000 were reanalysed with 5y average habits relating to 1996-2000. On this basis the dose in 2001 was 0.15 mSv compared with 0.13 mSv for 2000. A significant proportion of the increase in dose was due to the increase in concentrations of technetium-99 in 2001.

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 (see Appendix 6). However, using maximising assumptions for the dose coefficients, the dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 2001 was estimated to be 0.43 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 0.58 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. The estimates for Northern Ireland are made on the basis of a revised set of consumption and occupancy rates (Smith, *et al.*, 2002). There were small changes in the doses in each area when compared with those in 2000 (see following text table). It is expected that there will be fluctuations in concentrations due to normal sampling variability. All doses were well within the dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, appropriate to a consumption rate of 15 kg year^{-1} of fish from landings at Whitehaven and Fleetwood, is also given in Table 4.4. This consumption rate represents an average for typical fish-eating members of the public. Their dose was very low, 0.001 mSv in 2001.

Seafood doses from artificial radionuclides in the Irish Sea

Group	Dose, mSv	
	2000	2001
Northern Ireland	0.015	0.015
Dumfries and Galloway	0.033	0.040
Whitehaven	0.030	0.031
Sellafield	0.15	0.16
Isle of Man	0.008	0.007
Morecambe Bay	0.066	0.059
Fleetwood	0.023	0.019
North Wales	0.010	0.008

No consumption of uncommon seafood caught as by-catch of fishing in the Sellafield area was reported in 2001, though this practice has been observed in the past (MAFF and SEPA, 1999). Further information of concentrations in, and doses from, uncommon seafood have been reported (Swift, 2002).

The exposure of potential consumers of trout from a tarn at a local farm was also considered in 2001. Their dose was less than 0.005 mSv which was less than 0.5% of the dose limit to members of the public of 1 mSv. This includes a contribution due to Chernobyl and weapons test fallout. 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 small 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 2001 were similar to those data for the same locations in 2000 (Food Standards Agency and SEPA, 2001).

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 and results are comparable with those for 2000 (Food Standards Agency and SEPA, 2001). 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 in its assessments.

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 2001 are presented in Table 4.7. Measured dose rates were generally similar to those for 2000. 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 2001, including a component due to natural radiation, was 0.13 mSv, which was less than 1% of the appropriate dose limit of 50 mSv. Handling of fishing gear is therefore a minor pathway of radiation exposure.

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 were small changes for some radionuclides when compared with 2000. However, none of these were of sufficient magnitude to be likely 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 2001 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. Evidence for a site-related effect was found by examination of the maximum concentrations in milk of near and far farms. Concentrations in milk were generally similar to those in 2000 (Food Standards Agency and SEPA, 2001).

Levels of activity in bovine and ovine meat and offal continued to be analysed in 2001. In addition, 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 and sulphur-35. Plutonium concentrations were much lower than those found in seafood.

The fruit and vegetables that were sampled in 2001 included cabbage, carrots, damsons, marrow, onions, pears, potatoes, runner beans, sloes, sprouts, swede and turnips. The results were similar to those in previous years. In common with meat and offal samples, limited evidence for the effects of Sellafield discharges was found in data for tritium, carbon-14 and sulphur-35. Concentrations of transuranic radionuclides were generally very low, but the characteristic Sellafield signal in the plutonium isotopic ratio was observed in several fruits and vegetables. A ratio of $^{239+240}$Pu : ^{238}Pu of about 40 : 1 is expected for fallout.

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 0.037 mSv (Adult: 0.016; 15y: 0.020: 10y: 0.021). The most significant contributions to this dose were from sulphur-35, strontium-90 and ruthenium 106. The most important foodstuff was milk which accounted for more than 60% of the dose. The exposure is very likely to be an upper estimate of the effects of Sellafield discharges because: (i) it is based on the assumption that a radionuclide which is not detected in a sample is present at a concentration equivalent to the limit of detection; (ii) the effects of the background of artificial 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 2001 were very similar to those in 2000 (1y: 0.033 mSv). The dose of 0.010 mSv received by a typical adult consumer obtaining food from the vicinity of Sellafield 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. Remedial measures, including a substantial cull of pigeons in the area, have been 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. However, this precautionary advice is in the process of being reviewed in 2002, and feral pigeons recently caught in the vicinity of the site are to be analysed. The results will be made available on www.food.gov.uk. A full review of the incident was published in 1999 (CBC *et al*, 1999).

The Food Standards Agency were informed by BNFL that the Solvent Treatment Plant discharges had exceeded their investigation levels in May and June 2001. Routine analyses for iodine-129 in milk were brought forward for 11 farms in the surrounding area to establish whether any effect could be detected. No change in levels was observed.

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 2001 are given in Table 4.10. Evidence in support of the proposition that radioactivity in Drigg leachate might be transferring to foods was found in enhanced tritium levels in some foodstuffs. 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 0.016 mSv which was less than 2% of the dose limit for members of the public of 1 mSv (Table 4.9). This compares with 0.015 mSv in 2000.

4.1.4 Other Surveys

Contact dose-rate monitoring of intertidal areas

A routine programme of measurements of beta dose rates from shoreline sediments continued in 2001 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 0.20 mSv in 2001 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, from gaseous releases, were also undertaken to compare with results for the immediate area around Sellafield.

The results of measurements in 2001 are presented in Table 4.12. In general, the data are similar to those for 2000 (Food Standards Agency and SEPA, 2001) and show lower concentrations than are found in the direct vicinity of Sellafield. The evidence for sea-to-land transfer is limited. No technetium-99 was detected but some promethium-147 was detected in grass samples from Ravenglass. 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 2001 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 0.017 mSv which was less than 2% of the dose limit for members of the public of 1 mSv. This compares with 0.018 mSv for 2000 (Food Standards Agency and SEPA, 2001). 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 2001 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, however, the general trend is of reducing concentrations since 1996 (Figure 4.7). Although the spatial extent of the technetium-99 from Sellafield is clearly evident in this figure, so is the large reduction in levels as the effect of Sellafield becomes less pronounced in moving from the eastern Irish Sea, to the rest of the Irish Sea, to Scottish Waters and on to the North Sea. Movement southwards from Sellafield into the English Channel is insignificant.

Seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2001. 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 2001, seaweed harvesting in the Sellafield area continued to be rare. However, several plots of land fertilised by seaweed were identified and were investigated further. Samples of soil were analysed for a range of radionuclides by gamma-ray spectrometry and for technetium-99. The soil and compost data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged from 1 to 790 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.

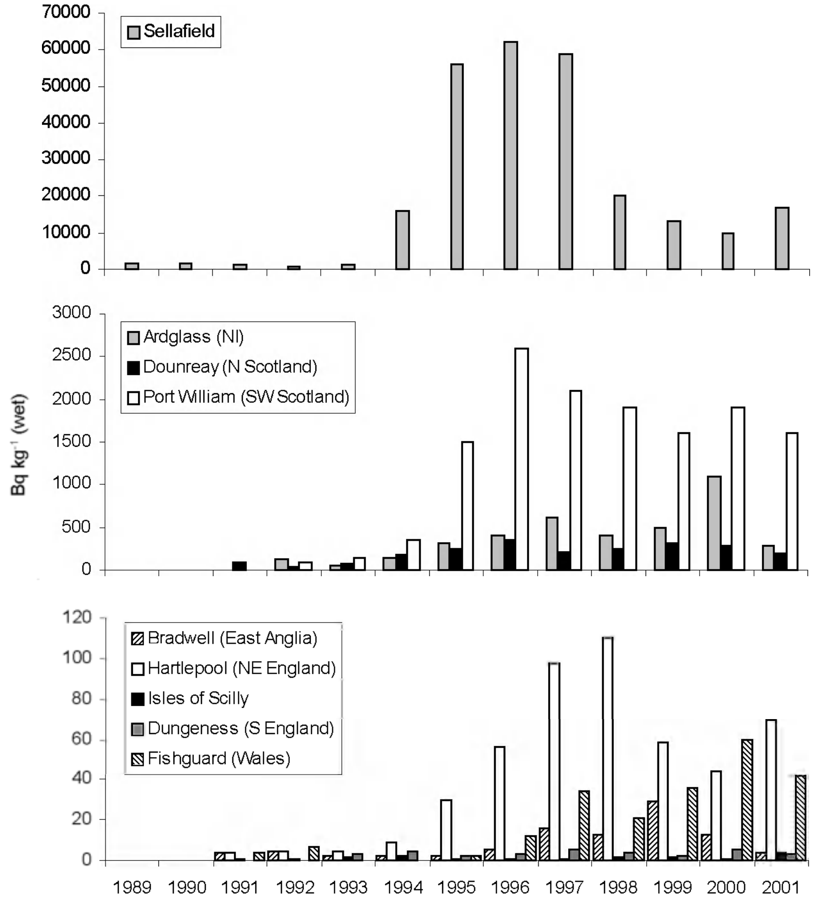

Figure 4.7 Technetium-99 concentrations in seaweed, Fucus vesiculosus

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 0.019 mSv, most of which was due to the seafood component of their diet. The highest dose due to technetium-99 in vegetables was 0.003 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 using a modelling approach 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 of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2001 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 industrial alginate production was detected.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2001; 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 2001 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 2001 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, increased from 71 TBq (2000) to 85 TBq in 2001. Discharges of gaseous effluents remained very low at a similar level to those for 2000.

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, habits surveys have 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, duck and vegetables. Indicator materials including grass and soil were also sampled.

Results for 2001 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 2000. The dose for the seafood consumption group was 0.018 mSv or less than 2% of the 1 mSv dose limit. The majority of the dose is attributable to Sellafield discharges transferred to the Springfields area with only a small percentage resulting from emissions from the Springfields site itself.

Skin irradiation of fishermen handling nets was 0.51 mSv in 2001. This is less than 2% of the relevant dose limit for members of the public.

In 2001, the most exposed group of terrestrial food consumers were adults consuming vegetables at high rates. Their dose was 0.006 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 2001, BNFL had authorisations to dispose of small amounts of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. An environmental monitoring programme for foodstuffs was carried out to investigate the different pathways that could be of radiological significance. Plants, rain water and sediments are also sampled as indicator materials.

Results for 2001 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 2000. 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 or 2001. 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 2001. The dose to the most exposed group of terrestrial food consumers was less than 0.005 mSv in 2001.

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 reduced in the area and is now only of minor importance. Nevertheless, this situation could change and will be kept under review. Samples of seawater and *Fucus vesiculosus*, as useful indicators, were collected in addition to seafood, sediments and dose rates. Terrestrial monitoring was expanded in 2000 and a greater number of samples are now collected and analysed. Monitoring of air at three locations was added to the programme in 2001.

Due to modification and refurbishment work on the station fuel ponds a routine pond purge was carried out in 2001. As a result of engineering problems, the station only operated two reactors for a significant part of 2001. In consequence, both liquid and atmospheric discharges for 2001 were lower than for previous years.

The results of routine monitoring in 2001 are presented in Tables 4.17(a), (b) and (c). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years. There were small increases in gamma dose rates in local intertidal areas.

The whole-body dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.044 mSv in 2001 which was less than 5% of the dose limit for members of the public of 1 mSv. This represents an increase above the value for 2000 of 0.032 mSv due to the increased gamma dose rates. Measurements of the contact beta dose-rate on fishing nets were below the limit of detection. A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the total dose to the local population; the greater proportion of the dose can be attributed to the emissions from Sellafield.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Monitoring of this area continues, although work carried out by the operator in recent years has led to a progressive decline in the number of these particles being found in the environment. Improvement works were carried out at the outfall in mid 1999 and further improvements to the effluent management system are in hand. During 2001, one particle of limescale was found compared with 3 in 2000 and 10 in 1999.

Concentrations of radionuclides in milk and grass were generally similar to those observed in 2000. 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 0.041 mSv which was 4% of the dose limit for members of the public of 1 mSv. Concentrations of radioactivity in air at locations near to the site were very low (Table 4.17 (c)). The dose from inhaling air containing caesium-137 at these concentrations was estimated to be less than 0.001 mSv.

Table 4.1. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2001

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			<0.25		<0.32	<0.42		<0.83	<0.12	8.3	<0.43	170
Sellafield coastal area	Plaice[a]	4	110		<0.20		<0.49	<0.90		<0.99	<0.11	6.5	<0.47	140
Sellafield coastal area	Bass	1			<0.09		<0.40	<0.71		<0.94	0.20	14	<0.58	
Sellafield coastal area	Mullet	1			<0.15		<1.2	*		<1.4	<0.15	9.2	<0.63	
Sellafield coastal area	Pollack	1			<0.06		<0.14	<0.14		<0.56	<0.05	11	<0.36	
Sellafield offshore area	Cod	1		54	0.14	0.069	<0.40	<0.67	1.3	<1.0	<0.11	5.3	<0.50	
Sellafield offshore area	Plaice[b]	2		120	0.23	0.085	<0.13	<0.16	64	<0.43	<0.05	6.3	<0.21	
Sellafield offshore area	Dab	2			<0.18		<0.43	<0.64		<0.98	<0.12	8.9	<0.47	
Sellafield offshore area	Whiting	2			<0.16		<0.65	<1.1		<1.5	<0.15	7.3	<0.74	
Sellafield offshore area	Spurdog	1			<0.11		<0.44	<0.73		<0.93	<0.10	8.6	<0.50	
Sellafield offshore area	Sole	1			<0.14		<0.57	<0.96	67	<1.3	<0.12	4.8	<0.51	
Sellafield offshore area	Lesser spotted dogfish	1			<0.06		<0.30	<0.47		<0.67	<0.06	10	<0.35	
Sellafield offshore area	Red gurnard	1			0.10		<0.22	<0.23		<0.65	<0.07	6.6	<0.34	
Ravenglass	Cod	4			<0.19		<0.41	<0.72		<0.81	<0.09	7.9	<0.47	
Ravenglass	Plaice[c]	4	110		<0.10		<0.27	<0.32		<0.73	<0.08	5.5	<0.35	
Ravenglass	Wrasse	1			<0.11		<0.25	<0.27		<0.77	0.09	11	<0.38	
Ravenglass	Conger eel	1			<0.09		<0.23	<0.20		<0.81	<0.09	2.7	<0.39	
Whitehaven	Cod	4		43	<0.10	<0.057	<0.30	<0.42		<0.77	<0.09	6.7	<0.42	
Whitehaven	Plaice	4			<0.12	0.052	<0.40	<0.61		<0.96	<0.11	4.3	<0.55	
Whitehaven	Ray	4			<0.08		<0.42	<0.72		<0.88	<0.09	4.7	<0.53	
Parton	Cod	4			<0.10		<0.35	<0.49		<0.86	<0.10	10	<0.55	
Seascale	Sandeels	1			0.28		<0.75	<1.9		<0.90	<0.09	4.1	<0.46	
Annaside	Grey mullet	1	<25		<0.07		<0.21	<0.21	1.9	<0.60	<0.07	3.6	<0.31	
Barrow	John Dory	1			<0.06		<0.18	<0.20		<0.53	<0.06	1.3	<0.26	
Morecambe Bay (Flookburgh)	Flounder	4		41	<0.12		<0.44	<0.69		<1.1	<0.11	14	<0.49	
Morecambe Bay (Morecambe)	Plaice[d]	4	<35		<0.09	0.023	<0.41	<0.70	2.2	<0.86	<0.09	4.3	<0.42	
Morecambe Bay (Morecambe)	Bass	2			<0.10		<0.84	<0.93		<1.1	<0.11	15	<0.61	
Morecambe Bay (Sunderland Point)	Whitebait	1			<0.07	0.15	<0.25	<0.39		<0.56	<0.06	6.8	<0.25	
Calder Farm	Rainbow trout	2			<0.14		<1.4	<0.97		<1.8	<0.23	33	<1.1	
River Derwent	Sea trout	1			<0.09		<1.6	*		<1.3	<0.12	4.0	<0.87	
Fleetwood	Cod	4		30	<0.08	0.026	<0.25	<0.30	0.75	<0.69	<0.08	3.9	<0.41	
Fleetwood	Plaice	4			<0.08		<0.28	<0.35		<0.69	<0.08	4.1	<0.31	
Isle of Man	Cod	2			<0.06		<0.24	<0.36		<0.53	<0.06	2.0	<0.31	
Isle of Man	Herring	3			<0.07		<0.29	<0.41		<0.71	<0.07	0.91	<0.44	
Isle of Man	Haddock	1			<0.07		<0.28	<0.47		<0.64	<0.07	1.8	<0.34	
Inner Solway	Plaice	1			<0.10		<0.10	<0.10		<0.32	<0.10	0.55	<0.21	
Inner Solway	Mullet	2			<0.10		<0.13	<0.14		<0.36	<0.10	1.2	<0.27	
Kirkcudbright	Plaice	3			<0.10		<0.13	<0.10		<0.53	<0.10	1.9	<0.31	
North Anglesey	Ray	4			<0.11		<0.63	<1.2		<1.2	<0.11	1.1	<0.56	
North Anglesey	Plaice[e]	2	<25	19	<0.06		<0.25	<0.34		<0.58	<0.06	2.6	<0.30	
Ribble Estuary	Flounder	1			<0.09		<0.44	<0.80		<0.96	<0.09	5.9	<0.60	
Ribble Estuary	Salmon	1			<0.12		<0.69	<1.5		<1.2	<0.12	0.32	<0.64	
Ribble Estuary	Bass	1			<0.11		<0.49	<0.73		<1.1	<0.11	18	<0.48	
Ribble Estuary	Sea trout	1			<0.13		<0.42	<0.48		<1.2	<0.13	2.5	<0.57	

Table 4.1. continued

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
Liverpool Bay	Flounder	2	<25											
Mersey Estuary	Flounder	1	<25											
Mersey Estuary	Dab	1	<25											
Northern Ireland	Cod	6		11	<0.07		<0.50	<0.41		<0.66	<0.07	2.2	<0.39	
Northern Ireland	Whiting	6			<0.08		<0.32	<0.53	1.1	<0.76	<0.08	4.0	<0.40	
Northern Ireland	Herring	4			<0.10		<0.57	<1.3		<0.99	<0.10	0.75	<0.61	
Northern Ireland	Spurdog	6			<0.09		<0.83	<0.44		<1.1	<0.10	4.3	<0.55	
Northern Ireland	Saithe	1			<0.05		<0.48	<1.3		<0.63	<0.06	4.1	<0.45	
West of Ireland	Mackerel	1			<0.09		<0.27	<0.29		<0.78	<0.08	0.13	<0.42	
Sound of Mull	Salmon	1			<0.12		<0.62	<1.2		<1.1	<0.11	0.34	<0.58	
Minch	Cod	4		21	<0.06		<0.35	<0.23		<0.62	<0.07	0.48	<0.37	
Minch	Plaice	4			<0.07		<0.48	<0.37		<0.64	<0.07	0.44	<0.32	
Minch	Haddock	4			<0.05		<0.31	<0.23		<0.54	<0.06	0.28	<0.33	
Minch	Herring	2			<0.07		<0.31	<0.43		<0.65	<0.07	0.39	<0.36	
Minch	Mackerel	2		24	<0.08	<0.032	<0.30	<0.37		<0.84	<0.09	0.35	<0.46	
Shetland	Fish meal[f]	4			<0.17	0.043	<0.66	<0.87		<1.7	<0.17	0.65	<0.94	
Shetland	Fish oil[f]	4			<0.10		<0.49	<0.91		<1.0	<0.11	<0.10	<0.61	
Northern North Sea	Cod	3		20	<0.10	<0.023	<0.50	<0.38		<0.99	<0.09	0.35	<0.42	
Northern North Sea	Plaice	3			<0.08		<0.72	<0.73		<0.82	<0.08	0.31	<0.40	
Northern North Sea	Herring	2			<0.06		<0.25	<0.39		<0.56	<0.06	0.41	<0.28	
Northern North Sea	Haddock	4		12	<0.06		<0.33	<0.24		<0.64	<0.07	0.33	<0.32	
Mid North Sea	Cod	4		9.1	<0.05	<0.022	<0.21	<0.36		<0.44	<0.05	0.38	<0.25	
Mid North Sea	Plaice	4		8.1	<0.09	<0.026	<0.41	<0.67		<0.86	<0.09	0.23	<0.43	
Southern North Sea	Cod	2			<0.06	0.015	<0.18	<0.21		<0.53	<0.06	0.44	<0.23	
Southern North Sea	Plaice	2			<0.05	0.020	<0.14	<0.16		<0.50	<0.06	0.25	<0.30	
Southern North Sea	Herring	2			<0.07		<0.25	<0.37		<0.65	<0.07	0.39	<0.39	
English Channel-East	Cod	4			<0.05	0.013	<0.19	<0.23		<0.49	<0.06	0.21	<0.28	
English Channel-East	Plaice	4			<0.06	<0.028	<0.19	<0.20		<0.57	<0.06	0.18	<0.27	
English Channel-West	Mackerel	4			<0.08		<0.37	<0.68		<0.76	<0.08	<0.18	<0.44	
English Channel-West	Plaice	4		13	<0.08	0.024	<0.29	<0.43		<0.78	<0.08	<0.11	<0.37	
English Channel-West	Whiting	4			<0.04	<0.027	<0.20	<0.31		<0.44	<0.05	0.32	<0.30	
Gt Yarmouth (retail shop)	Cod	4			<0.04		<0.18	<0.29		<0.43	<0.05	0.21	<0.26	
Gt Yarmouth (retail shop)	Plaice	4			<0.05		<0.25	<0.47		<0.51	<0.05	0.17	<0.26	
Skagerrak	Cod	3			<0.06		<0.32	<0.69		<0.56	<0.06	0.38	<0.36	
Skagerrak	Herring	3			<0.07		<0.29	<0.45		<0.66	<0.07	0.68	<0.35	
Iceland area	Cod	2			<0.06		<0.45	<0.26		<0.58	<0.06	0.17	<0.26	
Iceland processed	Cod	2		5.7	<0.05		<0.12	<0.12		<0.42	<0.04	0.20	<0.24	
Barents Sea	Cod	3			<0.10		<0.44	<0.95		<1.1	<0.11	0.22	<0.54	
Baltic Sea	Cod	4			<0.07		<0.30	<0.40		<0.76	<0.09	11	<0.48	
Baltic Sea	Herring	3			<0.07		<0.30	<0.46		<0.71	<0.08	6.5	<0.38	
Norwegian Sea	Cod	1			<0.07		<0.43	<0.84		<0.69	<0.08	0.34	<0.37	
Norwegian Sea	Herring	1			<0.25		<1.4	<2.4		<2.5	<0.24	0.30	<1.0	
Norwegian Sea	Saithe	1			<0.05		<0.30	<0.53		<0.53	<0.06	0.37	<0.38	
Celtic Sea	Cod	4		16	<0.06	0.019	<0.21	<0.27		<0.52	<0.05	0.66	<0.26	
Celtic Sea	Haddock	1			<0.06		<0.18	<0.19		<0.55	<0.07	0.10	<0.23	
Celtic Sea	Whiting	2			<0.06		<0.31	<0.54		<0.59	<0.07	0.41	<0.32	
Celtic Sea	Flounder	1			<0.07		<0.20	<0.22		<0.63	<0.07	0.90	<0.26	

* *not detected by the method used*

[a] *The concentrations of organic ^{3}H and ^{147}Pm were 96 and 0.025 Bq kg^{-1} respectively*

[b] *The concentration of ^{129}I was <0.33 Bq kg^{-1}*

[c] *The concentration of organic ^{3}H was 110 Bq kg^{-1}*

[d] *The concentration of organic ^{3}H was <27 Bq kg^{-1}*

[e] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*

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

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2001

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Aquatic Samples												
Sellafield coastal area	Crabs[a]	8	85	110	81	3.0	<0.22	1.1	<0.44	<0.46	60	<1.1
Sellafield coastal area	Lobsters	8	180	200	200	2.9	<0.22	0.47	<0.30	<0.45	3300	<0.99
Sellafield coastal area	*Nephrops*	2				0.61	<0.32		<0.89	<0.07	930	<1.2
Sellafield coastal area	Green crabs	1				17	<0.32		<0.54	<0.80		4.1
Sellafield coastal area[b]	Winkles	4			100	13	<0.43	3.1	<0.62	<0.92	300	16
Sellafield coastal area[b]	Mussels	4				8.2	<0.29	1.0	<0.38	<0.47		8.4
Sellafield coastal area[b]	Limpets	4			58	6.2	<0.27	2.8	<0.28	<0.31	660	8.8
Sellafield coastal area	Whelks	2			120	4.6	<0.39	0.17	<0.71	<1.3	730	6.9
Sellafield coastal area	Sea urchin	1				5.7	<0.51		<1.4	*		<1.8
Sellafield offshore area	Whelks	2				6.5	<0.58		<0.61	<0.72		12
St Bees	Winkles[c]	4	31	<25	130	16	<0.21	5.7	<0.24	<0.28	460	17
St Bees	Mussels	4				8.6	<0.28		<0.35	<0.45		13
St Bees	Limpets[d]	4				5.4	<0.28		<0.32	<0.45		8.9
Nethertown	Winkles	12	<26	<25	140	18	<0.45	6.7	<0.54	<0.79	320	23
Nethertown	Mussels	4	71	85	180	15	<0.39		<0.33	<0.36	1300	26
Nethertown	Dog whelks	1				57	<1.2		<1.0	<0.93		<4.0
Nethertown	Beadlet anemone[e]	1				4.8	<0.34		<0.34	<0.33		5.5
Whitriggs	Shrimps	1				<0.27	<0.61		<1.3	<2.7		<2.2
Drigg	Winkles	4			140	20	<0.38		<0.45	<0.58	420	22
Ravenglass	Crabs	4				1.5	<0.22	0.51	<0.43	<0.87	28	<0.80
Ravenglass	Lobsters	6				1.8	<0.23	0.26	<0.43	<0.57	2300	<0.86
Ravenglass	Winkles	2				6.0	<0.24		<0.33	<0.50		8.7
Ravenglass	Cockles	4			170	21	<0.26	0.98	<0.27	<0.27	53	9.2
Ravenglass	Mussels	4		51		6.6	<0.26		<0.26	<0.26	1600	8.6
Tarn Bay	Winkles	2				10	<0.31		<0.36	<0.43		12
Saltom Bay	Winkles	2				3.9	<0.26		<0.28	<0.37		5.5
Whitehaven	*Nephrops*	4	43	49	45	<0.23	<0.23	0.091	<0.38	<0.70	510	<0.78
Whitehaven	Whelks	2			89	2.5	<0.37	0.15	<0.47	<0.69		2.6
Silloth	Mussels	4		<25		0.66	<0.16		<0.23	<0.40		<0.67
Parton	Crabs	4			120	0.91	<0.47		<0.91	<1.8		<1.7
Parton	Lobsters	4				0.78	<0.31		<0.81	<0.13		<1.1
Parton	Winkles	4	<25	<25		5.2	<0.35		<0.44	<0.63		5.5
Parton	Mussels	2	71	30								
Haverigg	Cockles	2				4.6	<0.14		<0.14	<0.12		2.9
Millom	Mussels	2				1.7	<0.18		<0.31	<0.56		2.5
Red Nab Point	Winkles	4				0.96	<0.18		<0.25	<0.30		<0.91
Morecambe Bay (Flookburgh)	Shrimps	4			45	<0.08	<0.17		<0.22	<0.29	6.2	<0.60
Morecambe Bay (Morecambe)	Mussels	4	<63	79	45	0.50	<0.21		<0.43	<0.15	610	<0.83
Morecambe Bay (Flookburgh)	Cockles	4			52	2.3	<0.17	0.28	<0.23	<0.29	41	<0.64
Morecambe Bay (Middleton sands)	Cockles	2				3.5	<0.17		<0.20	<0.21		<0.64

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	0.71	<0.42	<0.08	2.0	<0.36	0.49	<0.20	<0.13	150
Sellafield coastal area	Lobsters	8	1.7	<0.29	<0.08	3.2	<0.44	0.54	<0.22	<0.21	2300
Sellafield coastal area	*Nephrops*	2	<0.23	<0.26	<0.11	5.9	<0.51		<0.29	<0.18	
Sellafield coastal area	Green crabs	1	0.38	1.0	<0.12	3.6	<0.53		<0.23	<0.21	
Sellafield coastal area[b]	Winkles	4	3.1	2.6	<0.17	7.3	<0.74	1.1	<0.43	<0.26	
Sellafield coastal area[b]	Mussels	4	<0.22	1.0	<0.11	2.2	<0.57		<0.28	<0.24	
Sellafield coastal area[b]	Limpets	4	1.4	3.8	<0.11	4.9	<0.47		<0.29	<0.19	
Sellafield coastal area	Whelks	2	2.0	0.55	<0.14	1.3	<0.78		<0.36	<0.34	
Sellafield coastal area	Sea urchin	1	<0.38	<0.33	<0.17	0.62	<0.61		<0.41	<0.21	
Sellafield offshore area	Whelks	2	2.2	0.93	<0.22	1.6	<0.77		<0.62	<0.33	
St Bees	Winkles[c]	4	2.3	2.1	<0.09	12	0.53	2.3	0.34	<0.16	
St Bees	Mussels	4	<0.21	1.4	<0.11	3.5	<0.69		<0.31	<0.22	
St Bees	Limpets[d]	4	1.2	4.2	<0.10	7.5	<0.65		<0.27	<0.24	
Nethertown	Winkles	12	3.4	2.8	<0.17	14	<1.1	4.5	<0.44	<0.35	500
Nethertown	Mussels	4	<0.24	1.9	<0.12	4.4	<1.0		<0.27	<0.27	1000
Nethertown	Dog whelks	1	3.5	<0.88	<0.45	3.4	<1.5		<0.86	<0.62	
Nethertown	Beadlet anemone[e]	1	<0.28	0.73	<0.13	2.8	<0.47		<0.37	<0.20	
Whitriggs	Shrimps	1	<0.42	<0.47	<0.21	2.0	<0.91		<0.61	<0.36	
Drigg	Winkles	4	3.4	2.8	<0.16	7.0	<0.78	2.0	<0.37	<0.37	560
Ravenglass	Crabs	4	<0.39	<0.18	<0.08	1.3	<0.37		<0.21	<0.15	120
Ravenglass	Lobsters	6	1.2	<0.21	<0.08	2.3	<0.46		<0.24	<0.19	1700
Ravenglass	Winkles	2	1.8	1.3	<0.10	8.1	<0.42		<0.27	<0.21	
Ravenglass	Cockles	4	<0.21	0.62	<0.11	4.9	0.63		0.38	<0.24	190
Ravenglass	Mussels	4	<0.20	0.91	<0.10	1.9	<0.49		<0.26	<0.23	
Tarn Bay	Winkles	2	1.9	0.85	<0.12	7.4	<0.49		<0.33	<0.23	
Saltom Bay	Winkles	2	<0.46	1.8	<0.10	7.5	<0.39		<0.30	<0.17	
Whitehaven	*Nephrops*	4	<0.16	<0.19	<0.08	5.0	<0.35		<0.25	<0.14	450
Whitehaven	Whelks	2	0.80	<0.31	<0.13	1.6	<0.57		0.35	<0.25	220
Silloth	Mussels	4	<0.12	<0.28	<0.07	4.1	<0.37		<0.18	<0.17	
Parton	Crabs	4	<0.41	<0.38	<0.17	2.1	<0.74		<0.45	<0.28	
Parton	Lobsters	4	<0.39	<0.25	<0.11	2.8	<0.53		<0.30	<0.23	
Parton	Winkles	4	<0.37	1.7	<0.14	9.0	<0.65		<0.36	<0.30	
Parton	Mussels	2									
Haverigg	Cockles	2	<0.10	0.45	<0.06	5.0	<0.57		<0.22	<0.12	
Millom	Mussels	2	<0.14	<0.28	<0.07	1.6	<0.46		<0.20	<0.22	
Red Nab Point	Winkles	4	<0.15	<0.44	<0.08	3.7	<0.44		<0.21	<0.21	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.12	<0.15	<0.06	4.3	<0.29		<0.19	<0.13	
Morecambe Bay (Morecambe)	Mussels	4	<0.15	<0.30	<0.08	3.7	<0.40		<0.21	<0.16	
Morecambe Bay (Flookburgh)	Cockles	4	<0.13	<0.19	<0.07	3.7	<0.32		<0.18	<0.15	
Morecambe Bay (Middleton sands)	Cockles	2	<0.12	<0.17	<0.07	4.6	<0.31		<0.18	<0.14	

Table 4.2. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Fleetwood	Lobsters	2				0.26	<0.20		<0.32	<0.51	1600	<0.74
Fleetwood	Squid	1				<0.12	<0.34		<0.49	<0.64		<1.4
Fleetwood	Whelks	4			55	0.31	<0.14	0.070	<0.17	<0.20	28	<0.52
Isle of Man	Lobsters	3				<0.06	<0.14		<0.13	<0.12	180	<0.50
Isle of Man	Scallops	3				<0.06	<0.14		<0.19	<0.29		<0.45
Isle of Man	Sea urchin	1				<0.11	<0.25		<0.26	<0.23	6.3	<1.1
Inner Solway	Shrimps	3				<0.10	<0.22	<0.16	<0.21	<0.16		<0.76
Southerness	Winkles	4				1.7	<0.16	<0.48	<0.13	<0.12		<1.1
Kirkcudbright	Scallops	4				<0.07	<0.10		<0.10	<0.10		<0.30
Kirkcudbright	Queens	7				<0.07	<0.11		<0.12	<0.13		<0.35
North Solway coast	Crabs	8	33	<28	65	0.60	<0.26	0.63	<0.27	<0.26	32	<0.98
North Solway coast	Lobsters	8			61	<0.28	<0.30	0.17	<0.37	<0.43	760	<1.1
North Solway coast	Winkles	8			61	<4.4	<0.23	0.35	<0.23	<0.25	370	<4.6
North Solway coast	Cockles	8			50	<1.7	<0.15	<0.43	<0.15	<0.14	19	<0.62
North Solway coast	Mussels	7			30	<0.60	<0.13	0.65	<0.14	<0.13	270	<0.59
Wirral	Shrimps	2		<25		<0.13	<0.34		<0.52	<0.73	2.7	<1.3
Wirral	Cockles	4				0.23	<0.10		<0.12	<0.10	28	<0.45
Liverpool Bay	Mussels	2		<25								
Mersey Estuary	Mussels	2		<25								
Ribble Estuary	Cockles	2				1.0	<0.13		<0.16	<0.20		<0.49
Ribble Estuary	Shrimps	2			44	<0.07	<0.15		<0.13	<0.12	6.9	<0.59
Ribble Estuary	Mussels	1				0.33	<0.13		<0.16	<0.18		<0.53
Knott End	Cockles	1				4.4	<0.15		<0.24	<0.38		<0.56
North Anglesey	Crabs	2				<0.12	<0.32		<0.55	<1.0	7.9	<1.2
North Anglesey	Lobsters	2				<0.06	<0.17		<0.21	<0.25	160	<0.58
Conwy	Mussels	2			35	<0.07	<0.15		<0.18	<0.19		<0.59
Northern Ireland	Lobsters	8			25	<0.18	<0.52		<1.2	<2.0	180	<2.0
Northern Ireland	*Nephrops*	8			34	<0.13	<0.40		<1.1	<0.89	150	<1.4
Northern Ireland	Winkles	4				<0.14	<0.37		<1.0	<1.2		<1.3
Northern Ireland	Mussels	2			10	<0.12	<0.35		<0.97	<0.47	34	<1.4
Skye	Lobster	1				<0.10	<0.10		<0.10	<0.10		<0.23
Skye	Molluscs	1				<0.10	<0.10		<0.10	<0.10		<0.19
Lewis	Seafood	1				<0.10	<0.10		<0.10	<0.10		<0.22
Islay	Crabs	1				<0.10	<0.10		<0.10	<0.10		<0.28
Islay	Molluscs	1				<0.10	<0.10		<0.10	<0.10		<0.25
Minch	*Nephrops*	4				<0.10	<0.38		<1.6	<0.80	38	<1.3
Northern North Sea	*Nephrops*	2				<0.08	<0.25		<0.47	<0.90	23	<0.81
Mid North Sea	Mussels[f]	1				<0.04	<0.10		<0.13	<0.14		<0.40
Southern North Sea	Cockles	2				<0.17	<0.16		<0.22	<0.28		<0.60
Southern North Sea	Mussels	4			14	<0.13	<0.34		<0.64	<1.3	1.1	<1.4
Southern North Sea	Cockles[g]	2				<0.08	<0.09		<0.10	<0.09	1.0	<0.34
Southern North Sea	Mussels[g]	1				<0.06	<0.16		<0.21	<0.25		<0.65
English Channel-East	Scallops	4			9.9	<0.07	<0.14		<0.21	<0.36		<0.45
English Channel-West	Crabs	4			20	<0.07	<0.19		<0.34	<0.72		<0.69
English Channel-West	Lobsters	4				<0.08	<0.21		<0.33	<0.52	0.56	<0.77
English Channel-West	Scallops	4			5.8	<0.10	<0.26		<0.41	<0.61		<0.98

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	<0.16	<0.18	<0.07	1.4	<0.42	<0.20	<0.18	960
Fleetwood	Squid	1	<0.24	<0.29	<0.13	0.89	<0.53	<0.38	<0.19	
Fleetwood	Whelks	4	<0.10	<0.13	<0.05	0.75	<0.28	<0.16	<0.13	
Isle of Man	Lobsters	3	<0.10	<0.13	<0.05	0.28	<0.27	<0.18	<0.14	200
Isle of Man	Scallops	3	<0.09	<0.11	<0.05	0.36	<0.26	<0.15	<0.11	
Isle of Man	Sea urchin	1	<0.18	<0.24	<0.10	0.12	<0.39	<0.29	<0.16	
Inner Solway	Shrimps	3	<0.12	<0.23	<0.10	5.9	<0.44	<0.11	<0.19	
Southerness	Winkles	4	<0.21	0.52	<0.10	<1.7	<0.31	<0.10	<0.15	
Kirkcudbright	Scallops	4	<0.08	<0.09	<0.07	<0.18	<0.17	<0.12	<0.09	
Kirkcudbright	Queens	7	<0.09	<0.10	<0.07	<0.23	<0.21	<0.12	<0.11	
North Solway coast	Crabs	8	<0.20	<0.26	<0.12	1.5	<0.51	<0.24	<0.24	
North Solway coast	Lobsters	8	<0.21	<0.28	<0.14	2.1	<0.58	<0.30	<0.27	
North Solway coast	Winkles	8	<0.65	<1.3	<0.11	2.0	<0.41	<0.22	<0.20	
North Solway coast	Cockles	8	<0.12	<0.18	<0.10	3.6	<0.34	<0.18	<0.18	
North Solway coast	Mussels	7	<0.10	<0.17	<0.08	2.0	<0.31	<0.14	<0.17	
Wirral	Shrimps	2	<0.24	<0.30	<0.13	1.7	<0.56	<0.38	<0.24	
Wirral	Cockles	4	<0.08	<0.12	<0.05	1.7	<0.27	<0.13	<0.14	
Liverpool Bay	Mussels	2								
Mersey Estuary	Mussels	2								
Ribble Estuary	Cockles	2	<0.09	<0.13	<0.05	2.1	<0.28	<0.15	<0.12	
Ribble Estuary	Shrimps	2	<0.12	<0.16	<0.07	2.2	<0.33	<0.20	<0.17	
Ribble Estuary	Mussels	1	<0.10	<0.14	<0.06	1.9	<0.28	<0.16	<0.14	
Knott End	Cockles	1	<0.11	<0.14	<0.06	5.7	<0.28	<0.13	<0.11	
North Anglesey	Crabs	2	<0.23	<0.26	<0.11	0.45	<0.48	<0.34	<0.17	
North Anglesey	Lobsters	2	<0.12	<0.14	<0.06	0.53	<0.28	<0.20	<0.13	150
Conwy	Mussels	2	<0.12	<0.16	<0.06	0.22	<0.35	<0.19	<0.18	
Northern Ireland	Lobsters	8	<0.37	<0.40	<0.19	<0.28	<0.86	<0.51	<0.33	
Northern Ireland	*Nephrops*	8	<0.27	<0.29	<0.13	1.2	<0.61	<0.37	<0.22	
Northern Ireland	Winkles	4	<0.25	<0.26	<0.13	0.29	<0.58	<0.33	<0.23	
Northern Ireland	Mussels	2	<0.25	<0.27	<0.13	0.40	<0.55	<0.30	<0.20	
Skye	Lobster	1	<0.10	<0.10	<0.10	<0.10	<0.17	<0.10	<0.10	
Skye	Molluscs	1	<0.10	<0.10	<0.10	<0.10	<0.14	<0.10	<0.10	
Lewis	Seafood	1	<0.10	<0.10	<0.10	0.36	<0.17	<0.10	<0.10	
Islay	Crabs	1	<0.10	<0.10	<0.10	0.17	<0.19	<0.10	<0.10	
Islay	Molluscs	1	<0.10	<0.10	<0.10	0.12	<0.19	<0.10	<0.10	
Minch	*Nephrops*	4	<0.26	<0.25	<0.11	0.41	<0.67	<0.31	<0.22	
Northern North Sea	*Nephrops*	2	<0.17	<0.18	<0.08	0.39	<0.42	<0.25	<0.18	
Mid North Sea	Mussels[f]	1	<0.08	<0.10	<0.04	<0.04	<0.26	<0.12	<0.14	28
Southern North Sea	Cockles	2	<0.12	<0.15	<0.07	0.13	<0.35	<0.20	<0.17	
Southern North Sea	Mussels	4	<0.25	<0.30	<0.13	<0.22	<0.61	<0.35	<0.24	
Southern North Sea	Cockles[g]	2	<0.06	<0.10	<0.04	0.09	<0.21	<0.10	<0.10	
Southern North Sea	Mussels[g]	1	<0.11	<0.16	<0.07	<0.06	<0.44	<0.17	<0.22	34
English Channel-East	Scallops	4	<0.09	<0.11	<0.05	0.05	<0.28	<0.14	<0.12	
English Channel-West	Crabs	4	<0.14	<0.16	<0.07	<0.06	<0.36	<0.20	<0.15	
English Channel-West	Lobsters	4	<0.15	<0.18	<0.08	<0.07	<0.40	<0.22	<0.17	
English Channel-West	Scallops	4	<0.18	<0.22	<0.10	<0.08	<0.47	<0.29	<0.20	

* *not detected by the method used*
[a] *The concentration of ^{129}I was <0.36 Bq kg^{-1}*
[b] *Samples collected by Consumer 116*
[c] *The concentration of ^{129}I was <0.56 Bq kg^{-1}*
[d] *The concentration of ^{129}I was <0.45 Bq kg^{-1}*
[e] *Actinia equina, a species of rock pool sea anemone*
[f] *Landed in Denmark*
[g] *Landed in Holland*

Table 4.3. Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 2001

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		0.0014	0.0071		0.012	<0.0000090	0.000080
Sellafield coastal area	Plaice	1		0.0041	0.020		0.038	*	0.000075
Sellafield coastal area	Bass	1					<0.22		
Sellafield coastal area	Mullet	1					<0.12		
Sellafield coastal area	Pollack	1					<0.17		
Sellafield coastal area	Crabs	2	0.0063	0.079	0.39	4.3	1.6	*	0.0033
Sellafield coastal area	Lobsters	2	0.0013	0.068	0.33	3.9	4.3	<0.0020	0.0054
Sellafield coastal area	*Nephrops*[a]	1		0.098	0.50		3.1	0.0031	0.0038
Sellafield coastal area	Green crabs	1					5.9		
Sellafield coastal area	Winkles[b]	1	0.0078	1.8	9.7	100	18	0.027	0.029
Sellafield coastal area	Mussels[b]	1		1.3	6.4	68	15	0.021	0.022
Sellafield coastal area	Limpets[b]	1		1.3	6.3	66	14	*	0.014
Sellafield coastal area	Whelks	1		0.40	2.0	21	6.9	*	0.015
Sellafield coastal area	Sea urchin	1					6.6		
Sellafield offshore area	Cod	1		0.0074	0.039		0.062	*	*
Sellafield offshore area	Plaice	1	0.00068	0.013	0.068		0.12	*	0.00014
Sellafield offshore area	Dab	2					<0.21		
Sellafield offshore area	Whiting	2					<0.47		
Sellafield offshore area	Spurdog	1					<0.29		
Sellafield offshore area	Sole	1					<0.10		
Sellafield offshore area	Lesser spotted dogfish	1					0.11		
Sellafield offshore area	Red Gurnard	1					0.24		
Sellafield offshore area	Whelks	1		0.53	2.5	28	9.4	*	0.018
St Bees	Winkles	1	0.017	3.8	19	190	35	*	0.049
St Bees	Mussels	2		1.6	7.7	81	17	<0.0068	0.023
St Bees	Limpets	1		1.6	8.6		16	*	0.036
Nethertown	Winkles	4	0.019	3.9	20	200	38	<0.0068	0.064
Nethertown	Mussels	4		2.2	11		22	<0.043	0.045
Nethertown	Dog whelks	1					6.3		
Nethertown	Beadlet anemone[c]	1					3.4		
Seascale	Sandeels	1					0.18		
Whitriggs	Shrimps	1					<0.39		
Drigg	Winkles	1	0.0094	2.4	12	120	24	*	0.037
Ravenglass	Cod	1		0.00024	0.0012		0.0028	*	*
Ravenglass	Plaice	1		0.0037	0.018		0.035	*	0.000087
Ravenglass	Wrasse	1					<0.08		
Ravenglass	Conger eel	1					<0.24		
Ravenglass	Crabs	1		0.050	0.25	2.6	1.3	*	0.0022
Ravenglass	Lobsters	1		0.071	0.36	3.7	5.7	*	0.011
Ravenglass	Winkles	2					20		
Ravenglass	Cockles	1		1.7	8.5	86	26	0.031	0.052
Ravenglass	Mussels	1		0.98	4.7	51	11	*	0.019
Tarn Bay	Winkles	1		1.7	8.5	88	18	*	*
Saltom Bay	Winkles	2					13		
Whitehaven	Cod	1		0.00028	0.0017		0.0035	*	*
Whitehaven	Plaice	1		0.00070	0.0037		0.010	*	*
Whitehaven	Ray	1		0.00029	0.0017		0.0026	*	0.000013
Whitehaven	*Nephrops*	1		0.053	0.28		1.5	*	0.0011
Whitehaven	Whelks	1		0.31	1.6	17	3.1	*	0.0063
Silloth	Mussels	1		0.59	3.0		5.9	*	0.0084
Parton	Cod	4					<0.36		
Parton	Crabs	4					1.2		
Parton	Lobsters	4					1.6		
Parton	Winkles	1		1.5	7.9	78	13	*	0.032
Annaside	Grey mullet	1					<0.08		
Haverigg	Cockles	1		1.3	7.1		16	0.029	0.029
Millom	Mussels	2					4.7		
Barrow	John Dory	1					<0.06		
Red Nab Point	Winkles	1		0.25	1.4		2.5	*	0.0049

Table 4.3. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Morecambe Bay (Flookburgh)	Flounder	1	0.00034	0.0018		0.0040	*	*
Morecambe Bay (Morecambe)	Plaice	4				<0.15		
Morecambe Bay (Morecambe)	Bass	2				<0.16		
Morecambe Bay (Sunderland Point)	Whitebait	1	0.051	0.29	2.6	0.48	*	*
Morecambe Bay (Flookburgh)	Shrimps	1	0.0050	0.029	<0.31	0.046	*	0.000081
Morecambe Bay (Morecambe)	Mussels	1	0.30	1.7		2.8	0.0051	0.0069
Morecambe Bay (Flookburgh)	Cockles	1	0.40	2.2	20	6.0	*	0.0071
Morecambe Bay (Middleton Sands)	Cockles	1	0.37	2.0		6.6	*	0.014
Calder	Rainbow trout	2				<0.28		
River Derwent	Sea trout	1				<0.26		
Fleetwood	Cod	1	0.00021	0.00095		0.0017	*	0.000014
Fleetwood	Plaice	1	0.00049	0.0027		0.0058	0.000023	0.000010
Fleetwood	Lobsters	2				0.67		
Fleetwood	Squid	1				<0.10		
Fleetwood	Whelks	1	0.11	0.56	4.1	0.75	*	*
Wirral	Shrimps	2				<0.24		
Knott End	Cockles	1	0.55	3.1		7.3	*	0.013
Ribble Estuary	Flounder	1				<0.39		
Ribble Estuary	Salmon	1				<0.33		
Ribble Estuary	Bass	1				<0.09		
Ribble Estuary	Sea trout	1				<0.33		
Ribble Estuary	Shrimps[g]	1	0.0019	0.011		0.020	*	*
Ribble Estuary	Cockles	1	0.16	0.87		2.5	*	0.0043
Ribble Estuary	Mussels	1				1.7		
Isle of Man	Cod	1	0.000034	0.00023		0.00052	*	*
Isle of Man	Herring	1	0.00013	0.00063		0.0011	*	*
Isle of Man	Haddock	1				<0.08		
Isle of Man	Lobsters	3				<0.20		
Isle of Man	Scallops	1	0.023	0.13		0.069	*	0.000084
Isle of Man	Sea urchin	1				0.19		
Inner Solway	Plaice	1				<0.10		
Inner Solway	Mullet	2				<0.12		
Inner Solway	Shrimps	1	0.0041	0.020		0.036		
Southerness	Winkles	1	0.76	4.0		8.8		
Kirkcudbright	Plaice	1	0.0016	0.057		0.0087		
Kirkcudbright	Scallops	2	0.020	0.097		0.11	*	*
Kirkcudbright	Queens	2	0.011	0.058		0.11	*	0.000067
North Solway coast	Crabs	2	0.026	0.11	1.3	0.75	0.0011	0.00070
North Solway coast	Lobsters	2	0.013	0.067	0.72	0.36	0.00081	0.00096
North Solway coast	Winkles	2	0.33	1.6	15	2.1	0.0046	0.0047
North Solway coast	Cockles	5	0.87	2.8	20	5.9	*	0.010
North Solway coast	Mussels	2	0.43	2.1	27	5.0	*	0.0092
Conwy	Mussels	1	0.017	0.095		0.18	*	*
Wirral	Cockles	1	0.17	0.93		2.3	*	0.0023
North Anglesey	Plaice	2				<0.13		
North Anglesey	Rays	1	0.0011	0.0057		0.048	0.000028	0.000095
North Anglesey	Crabs	1	0.0055	0.027		0.10	*	0.00022
North Anglesey	Lobsters	2				<0.12		
Northern Ireland	Cod	7				<0.17		
Northern Ireland	Whiting	1	0.00010	0.00058		0.00090	*	*
Northern Ireland	Herring	4				<0.34		
Northern Ireland	Spurdog	8				<0.16		
Northern Ireland	Saithe	1				<0.16		
Northern Ireland	Lobsters	8				<0.32		
Northern Ireland	*Nephrops*	1	0.0084	0.049		0.21	*	0.00036
Northern Ireland	Winkles	1	0.026	0.15		0.15	*	0.00030
Northern Ireland	Mussels	2				<0.16		

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
West of Ireland	Mackerel	1				<0.25		
Sound of Mull	Salmon	1				<0.30		
Skye	Lobsters	1				<0.10		
Skye	Molluscs	1				<0.10		
Lewis	Seafood	1				<0.10		
Islay	Crabs	1				<0.10		
Islay	Molluscs	1				<0.10		
Minch	Cod	1	0.000036	0.00019		0.00035	*	0.0000059
Minch	Plaice	4				<0.12		
Minch	Haddock	1	0.00032	0.0020		0.0023	*	0.00018
Minch	Herring	2				<0.12		
Minch	Mackerel	1	0.00013	0.00076		0.0013	*	*
Minch	*Nephrops*	1	0.00090	0.017		0.0070	*	0.000016
Shetland	Fish meal[d]	1	0.000042	0.00076		0.00017	*	*
Shetland	Fish oil[d]	4				<0.13		
Northern North Sea	Cod	1	0.000025	0.00020		0.00042	*	*
Northern North Sea	Plaice	3				<0.09		
Northern North Sea	Haddock	1	0.00011	0.00044		0.0010	*	0.0000097
Northern North Sea	Herring	2				<0.10		
Northern North Sea	*Nephrops*	1	0.00066	0.0045		0.0067	*	0.000032
Mid North Sea	Cod	4				<0.11		
Mid North Sea	Plaice	4				<0.24		
Mid North Sea	Mussels[e]	1				<0.32		
Southern North Sea	Cod	2				<0.06		
Southern North Sea	Plaice	2				<0.20		
Southern North Sea	Herring	2				<0.21		
Southern North Sea	Cockles	1	0.0023	0.015		0.0073	*	*
Southern North Sea	Cockles[f]	1	0.0020	0.0076		0.014	*	0.0013
Southern North Sea	Mussels	1	0.0012	0.0074		0.0032	*	*
Southern North Sea	Mussels[f]	1	0.00032	0.0031		0.0016	*	*
English Channel-East	Cod	4				<0.15		
English Channel-East	Plaice	4				<0.13		
English Channel-East	Scallops	1	0.00073	0.0031		0.0024	*	0.00011
English Channel-West	Mackerel	4				<0.23		
English Channel-West	Plaice	4				<0.16		
English Channel-West	Whiting	4				<0.15		
English Channel-West	Crabs	1	0.00038	0.0020		0.0035	*	0.000064
English Channel-West	Lobsters	4				<0.21		
English Channel-West	Scallops	1	0.00040	0.0057		0.0015	*	0.000015
Gt. Yarmouth (retail shop)	Cod	4				<0.13		
Gt. Yarmouth (retail shop)	Plaice	4				<0.12		
Skagerrak	Cod	3				<0.19		
Skagerrak	Herring	3				<0.18		
Iceland Area	Cod	2				<0.05		
Icelandic processed	Cod	1	<0.0015	0.00013		0.00019	*	*
Barents Sea	Cod	3				<0.20		
Baltic Sea	Cod	4				<0.27		
Baltic Sea	Herring	3				<0.17		
Norwegian Sea	Cod	1				<0.20		
Norwegian Sea	Herring	1				<0.18		
Norwegian Sea	Saithe	1				<0.15		
Celtic Sea	Cod	4				<0.14		
Celtic Sea	Haddock	1				<0.06		
Celtic Sea	Whiting	2				<0.17		
Celtic Sea	Flounder	1				<0.06		

** Not detected by the method used*
[a] Samples collected by Consumer 1060
[b] Samples collected by Consumer 116
[c] Actinia equina, a species of rock pool sea anemone
[d] Concentrations refer to weight as supplied
[e] Landed in Denmark
[f] Landed in Holland
[g] The concentration of ^{237}Np was 0.00018 Bq kg^{-1}

Table 4.4. Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 2001

Exposed population[b]	Foodstuffs consumed	Exposure mSv[a]												
		Total	^{14}C	^{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 (2001 habits)	Cod and other fish Crabs, lobsters and *Nephrops* Winkles and other molluscs	0.16[c]	0.004	0.002	0.024	0.002	0.002	0.005	0.005	0.029	0.005	0.058	<0.002	0.021
Sellafield fishing community (1997-2001 habits)	Fish Crabs, lobsters and *Nephrops* Winkles and other molluscs	0.15[c]	0.004	0.002	0.020	0.002	0.003	0.005	0.005	0.027	0.005	0.053	<0.002	0.021
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.031	0.001		0.003			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	0.040[c]	0.002		0.007		0.001	0.002	0.001	0.006		0.012	<0.002	0.008
Morecambe Bay	Mixed fish Shrimps Cockles and other molluscs	0.059[d]			0.004			0.006	0.002	0.009	0.002	0.020	<0.001	0.014
Fleetwood	Plaice and cod Shrimps Whelks	0.019	0.001					0.007		0.003		0.004	<0.004	
Isle of Man	Fish and shellfish[e]	0.007			0.002			0.002				0.001	<0.002	
Northern Ireland	Haddock and other fish *Nephrops* and crabs Mussels and other molluscs	0.015[f]			0.004	0.001		0.004				0.002	<0.002	0.003
North Wales	Fish and Shellfish[e]	0.008				0.001		0.002				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 1200 h $year^{-1}$ occupancy over intertidal sediments*
[e] *Local habits surveys have not been undertaken in these areas; representative species are adopted for fish, crustaceans and molluscs*
[f] *Including exposure due to 1100 h $year^{-1}$ occupancy over intertidal sediments*

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2001

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, $\mu Gy\ h^{-1}$
Cumbria			
Rockcliffe Marsh	Salt marsh	2	0.071
Newton Arlosh	Salt marsh	2	0.11
Parton	Winkle bed	4	0.090
Whitehaven - outer harbour	Mud and sand	12	0.084
Whitehaven - outer harbour	Coal and sand	12	0.11
Saltom Bay	Winkle bed	2	0.10
St Bees	Sand	4	0.069
Nethertown	Winkle bed	4	0.091
Sellafield	Sand	4	0.073
Drigg Barn Scar	Mussel bed	4	0.086
Ravenglass - Carleton Marsh	Salt marsh	1	0.18
Ravenglass - salmon garth	Mud and sand	1	0.11
Ravenglass - salmon garth	Mud, sand and stones	3	0.11
Ravenglass - salmon garth	Sand and stones	4	0.089
Ravenglass - salmon garth	Mussel bed	4	0.083
Ravenglass - ford	Mud and sand	4	0.10
Ravenglass - Raven Villa	Mud	3	0.11
Ravenglass - Raven Villa	Mud and sand	9	0.11
Ravenglass - Raven Villa	Salt marsh	12	0.17
Tarn Bay	Sand	2	0.065
Tarn Bay	Winkle bed	2	0.080
Haverigg	Mud	4	0.087
Haverigg	Sand	4	0.062
Millom	Mud and sand	4	0.086
Roosebeck	Mud and sand	1	0.067
Sand Gate Marsh	Salt marsh	1	0.084
Flookburgh	Mud and sand	1	0.071
High Foulshaw	Salt marsh	1	0.080
Lancashire			
Hest Bank	Mud and sand	1	0.070
Morecambe Central Pier	Mussel bed	4	0.073
Morecambe Central Pier	Mud and sand	4	0.073
Morecambe Bay	Mud	1	0.084
Half Moon Bay	Mud and sand	4	0.074
Sunderland Point	Mud	1	0.10
Colloway Marsh	Salt marsh	1	0.13
Aldcliffe Marsh	Salt marsh	1	0.098
Conder Green	Mud and sand	4	0.090
Conder Green	Salt marsh	4	0.11
Cockerham Marsh	Salt marsh	1	0.097
Cockerham Sands	Sand	1	0.074
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	0.074
Fleetwood	Mud	1	0.12
South-west Scotland			
Piltanton Burn	Salt marsh	3	0.061
Garlieston	Mud	2	0.069
Innerwell	Mud	7	0.082
Bladnoch	Mud	3	0.096
Creetown	Salt marsh	3	0.095
Carsluith	Mud	3	0.086
Skyreburn Bay (Water of Fleet)	Salt marsh	3	0.080
Cumstoun	Salt marsh	3	0.093
Kirkcudbright	Salt marsh	3	0.086
Cutters Pool	Winkle bed	7	0.086
Rascarrel Bay	Winkle bed	3	0.11
Palnackie Harbour	Mud	3	0.078
Gardenburn	Salt marsh	3	0.090
Kippford - Slipway	Mud	3	0.10
Kippford - Merse	Salt marsh	3	0.11
Carsethorn	Mud	3	0.076
Glencaple Harbour	Mud and sand	3	0.080

Table 4.6. Radioactivity in sediment from the Cumbrian coast and further afield, 2001

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}						
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria									
Newton Arlosh	Turf	2	3.3	<2.4	<2.7	<9.7	<3.7	<0.92	540
St Bees	Sand	4	4.5	<2.7	<2.1	<4.0	<1.2	<0.42	87
Sellafield	Sand	4	5.2	<3.0	<2.0	<4.6	<1.3	<0.43	90
Ravenglass - Carleton Marsh	Mud	1	64	<6.3	<12	190	23	<1.4	610
Ravenglass - Raven Villa	Mud and sand	4	26	<4.8	<4.1	51	7.2	<0.74	210
Millom	Mud and sand	4	7.4	<4.1	<5.0	<18	<3.5	<0.70	220
Flookburgh	Mud and sand	1	<0.44	<2.3	<3.6	<4.3	<1.2	<0.53	73
Sand Gate marsh	Turf	1	2.0	<2.3	<3.9	<5.6	<1.8	<0.63	160
Lancashire									
Conder Green	Turf	4	4.7	<4.7	<3.8	<8.8	<3.4	<0.95	300
Half Moon Bay	Mud and sand	4	4.1	<2.2	<3.1	<6.6	<2.3	<0.69	180
Morecambe	Mud and sand	4	3.7	<3.4	<3.0	<6.5	<3.6	<0.75	200
Scotland									
Bladnoch	NA	3	4.4	<0.32	<0.39	<3.9	<1.3	<0.19	370
Garlieston	NA	3	0.45	<0.12	<0.11	<0.56	<0.34	<0.10	33
Innerwell	Mud	5	5.3	<1.1	<1.9	<5.7	<1.6	<0.36	170
Carsluith[a]	NA	3	7.5	<0.26	<0.56	<8.7	<2.9	<0.16	300
Kippford Merse	Turf	3	2.5	<0.22	<0.36	<1.1	<0.85	<0.27	630
Kippford Slipway	NA	3	4.1	<0.27	<0.30	4.4	1.7	0.17	170
Palnackie Harbour	NA	2	2.7	<0.15	<0.14	1.8	0.78	<0.10	160
Carsethorn	NA	2	<0.10	<0.21	<0.16	<0.85	<0.28	<0.12	25
Kirkconnel Merse	NA	3	3.0	<0.27	<0.21	<2.9	<1.4	0.23	620
Campbeltown	NA	1	<0.10	<0.16	<0.12	<0.61	<0.20	<0.10	11
Dornoch Brow	NA	3	1.8	<0.20	<0.16	<1.6	<0.94	<0.11	140
Northern Ireland									
Lough Foyle	Mud and Sand	2	<0.35	<3.0	<7.5	<3.7	<0.91	<0.48	8.6
Portrush	Sand	2	<0.23	<3.1	<2.6	<3.0	<0.74	<0.33	0.73
Ballymacormick	Mud	1	<0.34	<3.8	*	<3.9	<0.99	<0.49	28
Ballymacormick	Mud and Sand	1	<0.23	<1.3	<2.4	<2.6	<0.67	<0.32	22
Strangford Lough- Nickey's point	Mud	1	<0.40	<2.2	<3.5	<4.7	<1.3	<0.60	48
Strangford Lough- Nickey's point	Mud and Sand	1	<0.22	<1.5	<3.1	<2.4	<0.59	<0.30	23
Dundrum Bay	Mud	1	<0.28	<2.6	<7.0	<3.0	<0.68	<0.36	12
Dundrum Bay	Sand	1	<0.42	<4.1	*	<4.4	<0.94	<0.51	5.9
Carlingford Lough	Mud	2	<0.36	<2.8	<6.6	<4.2	<1.2	<0.53	63
Oldmill Bay	Mud	2	<0.55	<3.5	<8.2	<5.5	<1.4	<0.63	55

Table 4.6. continued

Location	Material	No. of sampling observ- ations	Mean radioactivity concentration (dry), Bq kg^{-1}						
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	$^{243}Cm+^{244}Cm$
Cumbria									
Newton Arlosh	Turf	2	<5.7	<3.5	<2.7			260	
St Bees	Sand	4	<2.6	<1.3	<1.1			180	
Sellafield	Sand	4	<2.7	<2.0	<1.1			230	
Ravenglass - Carleton Marsh	Mud	1	39	21	7.5			1500	
Ravenglass - Raven Villa	Mud and sand	4	<5.3	3.5	3.8			500	
Millom	Mud and sand	4	<3.9	<2.7	<2.3			320	
Flookburgh	Mud and sand	1	<2.5	<1.1	<1.1			32	
Sand Gate marsh	Turf	1	<4.1	<1.5	<1.9			80	
Lancashire									
Conder Green	Turf	4	<4.8	<2.3	<2.3			180	
Half Moon Bay	Mud and sand	4	<3.7	<1.7	<2.3	11	64	110	0.23
Morecambe	Mud and sand	4	<3.7	<1.8	<2.3			120	
Scotland									
Bladnoch	NA	3	<1.3	2.7	1.6			320	
Garlieston	NA	3	<0.50	<0.21	<0.43	4.6	26	30	
Innerwell	Mud	5	<2.2	1.8	<1.7			200	
Carsluith[a]	NA	3	<1.3	<2.7	<1.2	28	180	250	
Kippford Merse	Turf	3	<1.1	3.8	1.6	26	150	410	
Kippford Slipway	NA	3	<0.96	1.6	1.1	25	130	180	
Palnackie Harbour	NA	2	<0.78	1.2	<0.60	22	120	180	
Carsethorn	NA	2	<0.76	<0.19	<0.60			3.0	
Kirkconnel Merse	NA	3	<1.4	2.6	<1.0	21	110	110	
Campbeltown	NA	1	<0.57	<0.14	<0.26			1.3	
Dornoch Brow	NA	3	<0.84	0.58	<0.55			70	
Northern Ireland									
Lough Foyle	Mud and Sand	2	<2.4	<1.0	<1.0	0.32	2.0	3.1	0.0042
Portrush	Sand	2	<2.3	<0.79	<0.84			<1.1	
Ballymacormick	Mud	1	<3.2	<1.1	<1.4	1.7	9.5	13	0.014
Ballymacormick	Mud and Sand	1	<1.6	<0.74	<0.71			11	
Strangford Lough- Nickey's point	Mud	1	<3.4	<1.2	<1.6	1.1	5.9	5.8	*
Strangford Lough- Nickey's point	Mud and Sand	1	<1.3	<0.70	1.3			4.3	
Dundrum Bay	Mud	1	<1.7	<0.90	<0.65			2.1	
Dundrum Bay	Sand	1	<2.5	<1.4	<0.96			1.8	
Carlingford Lough	Mud	2	<3.1	<1.1	<1.8	2.1	13	8.5	*
Oldmill Bay	Mud	2	<2.9	<1.6	<1.2	3.0	16	25	0.049

** not detected by the method used*
NA not available
[a] The concentrations of alpha and beta activities were 830 and 2200 Bq kg^{-1} respectively

Table 4.7. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2001

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, $\mu Sv\ h^{-1}$
A	Nets	5	0.070
	Ropes	5	0.063
S	Gill nets	1	0.048
	Nets	1	0.13
	Pots	1	0.078
T	Gill nets	4	0.095
	Pots	2	0.20
U	Nets	3	0.12
W	Gill nets	1	0.13
	Pots	2	0.078
X	Gill nets	4	0.075
	Pots	2	0.14
Z	Nets	1	0.18

Table 4.8. Radioactivity in terrestrial food and the environment near Sellafield, 2001

Material	Selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Milk Near farms[c]		11	<3.9	<5.4	16	<0.95	<0.28	0.10	<0.0045	<1.9	<0.54
Milk Near farms[c]	max		<5.3	11	21	<3.3	<0.30	0.21		<2.1	<0.58
Milk Far farms		4	<4.0	<4.5	14	<0.54	<0.27	0.058	<0.0075	<1.9	<0.57
Milk Far farms	max		<4.5	<5.3	17	<0.63	<0.28	0.070		<2.0	<0.61
Apples		3	<8.7	12	14	0.87	<0.27	0.24	0.065	<1.7	<0.57
	max		17	16	17	1.0	<0.40	0.35		<2.2	<0.80
Bovine kidney		1	<7.0	<7.0	21	3.1	<0.20	0.12	<0.030	<1.8	<0.40
Bovine liver		1	10	13	30	3.7	<0.30	0.041	<0.028	<2.0	<0.60
Bovine muscle		1	7.0	9.0	47	1.9	<0.40	<0.026	<0.014	<1.7	<0.50
Cabbage		1	<3.0	<3.0	9.0	0.80	<0.50	0.27		<2.6	<0.80
Carrots		1	<5.0	4.0	6.0	1.6	<0.30	0.39	<0.014	<1.7	<0.60
Damsons		1	<4.0	<4.0	19	1.8	<0.20	0.40		<2.2	<0.50
Eggs		1	8.0	13	31	<1.5	<0.30	0.053		<1.8	<0.60
Honey		2		<18	91	<0.40	<0.20	0.036		<1.3	<0.50
Honey	max			30	99	0.60		0.042			
Marrow		1	<5.0	<4.0	<2.0	<0.40	<0.20	0.16		<1.7	<0.60
Onions		1	<4.0	<4.0	7.0	1.3	<0.30	0.27		<1.3	<0.60
Ovine offal		1	<7.0	<7.0	57	2.4	<0.30	0.40	<0.019	<2.4	<0.70
Ovine muscle		1	3.0	5.0	73	<1.7	<0.20	<0.027	<0.030	<2.3	<0.60
Pears		1	<14	12	20	1.4	<0.30	0.38		<2.9	<0.60
Pheasants		1	5.0	9.0	29	<0.70	<0.30	0.041	0.049	<2.5	<0.80
Pigeons		1	5.0	7.0	30	2.3	<0.30	0.020		<2.6	<0.80
Potatoes		2	<2.5	5.0	19	<0.45	<0.25	0.094		<1.4	<0.55
Potatoes	max		<3.0	7.0	22	0.50	<0.30	0.096		<1.9	<0.60
Runner beans		1	<5.0	<4.0	<3.0	2.2	<0.30	0.28		<2.3	<0.50
Sloe berries		1	3.0	16	33	<0.20	<0.30	0.96		<2.3	<0.80
Sprouts		1									
Swede		1	<4.0	<4.0	14	2.7	<0.40	0.34		<2.5	<0.60
Turnips		1									
Grass		5					<0.47		0.075	<2.5	<1.3
Grass	max						<0.60		0.10	<2.9	2.2
Soil		3					<0.80			<3.1	<1.1
Soil[e]	max						1.2				

Table 4.8. continued

Material	Selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{129}I	^{137}Cs	Total Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk Near farms[c]		11	<0.013	<0.33	0.24		<0.00011	<0.00017	<0.046	<0.00016
Milk Near farms[c]	max		<0.016	<0.49	0.43		<0.00015	<0.00018	<0.051	<0.00023
Milk Far farms		4	<0.011	<0.31	0.15		<0.00013	<0.00018	<0.04	<0.00018
Milk Far farms	max		<0.012	<0.32	0.19					
Apples		3	<0.045		0.38		<0.0004	0.0012	<0.088	0.0032
	max		<0.049		0.80		0.0006	0.0025	<0.12	0.0042
Bovine kidney		1			2.1		<0.001	0.0015	<0.17	0.003
Bovine liver		1	<0.046		1.4		<0.0003	0.0015	0.12	0.0012
Bovine muscle		1	<0.033		0.96		<0.0002	<0.0004	<0.071	<0.0002
Cabbage		1	<0.039		0.10		0.00040	<0.0002	<0.068	<0.0003
Carrots		1	<0.079		0.056		<0.0004	0.0044	<0.15	0.0016
Damsons		1	<0.079		0.44		<0.0002	0.027	<0.10	0.0066
Eggs		1	<0.037		0.30		<0.0003	<0.0005	<0.17	<0.0005
Honey		2	<0.021		0.20		<0.0003	<0.0004	<0.093	0.00045
Honey	max		<0.022		0.31			<0.0005	<0.10	0.0006
Marrow		1	<0.033		<0.036		<0.0002	<0.0002	<0.11	0.0006
Onions		1	<0.093		<0.028		0.0003	<0.0003	<0.16	0.0009
Ovine offal		1	<0.042		2.3		<0.0003	0.0005	<0.092	0.001
Ovine muscle		1	<0.035		1.1		<0.0004	0.0003	<0.10	0.0002
Pears		1	<0.036		0.39		0.0005	0.0046	<0.089	0.006
Pheasants		1	<0.051		2.5		<0.0005	<0.0005	0.12	0.0003
Pigeons		1	<0.051		1.5		<0.0003	<0.0004	0.12	<0.0004
Potatoes		2	<0.052		0.097		<0.0003	0.00035	<0.12	0.00055
Potatoes	max		<0.066		0.15		0.0003	0.0005	<0.13	0.0006
Runner beans		1	0.31		0.082		0.0005	0.0018	<0.12	0.0038
Sloe berries		1	<0.074		1.6		0.0046	0.028	0.43	0.051
Sprouts		1				<0.035				
Swede		1	<0.042		0.16		<0.0004	0.001	<0.074	<0.0003
Turnips[d]		1				<0.035				
Grass		5		1.8						
Grass	max			2.5						
Soil		3		80		60				5.8
Soil[e]	max			97		64				6.0

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[b] *Except for milk where units are Bq l^{-1} and soil where dry concentrations apply*
[c] *The mean concentration of ^{131}I was <0.025 Bq l^{-1} and the maximum was <0.028 Bq l^{-1}*
[d] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0076, <0.00050 and 0.0067 Bq kg^{-1} respectively*
[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 9.3, 0.34 and 9.1Bq kg^{-1} respectively*

Table 4.9. Individual radiation exposures due to consumption of terrestrial foodstuffs near Sellafield and Drigg, 2001

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 Fruit	0.037	0.002	0.006	0.003	0.008	0.008	0.001	0.002	0.002	0.002	<0.002
Consumers near Drigg aged 1 y	Milk Potatoes	0.016		0.001	0.003	0.004	0.004	0.001	0.001		0.001	<0.001
Consumers near Ravenglass aged 1 y	Milk Potatoes	0.017		0.001	0.003	0.004	0.004	0.001	0.001		0.001	<0.001
Typical adult member of the public eating food grown near Sellafield	Milk Fruit	0.010				0.002	0.002		0.002		0.002	<0.003

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

Table 4.10. Radioactivity in terrestrial food and the environment near Drigg, 2001

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	<4.5	13	<0.58	<0.25	0.096	<0.0068	<1.8	<0.58	<0.014
Blackberries		1	5.0	17	<0.50	<0.20	0.53		<1.8	<0.50	<0.082
Cabbage		1	<4.0	<3.0	<0.30	<0.40	0.31	<0.029	<1.7	<0.60	<0.069
Carrots		1	4.0	7.0	<0.20	<0.30	0.82		<2.3	<0.40	<0.048
Duck		1	7.0	46	<1.8	<0.30	0.048	0.021	<2.4	<0.80	<0.063
Potatoes		1	9.0	28	<0.20	<0.40	0.094	<0.029	<1.6	<0.80	<0.047
Grass		2						<0.031			
Grass[d]	max							<0.032			
Soil		2									
Soil[e]	max										

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	0.25	<0.20		<0.00015	<0.00035	<0.054	0.00043
Blackberries		1	0.14			0.00020	0.0013	0.065	0.0034
Cabbage		1	0.084	0.20		<0.00030	0.00020	<0.088	<0.00030
Carrots		1	0.16			<0.00050	<0.00040	<0.13	<0.00040
Duck		1	3.7			0.00090	0.0056	0.080	0.0074
Potatoes		1	0.19	<0.20		0.00030	0.00030	<0.094	<0.00040
Grass		2		16	0.16				
Grass[d]	max			24	0.19				
Soil		2			34				
Soil[e]	max				40				

[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 <0.25 and <0.27 $Bq\ l^{-1}$ respectively
[d] The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.034, 0.0017 and 0.027 $Bq\ kg^{-1}$ respectively
[e] The concentrations of ^{234}U, ^{235}U and ^{238}U were 7.5, 0.30 and 9.6 $Bq\ kg^{-1}$ respectively

Table 4.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2001

Location	Ground type	No. of sampling observ-ations	$\mu Sv\ h^{-1}$
Whitehaven - outer harbour	Mud and sand	2	0.31
St Bees	Sand	2	0.12
Nethertown	Winkle bed	2	0.31
Sellafield pipeline	Sand	2	0.18
Drigg Barn Scar	Mussel bed	2	0.22
Ravenglass - Raven Villa	Salt marsh	2	0.53
Ravenglass - salmon garth	Mussel bed	2	0.24
Tarn Bay	Sand	2	0.12

Table 4.12. Radioactivity in terrestrial food and the environment near Ravenglass, 2001

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]	3	<4.1	16	<0.51	<0.29	0.070	<0.53	<0.54	<0.0057	<2.0	<0.56	<0.015
Milk[c,d]	max	<4.5	18	<0.58	<0.30	0.11	<0.55	<0.58	<0.0063		<0.58	
Blackberries	1	<4.0	18	<0.40	<0.30	0.55	<0.40	<0.30	<0.067	<2.0	<0.60	<0.054
Bovine kidney	1	12	24	<1.7	<0.50	0.15	<0.70	<0.40	<0.023	<3.6	<0.80	
Bovine liver	1	<6.0	33	<1.7	<0.30	<0.025	<0.40	<0.30	<0.014	<2.1	<0.60	<0.059
Bovine muscle	1	<4.0	25	<1.7	<0.30	<0.024	<0.20	<0.20	<0.017	<1.8	<0.50	<0.033
Broad beans	1								<0.025			
Cabbage	1	4.0	5.0	<0.80	<0.40	0.81	<0.50	<0.30	<0.025	<2.5	<0.80	<0.026
Carrots	1	7.0	10	<0.30	<0.30	0.18	<0.30	<0.40	<0.022	<3.0	<0.70	<0.050
Duck	1	<4.0	19	<1.7	<0.30	0.086	<0.60	<0.30	<0.023	<2.5	<0.80	<0.040
Honey	1	24	88	0.20	<0.20	0.088	<0.50	<0.40	<0.027	<1.6	<0.60	<0.011
Lettuce[e]	1								<0.036			
Ovine offal	1	<6.0	12	<1.7	<0.50	0.11	<0.60	<0.50	<0.020	<3.4	<0.60	<0.067
Ovine muscle	1	<5.0	35	<1.7	<0.30	<0.025	<0.40	<0.30	<0.019	<0.90	<0.60	<0.040
Potatoes	1	6.0	16	0.40	<0.40	0.091	<0.40	<0.30	<0.037	<1.2	<0.70	<0.026
Runner beans	1	6.0	<3.0	<0.40	<0.50	0.10	<0.30	<0.40	<0.028	<1.5	<0.70	<0.031
Grass	2								<0.035			
Grass	max											
Soil												
Soil[f]	max											

Material and selection[a]	Farms/ samples	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
		Total Cs	^{144}Ce	^{147}Pm	^{155}Eu	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[c,d]	3	0.23	<1.2	<0.20	<0.55		<0.00016	<0.00018	<0.048	<0.00018
Milk[c,d]	max	0.33	<1.3		<0.61		<0.00020	<0.00020	<0.051	<0.00020
Blackberries	1	0.44	<1.1		<0.50		<0.00030	0.0013	<0.12	0.0033
Bovine kidney	1	0.66	<1.3		<0.60		<0.0010	<0.00070	<0.21	0.0023
Bovine liver	1	1.1	<1.1		<0.50		<0.00040	0.0016	<0.11	0.0021
Bovine muscle	1	0.80	<1.0		<0.30		<0.00010	<0.00020	<0.068	0.00060
Broad beans	1					<0.035				
Cabbage	1	0.091	<1.1	1.0	<0.60		<0.00040	<0.00040	<0.090	0.00070
Carrots	1	0.23	<1.1		<0.60		<0.00050	<0.00030	<0.077	0.0010
Duck	1	2.9	<1.8		<1.3		<0.00030	0.00070	0.086	0.0013
Honey	1	0.71	<1.4		<0.80		<0.00060	0.00060	<0.11	0.0022
Lettuce[e]	1					0.041				
Ovine offal	1	0.55	<1.2		<0.70		<0.00090	0.0018	<0.14	0.0022
Ovine muscle	1	0.62	<1.1		<0.50		<0.00040	0.00090	<0.082	<0.00020
Potatoes	1	0.084	<1.3	<0.20	<0.40		<0.00050	0.00040	<0.081	0.00020
Runner beans	1	0.15	<1.3		<0.60		<0.00040	0.00060	<0.069	0.00080
Grass	2			15						
Grass	max			17						
Soil	2					50				
Soil[f]	max					62				

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[b] *Except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*
[c] *The mean concentration of ^{137}Cs was <0.30 Bq l^{-1} and the maximum was <0.31 Bq l^{-1}*
[d] *The mean concentration of ^{134}Cs was <0.25 Bq l^{-1} and the maximum was <0.26 Bq l^{-1}*
[e] *The concentration of ^{234}U, ^{235}U and ^{238}U were 0.019, <0.00090 and 0.019 Bq kg^{-1} respectively*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 11, 0.37 and 9.6 Bq kg^{-1} respectively*

Table 4.13. Radioactivity in aquatic plants from the Cumbrian coast and further afield, 2001

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
England													
St Bees	*Fucus vesiculosus*[a]	4	30	10	1.7	<0.17	<0.18	9800	1.2	0.30	1.5	<0.07	4.7
St Bees	*Porphyra*	4	36	1.6	0.12	<0.40	<0.62	14	7.8	<0.20	1.5	<0.10	1.4
St Bees	*Rhodymenia spp.*	2		3.8		<0.47	<0.86		12	<0.31	0.81	<0.11	9.1
Braystones South	*Porphyra*	4		2.4		<0.29	<0.45		19	<0.15	2.7	<0.07	2.3
Sellafield	*Fucus vesiculosus*	4		18	1.3	<0.36	<0.43	17000	3.2	<0.61	2.0	<0.12	6.5
Seascale	*Porphyra*[b]	52		3.1		<0.51	<0.30		19	<0.54	<3.9	<0.32	1.9
Ravenglass Ford South	Samphire	1		0.83		<0.13	<0.19	2.5	2.1	<0.06	0.35	<0.03	5.0
Half Moon Bay	*Fucus vesiculosus*	4		0.72		<0.27	<0.33	2900	<0.73	<0.15	<0.49	<0.09	5.0
Marshside Sands	Samphire	1		<0.03		<0.21	<0.52		<0.29	<0.06	<0.07	<0.03	0.48
Isle of Man	*Fucus vesiculosus*	3		<0.19		<0.59	<0.87	630	<1.4	<0.26	<0.31	<0.14	0.69
Wales													
Cemaes Bay	*Fucus vesiculosus*	2		<0.09		<0.60	<1.3	110	<0.89	<0.18	<0.18	<0.09	0.37
Porthmadog	*Fucus vesiculosus*	1	6.4	<0.04		<0.10	<0.08	18	<0.38	<0.08	<0.09	<0.05	0.43
Fishguard	*Fucus vesiculosus*	1	13	<0.05		<0.15	<0.17	42	<0.43	<0.09	<0.11	<0.05	0.09
Lavernock Point	*Fucus serratus*	2		<0.05		<0.17	<0.20	3.0	<0.44	<0.10	<0.10	<0.06	0.28
South Wales, manufacturer A	Laverbread	2		<0.08		<0.40	<0.68		<0.89	<0.16	<0.19	<0.09	<0.07
South Wales, manufacturer C	Laverbread	3		<0.09		<0.41	<0.69		<0.92	<0.17	<0.18	<0.09	<0.08
South Wales, manufacturer D	Laverbread	3		<0.09		<0.47	<0.99		<0.88	<0.16	<0.17	<0.09	<0.07
Northern Ireland													
Ardglass	*Fucus vesiculosus*	4	13	<0.18		<0.56	<0.72	290	<1.6	<0.30	<0.38	<0.17	1.2
Portrush	*Fucus serratus*	3		<0.06		<0.22	<0.31		<0.51	<0.12	<0.12	<0.06	0.19
Portrush	*Fucus vesiculosus*	2		<0.10		<0.88	<1.1		<1.1	<0.22	<0.23	<0.11	0.48
Strangford Lough	*Rhodymenia spp.*	4		<0.10		<0.38	<0.53	69	<0.91	<0.18	<0.19	<0.09	1.0
Carlingford Lough	*Ascophyllum nodosum*	1		<0.22		<0.78	<1.1		<2.0	<0.39	<0.38	<0.22	0.75
Carlingford Lough	*Fucus spp.*	4		<0.16		<0.96	<1.9	480	<1.8	<0.31	<0.38	<0.19	0.74
Isles of Scilly	*Fucus vesiculosus*	1	13	<0.04		<0.08	<0.06	3.9	<0.31	<0.07	<0.07	<0.04	<0.04
Scotland													
Port William	*Fucus vesiculosus*	7		<0.26		<0.18	<0.17	1600	<0.55	<0.13	<0.18	<0.09	1.2
Garlieston	*Fucus vesiculosus*	7		0.95		<0.23	<0.31	1800	<0.58	<0.13	<0.35	<0.09	4.9
Auchencairn	*Fucus vesiculosus*	6		0.99		<0.25	<0.30	4400	<0.66	<0.15	<0.53	<0.10	4.1
Knock Bay	*Porphyra*	3		<0.06		<0.35	<0.78	14	<0.60	<0.13	<0.13	<0.06	0.22
Cape Wrath	*Ascophyllum nodosum*	1	14	<0.06		<0.16	<0.18	410	<0.47	<0.10	<0.11	<0.06	0.35
Wick	*Fucus vesiculosus*	1	12	<0.07		<0.13	<0.11		<0.51	<0.11	<0.12	<0.06	0.25

Table 4.13. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
England												
St Bees	*Fucus vesiculosus*[a]	4	<0.27	<0.18	<0.14	1.6	7.8		3.6	0.0052	0.0045	
St Bees	*Porphyra*	4	<0.46	<0.31	<0.20	0.45	2.3	22	5.5	*	0.0079	160
St Bees	*Rhodymenia spp.*	2	<0.68	<0.34	<0.23	1.0	4.9		14	*	0.028	
Braystones South	*Porphyra*	4	<0.43	<0.22	<0.19	0.69	3.5	34	7.4	0.012	0.0092	
Sellafield	*Fucus vesiculosus*	4	<0.52	<0.28	<0.27	1.9	8.9		4.1	*	0.0096	11000
Seascale	*Porphyra*[b]	52	<1.5	<0.92	<0.74				6.8			
Ravenglass Ford South	Samphire	1	0.54	0.11	<0.07				12			
Half Moon Bay	*Fucus vesiculosus*	4	<0.38	<0.28	<0.19				0.84			2200
Marshside Sands	Samphire	1	<0.21	<0.08	<0.08				<0.08			
Isle of Man	*Fucus vesiculosus*	3	<0.70	<0.43	<0.31				<0.38			730
Wales												
Cemaes Bay	*Fucus vesiculosus*	2	<0.37	<0.25	<0.13				<0.08			180
Porthmadog	*Fucus vesiculosus*	1	<0.23	<0.16	<0.13				<0.20			
Fishguard	*Fucus vesiculosus*	1	<0.22	<0.16	<0.10				<0.06			260
Lavernock Point	*Fucus serratus*	2	<0.29	<0.16	<0.14				<0.19			180
South Wales, manufacturer A	Laverbread	2	<0.36	<0.24	<0.14				<0.11			
South Wales, manufacturer C	Laverbread	3	<0.34	<0.26	<0.13				<0.07			
South Wales, manufacturer D	Laverbread	3	<0.30	<0.26	<0.11				<0.06			76
Northern Ireland												
Ardglass	*Fucus vesiculosus*	4	<0.56	<0.52	<0.24				<0.28			
Portrush	*Fucus serratus*	3	<0.31	<0.20	<0.15				<0.24			
Portrush	*Fucus vesiculosus*	2	<0.53	<0.30	<0.19				<0.20			
Strangford Lough	*Rhodymenia spp.*	4	<0.39	<0.32	<0.16	0.059	0.32		0.58	0.00097	0.00060	
Carlingford Lough	*Ascophyllum nodosum*	1	<0.67	<0.66	<0.28				<0.15			
Carlingford Lough	*Fucus spp.*	4	<0.92	<0.47	<0.39				<0.48			
Isles of Scilly	*Fucus vesiculosus*	1	<0.14	<0.14	<0.07				<0.04			190
Scotland												
Port William	*Fucus vesiculosus*	7	<0.29	<0.21	<0.15				<0.36			
Garlieston	*Fucus vesiculosus*	7	<0.36	<0.19	<0.21				4.9			
Auchencairn	*Fucus vesiculosus*	6	<0.38	<0.22	<0.18				2.0			
Knock Bay	*Porphyra*	3	<0.35	<0.16	<0.15				<0.43			
Cape Wrath	*Ascophyllum nodosum*	1	<0.24	<0.19	<0.12				<0.15			480
Wick	*Fucus vesiculosus*	1	<0.22	<0.23	<0.11				<0.07			340

* *Not detected by the method used*

[a] *The concentration of ^{129}I was 5.2 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, 2001

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				1.6								
Newton Arlosh	Washed grass	1				0.92								
Newton Arlosh	Soil	1				11								
Sellafield 1707[b]	Beetroot	1	<0.06	<0.27	<0.44	26	<0.59	<0.12	<0.06	<0.05	<0.23	<0.20	<0.08	<0.05
Sellafield 1707[b]	Onions	1	<0.08	<0.34	<0.58	1.0	<0.78	<0.16	<0.07	<0.06	<0.30	<0.21	<0.11	<0.06
Sellafield 1707[b]	Potatoes	1	<0.07	<0.22	<0.24	4.0	<0.58	<0.14	<0.06	<0.06	<0.30	<0.23	<0.14	<0.18
Sellafield 1707[b]	Compost	1	<0.59	<2.8	<5.2	210	<5.2	<1.4	<0.69	29	<3.2	<1.5	<1.5	4.9
Sellafield 1707[b]	Soil	1	220	<4.6	<7.2	13000	62	9.4	<1.1	74	<5.0	2.6	2.5	280
Sellafield 14[b]	Onions	1	<0.04	<0.15	<0.20	1.3	<0.42	<0.10	<0.04	<0.04	<0.22	<0.12	<0.09	<0.08
Sellafield 14[b]	Potatoes	1	<0.04	<0.06	<0.04	14	<0.26	<0.06	<0.03	0.19	<0.11	<0.12	<0.05	<0.03
Sellafield 14[b]	Runner beans	1	<0.08	<0.32	<0.43	5.7	<0.89	<0.19	<0.09	<0.08	<0.44	<0.25	<0.21	<0.29
Sellafield 14[b]	Soil	1	17	<3.2	<5.3	2600	<7.2	3.2	<0.78	83	<3.5	<1.8	<1.6	25
Sellafield 1674[b]	Beetroot	1	<0.07	<0.27	<0.35	60	<0.61	<0.13	<0.07	<0.06	<0.25	<0.23	<0.10	<0.05
Sellafield 1674[b]	Leaf Beet	1	<0.04	<0.18	<0.27	790	<0.40	<0.08	<0.04	0.06	<0.15	<0.13	<0.06	<0.04
Sellafield 1674[b]	Onions	1	<0.05	<0.22	<0.35	3.3	<0.47	<0.10	<0.05	<0.04	<0.19	<0.15	<0.07	<0.04
Sellafield 1674[b]	Potatoes	1	<0.05	<0.19	<0.24	8.4	<0.50	<0.12	<0.05	0.27	<0.31	<0.17	<0.15	<0.23
Sellafield 1674[b]	Soil	1	0.93	<3.1	<5.1	810	<5.4	<1.6	0.77	66	<4.1	<1.5	<1.9	<3.2
Sellafield 1676[b]	Rhubarb	1	<0.09	<0.27	<0.32	23	<0.85	<0.18	<0.09	0.11	<0.30	<0.28	<0.12	<0.07
Sellafield 1676[b]	Soil	1	4.8	<1.5	<2.5	1200	<3.1	<0.86	<0.35	62	<1.9	<0.78	<0.78	32
Hutton Marsh	Grass	1				5.5								
Hutton Marsh	Washed grass	1				1.2								
Hutton Marsh	Soil	1				40								

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

Table 4.15(a). Radioactivity in food and the environment near Springfields, 2001

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{60}Co	^{99}Tc	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th
Aquatic samples								
Flounder	Ribble Estuary	1	<0.09		5.9			
Salmon	Ribble Estuary	1	<0.12		0.32			
Sea trout	Ribble Estuary	1	<0.13		2.5			
Bass	Ribble Estuary	1	<0.11		18			
Grey mullet	Ribble Estuary	1	<0.14	1.4	1.2			
Shrimps[c]	Ribble Estuary	2	<0.07	6.9	2.2	0.045	0.0099	0.014
Cockles	Ribble Estuary	2	1.0		2.1	0.012	0.32	0.37
Mussels	Ribble Estuary	1	0.33		1.9			
Samphire	Marshside Sands	1	<0.03		0.48			
Grass (washed)	Hutton Marsh	1		1.2				
Grass (unwashed)	Hutton Marsh	1		5.5				
Soil	Hutton Marsh	1		40				

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], 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		*			<0.39	
Salmon	Ribble Estuary	1		*			<0.33	
Sea trout	Ribble Estuary	1		*			<0.33	
Bass	Ribble Estuary	1		*			<0.09	
Grey mullet	Ribble Estuary	1		*			<0.31	
Shrimps[c]	Ribble Estuary	2	0.0044	*	0.0019	0.011	0.020	*
Cockles	Ribble Estuary	2	0.14	16	0.16	0.87	2.5	0.0043
Mussels	Ribble Estuary	1		18			1.7	
Samphire	Marshside Sands	1		*			<0.08	

Table 4.15(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], $Bq\ kg^{-1}$							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{129}I	Total Cs	^{230}Th	^{232}Th
Terrestrial samples										
Apples		1	<3.0	12	<0.30	0.052	<0.038	<0.030	0.0060	0.0022
Beetroot		1	<4.0	7.0	<0.30	0.091	<0.037	<0.037	0.0084	0.0014
Broad beans		1	5.0		<0.30	0.062	<0.055	0.13	0.0017	<0.0012
Cabbage		1	<4.0	7.0	<0.30	0.12	<0.025	<0.033	<0.00060	0.00070
Carrots		1	<4.0	7.0	<0.20	0.23	0.58	<0.060	0.014	0.0086
Duck		1	<4.0	29	<0.30	<0.019		2.3	<0.0018	<0.0021
Eggs		1	<5.0	34	<0.20	0.036	<0.036	0.16	<0.00090	<0.00090
Potatoes		1	<4.0	15	<0.30	0.027	<0.052	0.10	0.0057	0.0049
Sloe berries[d]		1	<4.0	24	<0.40	0.18	<0.087	0.13	0.010	<0.0010
Grass[d]		8			0.90					

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], $Bq\ kg^{-1}$							
			Total U	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am
Terrestrial samples										
Milk	Near farms	5	<0.0069							
Apples		1	<0.033				<0.00020	<0.00030	<0.063	<0.00040
Beetroot		1	<0.035				<0.00010	<0.00020	0.12	<0.00040
Broad beans		1	<0.035				<0.00040	0.00030	<0.11	0.0003
Cabbage		1	<0.034				<0.00040	<0.00040	<0.076	0.0004
Carrots		1	0.036				<0.00030	<0.00040	<0.13	<0.00050
Duck		1	<0.035				<0.00050	0.0014	<0.16	<0.00050
Eggs		1	<0.034				<0.00030	0.00020	<0.15	0.0002
Potatoes		1	<0.034				<0.00030	0.00020	<0.079	0.0004
Sloe berries		1	<0.033	0.014	0.0019	0.012	<0.00020	0.00080	<0.057	0.0011
Grass[d]		8	1.8							
	max		4.2	2.4	0.11	2.0				
Soil		4	160							
Soil	max		310	95	4.6	89				

* *not detected by the method used*

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

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

[c] *The concentration of ^{14}C and ^{237}Np were 44 and 0.00018 $Bq\ kg^{-1}$ respectively*

[d] *The concentration of ^{137}Cs was 28 $Bq\ kg^{-1}$*

Table 4.15(b). Monitoring of radiation dose rates near Springfields, 2001

Location	Material or ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Gamma dose rates at 1m			
Banks Marsh	Mud	2	0.13
Banks Marsh	Mud[a]	2	0.14
Banks Marsh	Salt marsh	2	0.13
Warton Marsh	Mud	2	0.12
Warton Marsh	Mud[a]	2	0.12
Warton Marsh	Salt marsh	2	0.10
Beta dose rates			$\mu Sv\ h^{-1}$
Lytham - Granny's Bay	Mud and sand	1	0.40
Ribble Estuary	Gill net	2	0.74
Ribble Estuary	Shrimp net	2	0.44
Banks Marsh	Mud	2	2.3
Banks Marsh	Salt marsh	2	0.68
Warton Marsh	Mud	2	1.7
Warton Marsh	Salt marsh	2	0.56

[a] *15cm above substrate*

Table 4.16. Radioactivity in food and the environment near Capenhurst, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{226}Ra	^{233}Pa	^{234}Th	^{234}U	$^{235}U+^{236}U$	^{238}U	^{237}Np	^{241}Am
Aquatic samples														
Dabs	Mersey Estuary	1	<25											
Flounder	Liverpool Bay	2	<25											
Flounder	Mersey Estuary	1	<25											
Shrimps	Wirral	2	<25	<0.13		1.7		*	*					<0.24
Mussels	Liverpool Bay	2	<25											
Mussels	Mersey Estuary	2	<25											
Cockles[b]	Dee Estuary	4		0.23		1.7	0.91	*	4.8					2.3
Cladophora[c]	Rivacre Brook	1		<0.04	44	0.51		*	77	11	0.58	6.9	1.7	<0.06
Elodea canadensis[d]	Rivacre Brook	1		<0.05	75	0.62		*	40	33	1.9	25	8.8	<0.18
Mud and Sand	Rivacre Brook	2		<0.19	140	4.4	14	110	410	36	1.7	23	0.51	<0.87
Freshwater	Rivacre Brook	2	4.4	<0.10	0.38	<0.10		*	*	0.73	*	0.51	0.0023	<0.12

Material	Location or selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H[f]	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk	Near Farms	5	<1.6	<0.0040				<0.0069
Milk	max		<1.9					<0.0071
Blackcurrants		1		<0.079				<0.035
Cabbage		1		<0.012				<0.034
Lettuce		1		<0.030				<0.035
Potatoes		1		<0.062	0.015	<0.0018	0.013	0.054
Rainwater		19	<2.7					
Rainwater	max		15					

* *not detected by the method used*

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

[b] *The concentrations of ^{238}Pu, $^{239+240}Pu$ and $^{243+244}Cm$ were 0.17, 0.93 and 0.0023 Bq kg^{-1} respectively.*

[c] *The concentration of beta activity was 200 Bq kg^{-1}*

[d] *The concentration of beta activity was 420 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.*

[f] *In distillate fraction of sample*

Table 4.17(a). Radioactivity in food and the environment near Chapelcross nuclear power station, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb
Aquatic samples									
Plaice	Inner Solway	1		<0.10		<0.10	<0.32	<0.10	<0.10
Plaice	North Solway	3		<0.10		<0.10	<0.53	<0.10	<0.16
Mullet	Inner Solway	2		<0.10		<0.14	<0.36	<0.10	<0.11
Shrimps	Inner Solway	3		<0.10	<0.16	<0.16	<0.76	<0.12	<0.23
Winkles[b]	Southerness	4		1.7	<0.48	<0.12	<1.1	<0.21	0.52
Cockles[c]	North Solway	8		<1.7	<0.43	<0.14	<0.62	<0.12	<0.18
Mussels	North Solway	7		<0.60	0.65	<0.13	<0.59	<0.10	<0.17
Seaweed[d]	Pipeline	3		0.93		<0.15	<0.61	<0.10	<0.75
Sediment	Pipeline	3		2.8		<0.35	2.7	<0.14	1.4
Sediment	Dornoch Brow	3		1.8		<0.16	<1.6	<0.12	<0.94
Seawater	Pipeline	3	20	<0.10		<0.10	<0.35	<0.10	<0.12
Seawater (high tide)	Pipeline	2	8.4	<0.10		<0.10	<0.25	<0.10	<0.10
Seawater	Southerness	3	8.2	<0.10		<0.10	<0.27	<0.10	<0.10
Seawater	North Solway	3	7.7						

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples										
Plaice	Inner Solway	1	<0.10	0.55	<0.10	<0.11			<0.10	
Plaice	North Solway	3	<0.10	1.9	<0.10	<0.15	0.0016	0.057	0.0087	
Mullet	Inner Solway	2	<0.10	1.2	<0.10	<0.14			<0.12	
Shrimps	Inner Solway	3	<0.10	5.9	<0.11	<0.19	0.0041	0.020	<0.12	
Winkles[b]	Southerness	4	<0.10	1.7	<0.10	<0.15	0.76	4.0	8.8	
Cockles[c]	North Solway	8	<0.10	3.6	<0.18	<0.18	0.87	2.8	5.9	0.010
Mussels	North Solway	7	<0.08	2.0	<0.14	<0.17	0.43	2.1	5.0	0.0092
Seaweed[d]	Pipeline	3	<0.10	28	<0.10	0.45	1.0	5.3	4.2	
Sediment	Pipeline	3	0.20	280	1.2	1.4	15	84	140	
Sediment	Dornoch Brow	3	<0.11	140	0.58	<0.55	8.6	44	83	
Seawater	Pipeline	3	<0.10	<0.17	<0.10	<0.11			<0.10	
Seawater (high tide)	Pipeline	2	<0.10	0.12	<0.10	<0.10			<0.10	
Seawater	Southerness	3	<0.10	<0.14	<0.10	<0.10	0.00042	0.0012	0.0022	

Table 4.17(a). continued

Material	Location or selection[e]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am
Terrestrial samples													
Milk		11	72	17	<2.6	<0.05	<0.13	<0.17	<0.29	<0.05	<0.05	<0.07	<0.05
Milk	max		140	20	<6.2	<0.05	<0.39	<0.22	<0.45	<0.05	<0.05	0.18	<0.06
Apples		4	100	<16	<0.50	<0.05	<0.10	<0.10	<0.24	<0.05	<0.05	<0.05	<0.05
Apples	max		150	18				<0.25	<0.31				<0.07
Barley		3	150	59	<0.84	<0.05	0.34	<0.08	<0.28	<0.05	<0.05	<0.05	<0.10
Barley	max		250	92	<0.89			<0.08	<0.30				<0.11
Cabbage		1	110	<15	<0.50	<0.50	0.35	<0.05	<0.14	<0.05	<0.05	<0.05	<0.05
Carrots		2	<54	<15	<0.50	<0.05	0.35	<0.06	<0.27	<0.05	<0.05	<0.05	<0.06
Carrots	max		100				0.45	<0.07	<0.40				
Cereal		1	37	110	<0.68	<0.05	0.37	<0.09	<0.35	<0.05	<0.05	<0.05	<0.09
Comfrey		1	30	<15	<0.50	<0.05	0.42	<0.05	<0.15	<0.05	<0.05	<0.08	<0.05
Damsons		1	20	16	<0.50	<0.05	<0.10	<0.06	<0.26	<0.05	<0.05	<0.05	<0.08
Elderberries		1	150	24	<0.50	<0.05	0.82	<0.05	<0.11	<0.05	<0.05	<0.05	<0.05
Hawthorn Berries		1	100	41	<0.50	<0.05		<0.11	<0.29	<0.05	<0.05	0.09	0.09
Maize		1	50	35	<0.50	<0.05	<0.10	<0.05	<0.12	<0.05	<0.05	<0.20	<0.05
Mallard		1	10	45	<1.2	<0.05	<0.10	<0.08	<0.35	<0.05	<0.05	0.59	<0.10
Onions		1	<5.0	<15	<0.50	<0.05		<0.08	<0.34	<0.05	<0.05	<0.05	<0.05
Pears		1	73	27	<0.50	<0.05	0.19	<0.05	<0.17	<0.05	<0.05	<0.05	<0.05
Pheasants		1	21	31	<1.4	<0.05	<0.10	<0.10	<0.41	<0.06	<0.05	0.55	<0.11
Potatoes		2	<24	18	<0.50	<0.05	<0.10	<0.05	<0.17	<0.05	<0.05	<0.05	<0.07
Potatoes	max		43	20					<0.26				<0.10
Turnips		1	120	<15	<0.50	<0.05	0.32	<0.05	<0.11	<0.05	<0.05	<0.05	<0.05
Widgeon		1	32	46	<1.3	<0.05	<0.10	<0.05	<0.30	<0.05	<0.05	2.2	<0.10
Wild Greens		1	<5.0	<15	2.7	<0.05	1.8	<0.05	<0.19	<0.05	<0.05	0.15	<0.07
Grass		3	<120	<16	1.0	<0.05	0.20	<0.23	<0.26	<0.05	<0.05	0.20	<0.07
Grass	max		350	17	1.1		0.25	<0.54	<0.36			0.22	<0.08
Soil		3	<23	<15	<1.3	<0.05	2.0	<0.09	<0.29	<0.05	<0.05	6.0	<0.32
Soil	max		47		<2.2		3.1	<0.13	<0.38	<0.06		7.3	0.59

[a] *Except for seawater and milk where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentration of ^{241}Pu was 9.5 Bq kg^{-1}*
[c] *The concentration of ^{14}C was 51 Bq kg^{-1}*
[d] *The concentrations of alpha and beta activity were 2.8 and 160 Bq kg^{-1} respectively*
[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(b). Monitoring of radiation dose rates near Chapelcross, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Southerness	Winkle bed	3	0.054
Glencaple Harbour	Mud and sand	3	0.080
Priestside Bank	Salt marsh	1	0.063
Powfoot Merse	Mud	3	0.082
Pipeline	Sand	3	0.098
Pipeline	Salt marsh	3	0.10
Battlehill	Sand	3	0.088
Dornoch Brow	Mud and sand	3	0.093
Dornoch Brow	Salt marsh	3	0.092
Browhouses	NA	3	0.091
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	3	<1.0

NA not available

Table 4.17(c). Radioactivity in air near Chapelcross, 2001

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Eastriggs	4	<0.017	0.017	0.16
Kirtlebridge	4	<0.018	<0.014	0.14
Brydekirk	4	<0.020	<0.018	0.13

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, or contractors, 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 authorisations granted by SEPA. The quantities discharged from Dounreay in 2001 were generally similar to those in 2000. This reflects the continuing shut down of processing activities within the fuel cycle area under a formal direction issued by the Nuclear Installations Inspectorate in May 1998.

In July 2001, The Minister for energy announced that no more PFR fuel would be reprocessed at Dounreay thus allowing UKAEA to focus on the challenges of decommissioning Dounreay. UKAEA sought the consent of the Nuclear Installations Inspectorate to open their Waste Receipt Assay Characterisation and Supercompaction Plant (WRACS) and to re-open three plants to handle Intermediate Level Wastes and the D1202 Fuel Fabrication Plant. NII consulted SEPA on these consents under the terms of a Memorandum of Understanding, then in draft form. Several of these consents were made conditional as a result of these consultations following SEPA assessments.

SEPA carried out an audit of the management arrangements for liquid radioactive wastes in 2001. The audit was observed by inspectors from the Environment Agency's Sellafield team to promote the interchange of regulatory experience.

Monitoring included sampling of air, grass and soil and 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), (b) and (c).

During 2001 UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. After regulatory action by SEPA UKAEA made improvements to the Quality Assurance relating to beach monitoring, particularly with respect to the control of the speed of the vehicle and the area monitored. In 2001, three fragments were recovered from Sandside Bay and three from the Dounreay foreshore. Surveys identified 129 fragments on the offshore seabed of which 122 were recovered. The caesium-137 activity measured in the fragments recovered from Sandside Bay range between 5.7 10^4 and 1 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.

The Dounreay Particles Advisory Group (DPAG), which was set up in 2000 to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments, continued to meet during 2001. In March 2001 SEPA published an interim report (on behalf of DPAG) which summarized DPAG's work up to December 2000. DPAG held its first public meeting at Dingwall in November 2001.

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 2001 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 and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. Concentrations of radionuclides in 2001 were generally similar to those for 2000, though strontium-90 levels increased in crabs. This is a single observation that is most likely due to the normal variability in the environment. No increase in discharge took place and no similar increase was observed in local molluscs. Technetium-99 in crabs, molluscs and seaweed remained at levels to be expected at this distance from Sellafield. The estimated dose from consumption of fish and shellfish by high-rate consumers was less than 0.005 mSv or less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The 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 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 2000. Measurements of gamma dose rates above areas of the foreshore remained similar to those for 2000. The radiation dose to the public from these rocky areas was less than 0.005 mSv which was less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The results for terrestrial samples are given in Table 5.1(a) and (c) and generally show low levels of radioactivity. Low levels of tritium, strontium-90, caesium isotopes, plutonium isotopes and americium-241 were found in samples. The ratio of plutonium isotopes 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 0.014 mSv which was less than 2% of the annual dose limit for members of the public of 1 mSv. The reduction from the datum for 2000 (0.020 mSv) was largely due to a reduction in the level of strontium-90 in potatoes. The dose estimate includes a contribution from consumption of beef and lamb based on concentrations for 2000. The FMD outbreak prevented sampling of these foodstuffs in the Dounreay area in 2001. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be less than 0.001 mSv.

A revised habit survey for the Dounreay site was published in 2001.

5.2 Harwell, Oxfordshire

Discharges of radioactive wastes from Harwell continued in 2001 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 close to 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 and also in runner beans but at very low levels. A trace amount of caesium-137 was detected in soil. 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 dose limit for members of the public of 1 mSv.

Concentrations of some nuclides, notably cobalt-60 and caesium-137, were enhanced close to the outfall for liquid discharges at Sutton Courtenay, but the levels were small in terms of any radiological effect. The concentration of tritium determined in local pike was well above the limit of detection, and higher than the value found at the control location at Newbridge. However, there are other potential sources of tritium in this area as indicated by earlier results for Newbridge (Food Standards Agency and SEPA, 2001). The concentration of caesium-137 in pike decreased in 2001 to 1.7 Bq kg^{-1} (2000: 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 riverbank has been assessed to estimate their external exposures. Consumption of indigenous freshwater fish was not found to occur, but it is considered prudent to include a component in the assessment of the angler's exposure. A consumption rate of 1 kg $year^{-1}$ was selected. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 2001 was 0.009 mSv, which was about 1% of the dose limit for members of the public of 1 mSv. The tritium contribution to this dose was substantially less than 0.001 mSv.

5.3 Winfrith, Dorset

Discharges of radioactive wastes from this site continued in 2001 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 were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. Concentrations of radionuclides in the marine environment continued at the low levels attained since closure of the SGHWR. Small amounts of technetium-99 found in seaweed may have been due to discharges from Sellafield, or Cap de la Hague, or equally weapons testing in the early 1960s. The radiation dose to the most exposed group of fish and shellfish consumers remained low in 2001 at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public.

Table 5.1(a). Radioactivity in food and the environment near Dounreay, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Aquatic samples										
Crabs[b]	Pipeline	6	<0.11	<0.20	1.3	<0.21	<0.18		<0.70	<0.10
Crabs	Strathy	4	<0.10	<0.20		<0.19	<0.21		<0.71	<0.10
Crabs	Kinlochbervie	4	<0.10	<0.16		<0.15	<0.19	<1.3	<0.55	<0.10
Crabs	Melvich Bay	4	<0.11	<0.22		<0.20	<0.19	<3.0	<0.78	<0.11
Winkles	Brims Ness	4	<0.11	<0.20	<0.11	<0.22	<0.24		<0.70	<0.10
Winkles	Sandside Bay	4	<0.12	<0.21	<0.17	<0.22	<0.25		<0.77	<0.11
Mussels	Echnaloch Bay	3	<0.10	<0.13		<0.12	<0.15		<0.47	<0.10
Seaweed[c]	Sandside Bay	4	<0.12	<0.15		<0.11	<0.10	190	<0.35	<0.10
Seaweed	Brims Ness	4	<0.10	<0.15		<0.11	<0.11		<0.39	<0.10
Seaweed	Kinlochbervie	4	<0.10	<0.20		<0.17	<0.15		<0.56	<0.10
Seaweed	Burwick Pier	4	<0.10	<0.13		<0.11	<0.10		<0.33	<0.10
Spume / sediment[d]	Oigins Geo	4	<1.1	<1.2		<0.99	<2.2		<3.8	<0.47
Sediment	Sandside Bay	4	<0.10	<0.18		<0.16	<0.15		<0.46	<0.10
Sediment	Rennibister	3	<0.13	<0.39		<0.27	<0.29		<0.95	<0.16
Sediment	Echnaloch Bay	1	<0.10	<0.28		<0.18	<0.16		<0.69	<0.11
Seawater[e]	Sandside Bay	4	<0.10	<0.10		<0.10	<0.10		<0.24	<0.10
Water[f]	Bore hole	4			<200					

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{125}Sb	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Aquatic samples										
Crabs[b]	Pipeline	6	<0.20	0.22	<0.41	<0.11	<0.18	0.017	0.065	0.044
Crabs	Strathy	4	<0.21	0.15	<0.42	<0.11	<0.19	0.0015	0.0056	0.0064
Crabs	Kinlochbervie	4	<0.16	0.21	<0.33	<0.10	<0.15	<0.00042	0.0031	0.0085
Crabs	Melvich Bay	4	<0.23	<0.15	<0.44	<0.12	<0.20	0.031	0.016	0.0076
Winkles	Brims Ness	4	<0.21	<0.18	<0.40	<0.11	<0.18	0.038	0.16	0.083
Winkles	Sandside Bay	4	<0.22	<0.15	<0.45	<0.12	<0.20	0.021	0.099	0.078
Mussels	Echnaloch Bay	3	<0.14	<0.10	<0.31	<0.10	<0.17	0.011	0.079	0.038
Seaweed[c]	Sandside Bay	4	<0.11	0.42	<0.25	<0.10	<0.14			0.45
Seaweed	Brims Ness	4	<0.12	0.31	<0.26	<0.10	<0.14			<0.16
Seaweed	Kinlochbervie	4	<0.27	0.86	<0.37	<0.10	<0.22			<0.19
Seaweed	Burwick Pier	4	<0.11	0.32	<0.22	<0.10	<0.13			<0.13
Spume / sediment[d]	Oigins Geo	4	<1.1	<6.2	<2.1	<0.49	<0.91	0.26	0.87	1.3
Sediment	Sandside Bay	4	<0.14	3.0	<0.39	0.77	0.54	3.7	15	12
Sediment	Rennibister	3	<0.31	<6.4	<0.74	<0.18	<0.52			<0.39
Sediment	Echnaloch Bay	1	<0.20	2.4	<0.58	<0.15	<0.31			0.54
Seawater[e]	Sandside Bay	4	<0.10	<0.10	<0.14	<0.10	<0.10			<0.10
Water[f]	Bore hole	4								

Table 5.1(a). continued

Material	Location or selection[g]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs
Terrestrial samples										
Barley		1	5.4	<0.05	0.45	<0.13	<0.38	<0.067	<0.05	<0.05
Cabbage		1	<5.0	<0.05	0.28	<0.05	<0.20	<0.050	<0.05	<0.05
Nettles[h]		1	<5.0	<0.05	3.1	<0.07	<0.27	<0.062	<0.05	0.43
Potatoes		2	<5.0	<0.05	<0.11	<0.05	<0.17	<0.050	<0.05	0.11
	max				0.12		<0.25			0.15
Grass[i]		6	<5.1	<0.05	0.52	<0.09	<0.35	<0.048	<0.05	1.3
Grass	max		5.3	<0.07	0.84	<0.11	<0.57	<0.050	<0.07	6.8
Soil[j]		6	<8.3	<0.06	1.3	<0.12	<0.50	<0.072	<0.08	21
Soil	max		<12	<0.07	2.3	<0.13	<0.55	<0.093	0.12	35

Material	Location or selection[g]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{144}Ce	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Terrestrial samples									
Barley		1	<0.27				<0.05	<0.05	<0.05
Cabbage		1	<0.15				<0.05	<0.05	<0.05
Nettles[h]		1	<0.18				<0.05	<0.05	<0.05
Potatoes		2	<0.12				<0.05	<0.05	<0.05
	max		<0.17						
Grass[i]		6	<0.24	<0.45	<0.05	<0.44	<0.050	<0.052	<0.06
Grass	max		<0.42	1.7	<0.12	1.8		0.060	<0.09
Soil[j]		6	<0.45	23	<0.66	20	<0.073	0.27	<0.19
Soil	max		<0.53	34	1.2	30	0.14	0.45	<0.26

[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 34 Bq kg^{-1}*
[c] *The concentrations of alpha and beta activity were <7.1 and 220 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 concentration of ^{3}H was <1.7 Bq l^{-1}*
[f] *The concentrations of ^{14}C, alpha and beta activities were <15, <10 and <100 Bq l^{-1} respectively*
[g] *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.*
[h] *The concentration of ^{14}C was 20 Bq kg^{-1}*
[i] *The concentration of ^{155}Eu was 0.21 Bq kg^{-1}*
[j] *The concentration of ^{155}Eu was 1.2 Bq kg^{-1}*

Table 5.1(b). Monitoring of radiation dose rates near Dounreay, 2001

Location	Material or ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over substrate			
Strathy Park	NA	1	0.064
Sandside Bay	Winkle bed	4	0.097
Oigin's Geo	Spume/sludge	3	0.15
Melvich	Saltmarsh	1	0.066
Melvich	Sand	1	<0.047
Strathy	Sand	1	<0.047
Thurso	Riverbank	1	0.080
Archrergon Hill	Soil	1	0.052
Archvarasal	Soil	1	0.073
Thurso Park	Soil	1	0.067
Borrowstone Mains	Soil	1	0.077
Hallam Farm	Soil	1	0.076
Beta dose rates			$\mu Sv\ h^{-1}$
Sandside Bay	Sediment	4	<1.0
PLZ	N/A	1	<1.0
Oigin's Geo	Surface sediment	3	<1.0
Brims Ness	Surface sediment	4	<1.0

NA Not available

Table 5.1(c). Radioactivity in air near Dounreay, 2001

Location	No. of sampling observa-tions	Mean radioactivity concentration, $mBq\ m^{-3}$		
		^{137}Cs	Total alpha	Total beta
Shebster	10	<0.043	<0.0084	<0.076
Reay	9	<0.013	<0.0063	0.080
Forss	10	<0.021	<0.0061	0.082

Table 5.2(a). Radioactivity in food and the environment near Harwell, 2001

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	^{238}Pu	^{239}Pu ^{240}Pu	^{241}Am
Aquatic samples										
Pike	Outfall (Sutton Courtenay)	1	97	110	<0.03	<0.05	1.7			<0.06
Pike	Newbridge	1	<25	<25	<0.03	<0.04	<0.04	0.000026	0.000072	0.00035
Pike	Staines	1	<25	<25	<0.05	<0.04	0.21			<0.12
Pike	Shepperton	1	<25	<25	<0.05	<0.07	0.16			<0.18
Pike	Teddington	1	<25	<25	<0.03	<0.05	0.27			<0.15
Flounder	Beckton	1		<25	<0.05	<0.05	0.23			<0.14
Nuphar lutea	Newbridge	1		<25	<0.03	<0.05	0.05			<0.04
Nuphar lutea	Staines	1		<25	0.05	<0.05	0.19			<0.05
Mud	Position 'E' [b]	2			<0.47	4.6	350			<2.3

Material	Location or selection[c]	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	5	<4.0	<4.0	<0.32	<0.28	<0.32
Milk	Near farms max				<0.40	<0.30	<0.40
Apples		1	<4.0	<4.0	<0.20	<0.30	<0.30
Blackberries		1	<4.0	<4.0	<0.40	<0.40	<0.40
Cabbage		1	<4.0	<4.0	<0.40	<0.30	<0.30
Honey		1		6.0	<0.10	<0.20	<0.20
Potatoes		1	<4.0	<4.0	<0.40	<0.30	<0.30
Runner beans		1	<4.0	4.0	<0.30	<0.30	<0.30
Soil		1			<0.40	<0.40	2.9

[a] *Except for milk where units are Bq* l^{-1} *and for sediment where dry concentrations apply*
[b] *Near the outfall*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected maxima. If no 'max' is given the mean is also the maximum.*

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1m over river bank			
Position "E"[a]	Soil	2	0.076

[a] *near the outfall*

Table 5.3. Radioactivity in food and the environment near Winfrith, 2001

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	Total beta
Aquatic samples											
Cod	Weymouth Bay	2	<0.05	<0.16		0.33			<0.10		
Plaice	Weymouth Bay	2	<0.06	<0.17		0.13			<0.17		
Crabs	Chapman's Pool	1	0.35	<0.14		<0.05	0.00018	0.00094	0.0026	0.000060	
Crabs[b]	Lulworth Banks	1	<0.20	<0.39		<0.15	0.00019	0.00089	0.0016	*	
Pacific Oysters	Poole	1	<0.09	<0.20		<0.07			<0.17		
Cockles	Poole	1	0.80	<0.08		0.06			<0.09		
Whelks	Weymouth Bay	1	0.25	<0.11		<0.04			<0.05		
Whelks	Poole	1	0.25	<0.10		<0.04	0.00044	0.0022	0.0023	0.000039	
Fucus serratus	Kimmeridge	1	0.83	<0.22	0.98	0.04			<0.29		150
Fucus serratus	Bognor Rock	1	0.84	<0.12	5.1	0.08			<0.05		

Material	Location or selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}			
			Organic ^{3}H	^{3}H	^{60}Co	^{137}Cs
Terestial samples						
Milk	Near farms	4	<4.1	<4.1	<0.29	<0.33
Milk	Near farms max		<4.5	<4.5	<0.38	<0.35
Apples		1	<4.0	4.0	<0.40	<0.30
Blackcurrants		1	<4.0	<4.0	<0.30	<0.30
Cabbage		1	<4.0	<4.0	<0.20	<0.30
Carrots		1	2.0	4.0	<0.30	<0.30
Eggs		1	<4.0	<4.0	<0.30	<0.30
Honey		1		<6.0	<0.30	2.5
Potatoes		1	<4.0	<4.0	<0.30	<0.20

* *Not detected by the method used*
[a] *Except for milk where units are Bq l^{-1}*
[b] *The concentration of ^{14}C was 6.4 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.*

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 2001. 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 from the 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.

Discharges of caesium-137 in liquid wastes from Oldbury increased from 9% (2000) to 69% of the annual limit in 2001. The Quarterly Notification Level (QNL) was exceeded and full reports were made to the relevant regulatory body, the Environment Agency. The most likely reason for the increase was an increased frequency of receipt of empty contaminated spent fuel skips being returned from Sellafield. The QNL was also exceeded at Oldbury for discharges of carbon-14 in gaseous wastes in May 2001. A small fire occurred in a tiled enclosure in a laboratory facility at the Berkeley Centre in July 2001. All of these occurrences were considered when interpreting the results of monitoring at the sites.

A recent habit survey has confirmed that the two potentially critical pathways for public radiation exposure in the aquatic environment were internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of seafood were analysed and gamma dose rates are monitored. Measurements of tritium in seafood were made in 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.

Data for 2001 are presented in Tables 6.1(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were generally similar to those in recent years. Unfortunately shrimp samples, which are good indicators of local sources, were not available in 2001 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. Small increases were observed in concentrations of caesium isotopes in mud and these are likely to have been due to the increased discharges from Oldbury. The enhanced dose rate at Beachley could also have been due to this increase. 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 unchanged at less than 0.005 mSv which was less than 0.5% of the 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 gaseous disposals from the sites were seen in blackberries. Carbon-14 was detected in local foodstuffs, at levels slightly above background values but there was no indication of a significant increase associated with the QNL being exceeded at Oldbury. Similarly the analyses of milk for uranium isotopes made in connection with the fire at Berkeley show no enhancement above normal levels. The most exposed group dose continued to be low and was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit.

6.2 Bradwell, Essex

This Magnox power station stopped electricity production in March 2002 after 40 years of operation and is now undergoing defuelling prior to decommissioning. It is authorised to discharge gaseous wastes to the local environment and liquid wastes to the estuary of the River Blackwater. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples for tritium, carbon-14 and sulphur-35. Aquatic sampling was directed at consumption of locally caught fish and shellfish. 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. Limpets and sea urchins were collected as part of a research project into uncommon seafood (Swift, 2002).

Measurements for 2001 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 2000. The technetium-99 detected in *Fucus vesiculosus* at Waterside was likely to be 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 dose limit for members of the public of 1 mSv.

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication that tritium and carbon-14 levels had been 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 0.005 mSv which was less than 1% of the 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 of tritium, carbon-14 and sulphur-35 were made in terrestrial samples. Marine monitoring included gamma and beta dose rate measurements in Rye Harbour and analysis of seafood and indicator materials. The results of a EC audit of the surveillance programme were published in 2001 (see Section 2.1.1).

The results of monitoring for 2001 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 0.007 mSv which was less than 1% of the dose limit for members of the public of 1 mSv.

Activity concentrations in many terrestrial foods were close to the limits of detection. Levels of carbon-14 were generally within the range of activity concentrations observed for background, however, some enhancements were observed particularly in peas. Low concentrations of 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 2001 was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public.

6.4 Hartlepool, Cleveland

This station is powered by twin AGRs. A habits survey has examined the potential pathways for radiation exposure due to liquid effluent disposals and this established that exposures could be represented by consumption of local fish and shellfish and external 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 2001 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 relatively high value of caesium-137 in honey (34 Bq kg^{-1}) is likely to be due to Chernobyl fallout since the bees from the relevant hives are known to feed on upland heather. The most exposed group dose in 2001 was 0.008 mSv which was less than 1% of the dose limit for members of the public of 1 mSv. This estimate includes a contribution from consumption of honey.

Although observed in the past, high levels of tritium in seawater were not observed in 2001. However, the level of tritium associated with organic material in winkles was unexpectedly high at about 70 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* increased this year (69 Bq kg^{-1}: 2001; 44 Bq kg^{-1}: 2000; 58 Bq kg^{-1}: 1999; 110 Bq kg^{-1}: 1998 (see also Figure 4.7)). However, the overall trend is expected to continue to be downwards. 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 critical consumption group does not spend time over the enhanced slag. If the polonium and lead levels in winkles were enhanced then their dose should be assessed. No enhancement of polonium-210 in seafood has been found in the area (Rollo *et al.*, 1992). 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 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.

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* *Study of tritium and carbon-14 in seafood: RO3014*

The results for 2001 are given in Tables 6.5(a) and (b). In general, similar levels to those for 2000 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 2001 to the most exposed group of fishermen was based on revised data from a recent habits survey. Including a component due to external radiation the dose was 0.059 mSv which is well within the dose limit for members of the public of 1 mSv. There was little change from the estimate for 2000 of 0.066 mSv (Food Standards Agency and SEPA, 2001). Most of this exposure was due to the effects of disposals from Sellafield.

The effects of gaseous disposals were also difficult to detect in 2001. Small enhancements of concentrations of carbon-14 were apparent in some samples. The most exposed group dose was estimated to be 0.008 mSv which was less than 1% of the dose limit for members of the public of 1 mSv.

6.6 Hinkley Point, Somerset

At this establishment there are two separate 'A' and 'B' nuclear power stations; the 'A' station comprises Magnox reactors and the 'B' station AGRs. Magnox Electric announced the closure of Hinkley Point 'A' in May 2000 and the station is now undergoing defuelling prior to decommissioning. Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Additional milk samples were obtained this year to investigate an anomalous caesium-137 result from a deposition collector used by the operators of the site. The result was from a tacky shade that could not be collected for about six months due to restrictions on access caused by the foot and mouth outbreak. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the Amersham plc plant at Cardiff. This year additional samples were collected as part of a research project to study uncommon seafood (Swift, 2002).

The environmental results for 2001 are presented in Tables 6.6 (a) and (b). Where results can be compared, the concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in 2000. Further information of tritium levels in seawater from the Bristol Channel is given in Section 11. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, weapons test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from Amersham plc, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were difficult to distinguish from the natural background. The most exposed group of local fishermen were estimated to receive a dose of 0.014 mSv which was less than 2% of the dose limit for members of the public of 1 mSv. This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff.

Results for 2001 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. No increase in the caesium-137 concentrations was observed in milk samples taken to investigate the anomalous air particulate result found by the operators of the site. 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 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 dose limit for members of the public of 1 mSv.

6.7 Hunterston, North Ayrshire

At this location there are two separate nuclear power stations – Hunterston 'A' and Hunterston 'B'. Hunterston 'B' is owned and operated by British Energy while Hunterston 'A' is owned by British Nuclear Fuels. Hunterston 'A' was powered by twin Magnox reactors and Hunterston 'B' is powered by a pair of AGRs. Hunterston 'A' ceased power production at the end of March 1990. 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.

Authorised liquid discharges are made to the Firth of Clyde by Hunterston 'B' via the stations cooling water outfall. Currently authorised liquid discharges from Hunterston 'A' are also made via the same outfall. Gaseous discharges are made via separate discharge points from the Hunterston 'A' and Hunterston 'B' stations.

Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as indicator materials. The scope of the terrestrial monitoring programme was enhanced in 2000 and now includes the analysis of a comprehensive range of wild and locally produced foods. In addition, air, grass and soil are sampled to provide background information.

The results of monitoring in 2001 are shown in Tables 6.7(a), (b) and (c). 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. Concentrations of technetium-99 from Sellafield in lobsters remained at about 220 Bq kg^{-1}. In *Nephrops*, concentrations increased (2001: 320 Bq kg^{-1}; 2000: 5.7 Bq kg^{-1}). It is unclear why this had occurred. It is very unlikely that *Nephrops* could have moved from the eastern Irish Sea where such levels are to be expected. It is possible, however, that the sample was not locally caught. Small concentrations of tritium and activation products such as manganese-54 that are likely to have originated from the site were also detected, however, these were of negligible radiological significance. In 2001, the dose to the critical group from external radiation and consumption of fish and shellfish was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv. This assessment includes new data from a recent habits survey on the consumption of seafood at Hunterston. Approximately 50 % of the dose to the critical group resulted from technetium-99 in seafood.

The concentrations of radionuclides in air, milk, vegetables and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. The radiation dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was estimated to be 0.028 mSv which was less than 3% of the dose limit for members of the public of 1 mSv. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be less than 0.001 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 2001 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. The presence of silver-110m and caesium-134 suggests a local input and this may be associated with increased discharges from

Sizewell 'A'. Tritium levels in seafood were low. In 2001, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. Measured gamma dose rates were indistinguishable from the natural background. The above assessment includes a contribution for external exposure based on a calculation using radionuclide concentrations in sediment and new consumption and occupancy rates from a habits survey completed in 2001.

Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit showed very low levels of artificial radioactivity near the power stations in 2001. Trace quantities of sulphur-35 were detected in some samples. The estimated dose to the most exposed group of consumers eating such foods was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

6.9 Torness, East Lothian

This station, which is powered by two AGRs, came into operation at the end of 1987.

A local habits survey was carried out during August 2001 to investigate radiological pathways associated with discharges and direct radiation from the site. The results, where relevant, have been included in the dose assessment in this report.

A review of the monitoring programme at this site was undertaken in 2000, and resulted in increased sampling of milk, vegetables, fruit, seafood, seawater, seaweed and soil. Various plants also were monitored as indicator materials and air sampling was introduced in 2001 to investigate the inhalation pathway. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

The results of this monitoring in 2001 are shown in Tables 6.9(a), (b) and (c). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace levels of activation products 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 dose limit for members of the public of 1 mSv.

Beta radiation from fishermen's nets and pots was below the limit of detection. Gamma dose rates on beaches were generally indistinguishable from natural background though data for St Abbs were higher. The effects of discharges from the power station were seen in low levels of tritium and sulphur-35 in terrestrial foods and indicator materials. The dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.017 mSv**,** which was less than 2% of the dose limit for members of the public of 1 mSv. The dose from inhaling air containing caesium-137 at the concentrations reported was estimates to be less than 0.001 mSv.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned. Low level discharges continued during 2001 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 Welsh Assembly Government 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 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, blackberries, and runner beans but at levels similar to that in the regional diet. The source is unknown but it is very unlikely to be Trawsfynydd. The most likely source of radiocaesium in sheep products, hazelnuts and sloes is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. Detected activities were low, and 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 2001.

The most exposed group for terrestrial foods at Trawsfynydd in 2001 were adults who received doses of 0.014 mSv which was less than 2% of the dose limit for members of the public of 1 mSv. This assessed dose includes a contribution from the radiocaesium activity detailed above.

In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where the possible exposure pathway to anglers is an issue were only slightly enhanced above background and were similar to those in 2000.

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 2001 were unchanged. The activity concentrations in sediments and the residual activity in the fish that result from earlier discharges predominate at this stage. The dose to the most exposed group of anglers was 0.034 mSv in 2001, which was about 3% of the 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 2001 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is carried out on behalf of the Welsh Assembly Government and the Food Standards Agency. Such discharges and effects are very low.

The results of the programme, including research samples (Swift, 2002), in 2001 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 2000, 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 0.011 mSv which was about 1% of the 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 terrestrial food consumers remained low at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public.

Table 6.1(a). Radioactivity in food and the environment near Berkeley and Oldbury nuclear power stations, 2001

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
Aquatic samples							
Salmon	Beachley	2	<25	31	<0.07	0.23	<0.14
Elvers	River Severn	1	<25		<0.16	<0.13	<0.26
Fucus vesiculosus	2 km SW Berkeley	1			0.58	2.3	<0.66
Mud	Hills Flats	1			2.4	36	2.0
Mud	1 km south of Oldbury	1			2.6	35	2.4

Material	Location or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
				^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs
Terrestrial samples								
Milk[c]	Near farms		7	<3.9	18	<0.62	<0.28	<0.30
Milk	Near farms	max		<4.0	20	<1.0	<0.30	<0.33
Milk	Far farms		1	<3.8	18	<0.50	<0.25	<0.30
Apples			1	<4.0	16	0.40	<0.30	<0.40
Blackberries			1	<4.0	19	1.4	<0.30	<0.30
Cabbage			1	<4.0	<3.0	0.70	<0.30	<0.30
Carrots			1	<4.0	7.0	<0.40	<0.30	<0.40
Honey			1	<6.0	110	<0.40	<0.30	<0.40
Potatoes			1	<4.0	22	<0.30	<0.30	<0.30
Runner beans			1	<4.0	6.0	0.70	<0.20	<0.20
Wheat			1	<6.0	83	<0.70	<0.30	<0.40

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

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

[c] *The concentrations of ^{234}U, ^{235}U, and ^{238}U were 0.0044 (max 0.0071), <0.00045 (max <0.00050) and <0.0032 (max 0.0044) Bq l^{-1} respectively.*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Lydney Locks	Mud	1	0.068
Lydney Locks	Mud and sand	1	0.062
2km south west of Berkeley	Mud	1	0.076
Hills Flats	Mud	1	0.066
Tollesbury	Mud	1	0.072
Tollesbury	Salt marsh	1	0.077
1km south of Oldbury	Mud	1	0.067
Severn Bridge area	Stones	1	0.063
New Severn Bridge area	Mud	1	0.062
New Severn Bridge area	Salt marsh	1	0.064
Beachley	Mud	1	0.088

Table 6.2. Radioactivity in food and the environment near Bradwell nuclear power station, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{14}C	^{60}Co	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Aquatic samples										
Sole	Bradwell	2		<0.05	<0.08	0.49			<0.13	
Bass	Pipeline	1		<0.08	<0.09	0.90			<0.35	
Mullet	Pipeline	1		<0.07	0.40	2.6			<0.07	
Native oysters	Tollesbury N. Channel	1	13	<0.02	0.08	0.28	0.00016	0.00085	0.0023	0.00011
Pacific oysters	Goldhanger Creek	2		<0.04	<0.08	0.35			<0.10	
Winkles	Pipeline	2		<0.20	<0.19	0.88			<0.24	
Winkles	Heybridge Basin	2		<0.19	<0.22	1.4			<0.70	
Slipper limpets	Pipeline	1	5.4	<0.08	<0.09	0.29	0.00030	0.0020	0.0030	*
Green sea urchin[b]	Pipeline	1		<0.11	<0.12	0.63			<0.08	
Fucus vesiculosus[c]	Waterside	2		<0.13	0.48	3.5			<0.07	
Leaf Beet	Tollesbury	1		<0.10	<0.10	<0.08			<0.19	
Samphire	Tollesbury	1		<0.06	0.08	0.64			<0.07	

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	Near farms	5	<4.0	18	<0.49	<0.29	<0.26	<0.30
Milk	Near farms max		<4.3	24	<0.55	<0.33	<0.30	<0.33
Milk	Far farms	1	<4.0	15	<0.50	<0.33	<0.28	<0.30
Apples		1	<4.0	16	0.40	<0.30	<0.20	<0.30
Blackberries		1	<4.0	23	1.4	<0.30	<0.30	<0.30
Cabbage		2	5.0	12	<0.70	<0.25	<0.30	<0.40
Cabbage	max		7.0	13	0.80	<0.30	<0.40	
Carrots		1	<4.0	10	1.6	<0.40	<0.30	<0.30
Potatoes		1	5.0	18	0.40	<0.30	<0.20	<0.20
Rape		1	31	110	<1.0	<0.40	<0.40	<0.40
Raspberries		1	<4.0	28	0.50	<0.30	<0.20	<0.20
Lucerne		1	<4.0	3.0	2.4	<0.30	<0.30	<0.30

* *Not detected by the method used*

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

[b] Psammechinus miliaris, *an edible sea urchin*

[c] *The concentrations of beta activity and ^{99}Tc were 200 and 3.7 Bq kg^{-1} respectively*

[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 6.3(a). Radioactivity in food and the environment near Dungeness nuclear power stations, 2001

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[b]	Pipeline	2	<25	<0.09		<0.16	<0.19			<0.20		
Cod	Pipeline	2	<25	<0.04		0.23	<0.11			<0.14		
Bass	Pipeline	1	<25	<0.04		0.37	<0.09			<0.05		
Crabs	Hastings	1		<0.07		<0.06	<0.20			<0.27		
Shrimps[c]	Pipeline	2	<25	<0.20		<0.18	<0.35			<0.24		
Whelks[d]	Pipeline	2		<0.14		<0.10	<0.19	0.00077	0.0026	0.0023	0.00012	0.00014
Cuttlefish	Hastings	1		<0.04		<0.04	<0.11			<0.10		
Fucus vesiculosus	Copt Point	1			3.2							
Mud and sand	Rye Harbour	2		1.1		1.1	<1.2	0.064	0.32	0.29	*	0.012
Seawater	Pipeline	2	<1.9									

Material	Location or selection[e]	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[f]	Far Farms	2	<3.9	15	<0.49	<0.28	<0.25	<0.29
Milk[f]	Far Farms	max	<4.0	16	<0.50	<0.30		<0.30
Blackberries		1	<4.0	17	0.50	<0.40	<0.30	<0.30
Eggs		1	<5.0	16	1.0	<0.30	<0.20	<0.20
Honey		1	<6.0	92	0.50	<0.20	<0.20	<0.20
Peas		1	<6.0	91	<0.80	<0.40	<0.30	<0.30
Potatoes		1	<4.0	21	0.80	<0.30	<0.30	<0.30
Sea kale		1	5.0	42	1.7	<0.30	<0.30	0.50
Wheat		1	<6.0	99	<0.80	<0.40	<0.30	<0.30
Grass		1	<5.0	9.0	0.80	<0.40	<0.30	<0.30

* *Not detected by the method used*

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

[b] *The concentration of organic ^{3}H was <25 Bq kg^{-1}*

[c] *The concentrations of organic ^{3}H and ^{14}C were <25 and 19 Bq kg^{-1} respectively*

[d] *The concentration of ^{90}Sr was <0.029 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.*

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

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1m over intertidal areas			
Rye Harbour	Mud and sand	2	0.063
Beta dose rates			µSv h^{-1}
Rye Harbour	Mud and sand	2	0.091

Table 6.4(a). Radioactivity in food and the environment near Hartlepool nuclear power station, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm
Aquatic samples											
Plaice	Pipeline	2	<25	<25	17	<0.10	0.29			<0.37	
Cod	Pipeline	2				<0.06	0.56			<0.17	
Crabs	Pipeline	2			25	<0.04	0.09	0.00068	0.0035	0.0062	0.000012
Winkles	Paddy's Hole	2	68	71		<0.06	0.44	0.0097	0.063	0.025	*
Fucus vesiculosus[b]	Pilot Station	2				<0.05	0.12			<0.13	
Sea water	Pipeline	2		5.8							

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	Far Farms[d]		5	<3.8	18	<0.48	<0.28	<0.29
Milk	Far Farms[d]	max		4.0	22	<0.50	<0.30	<0.30
Apples			1	<4.0	16	0.50	<0.20	<0.30
Cabbage			1	6.0	12	<0.60	<0.40	<0.30
Carrots			1	<4.0	14	<0.30	<0.30	<0.30
Honey			1	<6.0	94	<0.30	<0.40	34
Onions			1	<4.0	12	0.50	<0.40	<0.30
Parsnips			1	4.0	15	0.40	<0.40	<0.40
Plums			1	<4.0	11	<0.30	<0.30	<0.30
Potatoes			1	<4.0	26	0.30	<0.30	<0.30
Wheat			1	<6.0	97	<0.60	<0.40	<0.30

* *not detected by the method used*

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

[b] *The concentrations of ^{99}Tc and beta activity were 69 and 200 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] *There are no "near" farms producing milk near this site*

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2001

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	0.19

Table 6.5(a). Radioactivity in food and the environment near Heysham nuclear power stations, 2001

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples											
Flounder	Flookburgh	4		41	<0.12			<1.1	<0.31	<0.11	14
Plaice[c]	Morecambe	4	<35		<0.09	0.023	2.2	<0.86	<0.20	<0.09	4.3
Bass	Morecambe	2			<0.10			<1.1	<0.28	<0.11	15
Whitebait	Sunderland Point	1			<0.07	0.15		<0.56	<0.14	<0.06	6.8
Shrimps	Flookburgh	4		45	<0.08		6.2	<0.60	<0.15	<0.06	4.3
Cockles	Middleton Sands	2			3.5			<0.64	<0.17	<0.07	4.6
Cockles	Flookburgh	4		52	2.3	0.28	41	<0.64	<0.19	<0.07	3.7
Winkles	Red Nab Point	4			0.96			<0.91	<0.44	<0.08	3.7
Mussels[d]	Morecambe	4	79	45	0.50		610	<0.83	<0.30	<0.08	3.7
Fucus vesiculosus[e]	Half Moon Bay	4			0.72		2900	<0.73	<0.49	<0.09	5.0
Mud and sand	Flookburgh	1			<0.44			<4.3	<1.2	<0.53	73
Mud and sand	Half Moon Bay	4			4.1			<6.6	<2.3	<0.69	180
Mud and sand	Morecambe Central Pier	4			3.7			<6.5	<3.6	<0.75	200
Turf	Conder Green	4			4.7			<8.8	<3.4	<0.95	300
Turf	Sand Gate Marsh	1			2.0			<5.6	<1.8	<0.63	160
Seawater	Pipeline	2	140								
Seawater	Half Moon Bay	1								0.002	0.17

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], 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	<0.36	<0.20	0.00034	0.0018		0.0040	*	*
Plaice[c]	Morecambe	4	<0.27	<0.17				<0.15		
Bass	Morecambe	2	<0.29	<0.22				<0.16		
Whitebait	Sunderland Point	1	<0.19	<0.10	0.051	0.29	2.6	0.48	*	*
Shrimps	Flookburgh	4	<0.19	<0.13	0.0050	0.029	<0.31	0.046	*	0.000081
Cockles	Middleton Sands	2	<0.18	<0.14	0.37	2.0		6.6	*	0.014
Cockles	Flookburgh	4	<0.18	<0.15	0.40	2.2	20	6.0	*	0.0071
Winkles	Red Nab Point	4	<0.21	<0.21	0.25	1.4		2.5	*	0.0049
Mussels[d]	Morecambe	4	<0.21	<0.16	0.30	1.7		2.8	0.0051	0.0069
Fucus vesiculosus[e]	Half Moon Bay	4	<0.28	<0.19				0.84		
Mud and sand	Flookburgh	1	<1.1	<1.1				32		
Mud and sand	Half Moon Bay	4	<1.7	<2.3	11	64		110	*	0.23
Mud and sand	Morecambe Central Pier	4	<1.8	<2.3				120		
Turf	Conder Green	4	<2.4	<2.3				180		
Turf	Sand Gate Marsh	1	<1.5	<1.9				80		

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs
Terrestrial samples								
Milk	Near farms[f]	6	<4.1	20	<0.52	<0.30	<0.25	<0.29
Milk	Near farms[f]	max	<4.5	30	<0.58	<0.40	<0.30	<0.35
Apples		1	<4.0	18	<0.20	<0.20	<0.30	<0.30
Cabbage		1	<4.0	<3.0	<0.30	<0.40	<0.30	<0.40
Honey		1	<6.0	91	0.20	<0.20	<0.20	<0.20
Potatoes		1	<4.0	20	0.10	<0.30	<0.30	<0.30
Sprouts		1	<3.0	10	<0.30	<0.40	<0.40	<0.40
Swede		1	<4.0	12	<0.20	<0.40	<0.30	<0.40

** Not detected by the method used*

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

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

[c] The concentration of organic ^{3}H was <27 Bq kg^{-1}

[d] The concentration of organic ^{3}H was <63 Bq kg^{-1}

[e] The concentration of beta activity was 2200 Bq kg^{-1}

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

Table 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2001

Location	Ground type	No. of sampling observa-tions	µGy h-1
Gamma dose rates at 1 m over intertidal areas			
Roosebeck	Mud and sand	1	0.067
Sand Gate Marsh	Salt marsh	1	0.084
Flookburgh	Mud and sand	1	0.071
High Foulshaw	Salt marsh	1	0.080
Hest Bank	Mud and sand	1	0.070
Morecambe Central Pier	Mussel bed	4	0.073
Morecambe Central Pier	Mud and sand	4	0.073
Morecambe Bay	Mud	1	0.084
Half Moon Bay	Mud and sand	4	0.074
Sunderland Point	Mud	1	0.10
Colloway Marsh	Salt marsh	1	0.13
Aldcliffe Marsh	Salt marsh	1	0.098
Conder Green	Mud and sand	4	0.090
Conder Green	Salt marsh	4	0.11
Cockerham Marsh	Salt marsh	1	0.097
Cockerham Sands	Sand	1	0.074
Fleetwood	Mud	1	0.12

Table 6.6(a). Radioactivity in food and the environment near Hinkley Point nuclear power stations, 2001

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am
Aquatic samples													
Cod	Stolford	3	580	690	36	<0.07	<0.07	<0.16	<0.08	0.71	<0.34	<0.15	<0.15
Spurdog	Stolford	1	280	260	18	<0.05	<0.05	<0.12	<0.05	0.32	<0.33	<0.15	<0.21
Flounder	Stolford	1	4800	5300	88	<0.10	<0.10	<0.20	<0.10	0.40	<0.38	<0.15	<0.08
Rays	Stolford	1	2200	2500		<0.26	<0.23	<0.53	<0.26	1.7	<1.1	<0.39	<0.45
Whiting	Stolford	1	960	1300	34	<0.16	<0.17	<0.32	<0.16	0.46	<0.54	<0.22	<0.11
Grey mullet	Stolford	1	26	40	32	<0.12	<0.14	<0.29	<0.14	1.5	<0.47	<0.19	<0.10
Brill	Stolford	1				<0.11	<0.11	<0.22	<0.11	0.19	<0.43	<0.16	<0.08
Poor cod	Stolford	1	2200	2200	71	<0.13	<0.14	<0.28	0.16	1.0	<0.51	<0.20	<0.10
Sprats	Stolford	1		<25		<0.11	<0.09	<0.24	<0.11	0.20	<0.69	<0.31	<0.48
Eels	Stolford	2	750	850	71	<0.14	<0.13	<0.28	<0.22	1.6	<0.54	<0.22	<0.21
Twaite shad	Stolford	1	170	170	47	<0.05	<0.05	<0.10	<0.05	0.93	<0.22	<0.09	<0.05
Trigger fish	Stolford	1				<0.23	<0.24	<0.46	<0.24	<0.19	<0.79	<0.31	<0.16
Shrimps[b]	Stolford	2	2000	2100	57	<0.15	<0.14	<0.33	<0.17	0.68	<0.65	<0.28	0.0045
Whelks	Stolford	1		3000	73	<0.18	<0.19	<0.40	<0.18	0.47	<0.68	<0.30	<0.35
Limpets	Stolford	1	140	160	17	<0.13	<0.13	<0.28	0.37	1.3	<0.49	<0.19	<0.10
Dog whelks	Stolford	1	2600	3000	62	<0.14	<0.11	<0.24	<0.12	0.35	<0.54	<0.16	<0.08
Rough winkles	Stolford	1	1900		56	<0.20	<0.18	<0.42	<0.18	0.42	<1.1	<0.38	<0.34
Fucus vesiculosus[c]	Pipeline	1				1.6	2.4	0.48	4.1	29	<0.37	0.15	0.13
Ascophylum nodosum	Stolford	1	49	65	14	<0.04	<0.04	<0.10	0.11	0.76	<0.26	<0.12	<0.12
Sea lettuce	Stolford	1				<0.08	<0.07	<0.15	0.16	1.2	<0.37	<0.15	<0.18
Enteromorpha	Stolford	1	<25	26	14	<0.12	<0.11	<0.32	0.57	4.2	<0.69	<0.29	<0.25
Mud	1.6 km east of pipeline	1				<0.42	<0.38	<0.91	3.8	39	2.2	2.5	0.51
Mud and sand	River Parrett	1				<0.34	<0.29	<0.71	1.8	33	<1.6	2.1	0.79
Seawater	Pipeline	1		85									

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	Near farms	5	<4.0	15	<0.51	<0.29	<0.28	<0.30
Milk	Near farms	max	<4.3	18	<0.60	<0.30	<0.33	<0.33
Milk	Far Farms	1	<4.0	16	<0.65	<0.28	<0.28	<0.28
Milk	Near farms[e]	1					<0.44	<0.39
Apples		2	<5.0	17	0.80	<0.35	<0.30	<0.30
Apples		max	6.0	19	1.2	<0.40		
Blackberries		1	14	29	0.90	<0.30	<0.30	<0.30
Cabbage		1	4.0	16	<0.70	<0.30	<0.30	<0.30
Carrots		1	<4.0	19	<0.40	<0.30	<0.30	<0.30
Honey		1	<6.0	92	2.6	<0.40	<0.30	<0.30
Oats		1	<6.0	90	<0.60	<0.30	<0.40	<0.40
Potatoes		1	<4.0	20	1.8	<0.40	<0.30	<0.30
Runner beans		1	19	15	1.3	<0.30	<0.30	<0.30

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *The concentrations of ^{238}Pu, $^{239+240}Pu$ and $^{243+244}Cm$ were 0.00063, 0.0032 and 0.000037 Bq kg^{-1} respectively*
[c] *The concentration of beta activity was 410 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] *Taken as part of special investigations*

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
River Parrett	Mud and sand	1	0.071

Table 6.7(a). Radioactivity in food and the environment near Hunterston nuclear power station, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{54}Mn	^{60}Co	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Aquatic samples														
Cod	Millport	2	<0.10	<0.10	<0.17		<0.34	<0.10	2.4	<0.23	<0.11			<0.10
Hake	Millport	1	<0.10	<0.10	<0.10		<0.64	<0.10	3.1	<0.34	<0.16			<0.10
Crabs[b]	Millport	2	<0.10	<0.10	<0.12		<0.21	<0.10	0.41	<0.16	<0.10	0.0032	0.024	0.031
Nephrops	Millport	2	<0.10	<0.10	<0.10	320	<0.20	<0.10	1.4	<0.16	<0.10			<0.11
Lobsters	Largs	1	<0.10	<0.10	<0.10	220	<0.17	<0.10	0.42	<0.13	<0.10			<0.10
Squat lobsters	Largs	4	<0.10	<0.10	<0.12	17	<0.27	<0.10	0.42	<0.17	<0.11	0.0011	0.038	0.022
Winkles	Pipeline	2	0.68	0.37	<0.27		<0.76	0.67	0.81	<0.51	<0.23	0.054	0.29	0.53
Scallops	Largs	3	<0.10	<0.10	<0.11		<0.19	<0.10	0.34	<0.15	<0.10	0.0029	0.028	0.13
Seaweed	N of pipeline	2	1.6	0.40	<0.12		<0.33	<0.10	1.5	<0.20	<0.11			<0.11
Seaweed	Pipeline	2	1.0	0.41	<0.10		<0.30	<0.10	1.0	<0.19	<0.12			<0.16
Seaweed	S of pipeline	2	2.9	0.49	<0.11		<0.38	<0.10	1.5	<0.23	<0.13			<0.12
Sediment	Pipeline	2	<0.21	0.17	<0.19		<0.51	<0.10	12	<0.47	0.26			<0.32
Sediment	Millport	2	<0.10	<0.10	<0.18		<0.46	<0.10	6.6	<0.41	<0.16			0.34
Sediment	Ardneil Bay	2	<0.10	<0.10	<0.18		<0.41	<0.10	3.5	<0.40	<0.20			<0.18
Sediment	Gulls Walk	2	<0.10	<0.10	<0.24		<0.52	<0.10	6.3	<0.49	<0.24			<0.41
Seawater[c]	Pipeline	4	<0.10	<0.10	<0.41		<0.30	<0.10	<0.10	<0.20	<0.10			<0.10

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	^{90}Sr	^{95}Nb	^{106}Ru	^{110m}Ag	^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Terrestrial samples															
Milk		6	<11	<21	<2.7	<0.05	<0.10	<0.20	<0.31	<0.05	<0.14	<0.19	<0.05		
Milk	max		<29	25	<3.8			<0.21	<0.40	<0.06	0.41	<0.25	<0.06		
Apples		2	<5.0	25	<0.59	<0.05	<0.13	<0.07	<0.38	<0.05	<0.05	<0.27	<0.12		
Apples	max			27	0.67		0.16		<0.40				<0.14		
Barley[e]		2	<5.0	110	<1.5	<0.05	0.25	<0.13	<0.40	<0.06	<0.59	<0.30	<0.15		
Barley	max			140	1.8		0.33	<0.16			1.1	<0.31			
Blackberries		1	<5.0	22	<0.50	<0.05	1.0	<0.05	<0.28	<0.05	0.09	<0.21	<0.10		
Cabbage		1	<5.0			<0.05		<0.13	<0.36	<0.05	<0.05	<0.28	<0.07		
Carrots		2	<5.0	15	<0.50	<0.05	0.17	<0.07	<0.25	<0.05	<0.05	<0.17	<0.07		
Carrots	max							<0.09				<0.18	<0.08		
Hawthorn berries		1	120	55	<0.50	<0.05	1.6	<0.06	<0.32	<0.05	0.25	<0.22	<0.11		
Leeks		1	<5.0			<0.05		<0.09	<0.35	<0.05	<0.05	<0.21	<0.06		
Nettles		1	6.6	25	6.3	<0.05	4.1	<0.05	<0.25	<0.05	<0.05	<0.17	<0.08		
Onions		1	<5.0	12	0.61	<0.05	<0.10	<0.05	<0.10	<0.05	<0.05	<0.07	<0.05		
Potatoes		2	<5.0	19	<0.65	<0.05	<0.10	<0.09	<0.35	<0.05	<0.07	<0.23	<0.09		
Potatoes	max			22	0.80				<0.36		0.09				
Rabbit		3	<5.0	<22	<2.1	<0.05	<0.10	<0.06	<0.13	<0.05	<0.07	<0.09	<0.05		
Rabbit	max			35	3.4				<0.14		0.09	<0.11			
Rowan berries		1	<5.0	30	<0.50	<0.05	0.24	<0.10	<0.40	<0.05	0.05	<0.27	<0.11		
Turnips		1	5.2	17	<0.50	<0.05	0.10	<0.05	<0.20	<0.05	<0.05	<0.12	<0.05		
Grass		4	<6.0	29	<2.0	<0.05	0.65	<0.06	<0.27	<0.05	0.13	<0.17	<0.09	0.13	140
Grass	max		7.8	42	2.9		0.84		<0.35		0.20	<0.22	<0.12	0.24	270
Soil[f]		4	<8.4	<21	<1.0	<0.05	1.0	<0.07	<0.36	<0.06	16	<0.31	<0.19	150	0.66
Soil	max		<12	28	<1.7		1.4	<0.09	<0.45		19	<0.38	0.30	270	0.80

[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 32 Bq kg^{-1}*

[c] *The concentration of ^{3}H was 3.8 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.*

[e] *The concentration of ^{54}Mn was 0.06 Bq kg^{-1}*

[f] *The concentration of ^{155}Eu was 0.38 Bq kg^{-1} (max 0.62)*

Table 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2001

Location	Ground type	No. of sampling observations	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Largs Bay	NA	2	0.061
Kilchatten Bay	NA	2	<0.051
Millport	NA	2	<0.052
Gulls Walk	NA	2	<0.053
0.5 km north of pipeline	NA	2	<0.051
0.5 km south of pipeline	NA	2	0.062
Ardneil Bay	NA	2	<0.048
Ardrossan Bay	NA	2	<0.050

NA Not available

Table 6.7(c). Radioactivity in air near Hunterston, 2001

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Fairlie	11	<0.016	<0.0089	0.12
West Kilbride	11	<0.016	<0.0087	0.11
Biglies	7	<0.012	<0.0096	0.096

Table 6.8(a). Radioactivity in food and the environment near Sizewell nuclear power stations, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{110m}Ag	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Aquatic samples												
Cod	Sizewell	1		<25		<0.06	<0.03	0.43			<0.09	
Sole	Sizewell	2	<25	<25		<0.17	<0.09	0.25			<0.07	
Crabs	Sizewell	2			9.9	<0.28	<0.15	0.17	0.000073	0.00040	0.0010	0.000054
Shrimps	Sizewell	1	<25	<25		<0.13	0.29	1.6	0.000055	0.00025	0.00027	*
Pacific Oyster	Blyth estuary	1				0.09	<0.03	0.03			<0.11	
Whelks	Dunwich	1				<0.09	<0.05	0.10			<0.06	
Mussels	River Alde	1	<25	<25		<0.33	<0.19	<0.16			<0.37	
Sand	Aldeburgh	2				<0.21	<0.13	0.32			<0.29	
Seawater	Aldeburgh	2		5.3								

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{110m}Ag	^{134}Cs	^{137}Cs
Terrestrial samples								
Milk	Near farms	3	<4.0	18	<0.53	<0.28	<0.26	<0.28
Milk	Near farms	max	<4.3	21	<0.63	<0.30	<0.28	<0.30
Milk	Far farms	3	<3.7	17	<0.49	<0.31	<0.29	<0.32
Milk	Far farms	max	<4.0	23	<0.50	<0.33	<0.30	<0.33
Apples		1	<3.0	13	0.50	<0.30	<0.20	<0.30
Blackberries		1	<4.0	18	2.6	<0.30	<0.30	<0.30
Cabbage		1	3.0	9.0	<0.60	<0.40	<0.30	<0.40
Carrots		1	<4.0	9.0	<0.40	<0.20	<0.20	<0.30
Honey		1	<6.0	57	0.40	<0.30	<0.30	<0.30
Potatoes		1	<4.0	14	<0.40	<0.20	<0.20	<0.30
Raspberries		1	4.0	13	1.4	<0.40	<0.40	<0.40
Runner beans		1	<4.0	<3.0	3.3	<0.20	<0.20	<0.30
Wheat		1	<5.0	110	1.2	<0.30	<0.30	<0.30

** not detected by the method used*

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

[b] 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 6.8(b). Monitoring of radiation dose rates near Sizewell nuclear power stations, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Southwold Harbour	Mud	1	0.055
Walberswick	Mud	1	0.062
Dunwich Beach	Sand and stones	1	0.044
Sizewell Beach	Sand	1	0.044
Thorpeness	Sand and stones	1	0.047
River Alde	Mud	1	0.065
Aldeburgh	Salt marsh	1	0.051
Aldeburgh	Sand	1	0.047
Aldeburgh	Sand and gravel	2	0.043
Orford	Mud and sand	1	0.049

Table 6.9(a). Radioactivity in food and the environment near Torness nuclear power station, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{54}Mn	^{60}Co	^{110m}Ag	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Aquatic samples										
Cod	Pipeline	1	<0.10	<0.10	<0.10	0.56	<0.10			<0.10
Cod	White Sands	1	<0.10	<0.10	<0.10	0.44	<0.11			<0.10
Crabs[b]	Cove	2	<0.10	<0.10	<0.10	0.15	<0.18			<0.11
Lobsters[c]	Cove	1	<0.10	<0.11	<0.10	0.17	<0.21			<0.11
Nephrops	Dunbar	3	<0.13	<0.13	<0.13	0.39	<0.24	0.00099	0.0061	0.0052
Winkles[d]	Pipeline	2	<0.10	<0.17	0.14	<0.29	<0.14			<0.10
Seaweed	Pipeline	2	<0.30	<0.27	<0.10	0.37	<0.14			<0.12
Seaweed	Thornton Loch Beach	2	0.77	0.32	<0.10	0.32	<0.14			<0.13
Seaweed	White Sands	2	<0.10	<0.10	<0.10	0.32	<0.14			<0.15
Sediment	Eyemouth	2	<0.10	<0.10	<0.10	2.7	0.49			0.32
Sediment	Dunbar Inner Harbour	2	<0.10	<0.10	<0.10	3.2	<0.47			<0.23
Sediment	Barns Ness	2	<0.10	<0.10	<0.10	2.5	0.78			<0.26
Sediment	Thornton Loch	2	<0.10	<0.10	<0.10	1.3	<0.32			<0.20
Sediment	Heckies Hole	1	<0.10	<0.10	<0.16	18	1.7			<0.37
Salt marsh	Belhaven Bay	2	<0.10	<0.10	<0.10	0.64	<0.24			<0.21
Seawater[e]	Pipeline	3	<0.10	<0.10	<0.10	<0.10	<0.10			<0.10

Material	Location or selection[f]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{110m}Ag	^{137}Cs	^{241}Am	Total alpha	Total beta
Terrestrial Samples												
Milk		1	<5.1	20	<2.0	<0.05	<0.10	<0.05	<0.05	<0.05		
Broccoli		1	19	23	<1.1	<0.05	1.3	<0.05	<0.05	<0.11		
Ground Elder		1	<5.0	38	4.3	<0.05	1.3	<0.05	0.28	<0.08		
Hawthorn Berries		1	10	51	<0.50	<0.05	4.5	<0.05	0.07	<0.12		
Leeks		1	<5.4	13	1.0	<0.05	0.36	<0.05	0.08	<0.11		
Nettles		1	<5.0	39	6.2	<0.05	1.6	<0.05	0.11	<0.08		
Parsnips		1	<5.3	20	<0.50	<0.05	0.22	<0.05	<0.05	<0.07		
Potatoes		1	<5.2	31	<0.50	<0.05	0.059	<0.05	<0.05	<0.06		
Rosebay willow herb		1	<5.0	24	0.60	<0.05	0.61	<0.05	<0.05	<0.09		
Grass		6	<8.3	47	<1.4	<0.05	0.50	<0.05	<0.08	<0.11	<0.28	160
Grass	max		12	69	2.6	<0.06	1.2	<0.06	0.16	<0.14	0.61	320
Soil[g]		6	<7.9	<19	<1.0	<0.05	1.1	<0.06	9.4	<0.42	100	0.92
Soil[g]	max		<12	24	<1.5		2.2	<0.07	17	0.84	220	1.5

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentrations of ^{14}C and ^{99}Tc were 34 and <2.1 Bq kg^{-1} respectively*
[c] *The concentration of ^{99}Tc was 42 Bq kg^{-1}*
[d] *The concentrations of alpha and beta activity were 7.5 and 110 Bq kg^{-1} respectively*
[e] *The concentration of ^{3}H was <1.4 Bq l^{-1}*
[f] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum*
[g] *The concentration of ^{155}Eu was 0.72 (max 0.96) Bq kg^{-1}*

Table 6.9(b). Monitoring of radiation dose rates near Torness nuclear power station, 2001

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over intertidal areas			
Heckies Hole	NA	1	0.072
Dunbar Inner Harbour	NA	2	0.075
Belhaven Bay	Salt marsh	2	<0.053
Barns Ness	NA	2	0.054
Skateraw	NA	1	0.064
Thornton Loch	NA	2	<0.054
St Abbs	NA	2	0.095
Eyemouth	NA	2	0.059
Beta dose rates on fishing gear			$\mu Sv\ h^{-1}$
Cove	Lobster Pots		<1.0
Dunbar Harbour	Nets		<1.0

NA Not available

Table 6.9(c). Radioactivity in air near Torness, 2001

Location	No. of sampling observa-tions	Mean radioactivity concentration, $mBq\ m^{-3}$		
		^{137}Cs	Total alpha	Total beta
Innerwick	8	<0.010	<0.0083	0.12
Cockburnspath	6	<0.011	<0.0073	0.099

Table 6.10(a). Radioactivity in food and the environment near Trawsfynydd nuclear power station, 2001

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Freshwater samples										
Brown trout	Lake	6		21	<0.15	7.3	<1.9	<0.59	<0.37	69
Rainbow trout	Lake	5			<0.12		<1.2	<0.27	<0.13	1.2
Perch[c]	Lake	4			<0.21	6.0	<2.5	<0.81	<0.58	100
Rudd	Lake	1			<0.09		<1.2	<0.50	0.70	110
Mud	Pipeline	2			46		<23	27	22	3500
Water	Bailey Bridge	1	<1.4							
Water	Cold Lagoon	2							*	0.01

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], 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	<0.44	<0.42	0.00038	0.0015	0.0029	0.000031
Rainbow trout	Lake	5	<0.37	<0.23			<0.22	
Perch[c]	Lake	4	<0.61	<0.47	0.000120	0.00037	0.00068	0.000023
Rudd	Lake	1	<0.29	<0.26			<0.14	
Mud	Pipeline	2	23	15			94	

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
Terrestrial Samples									
Milk	Near farms	1	<4.8	15		<0.30	0.048		
Milk	Far farms	1	<4.0	17		<0.30	0.058		
Blackberries		2	<3.5	15	<0.35	<0.40		<0.35	<0.35
Blackberries	max	2	<4.0		0.40	<0.50		<0.40	<0.40
Chicken		1	<5.0	30		<0.20	<0.024		
Eggs		1	<5.0	18	<1.5	<0.20		<0.30	<0.30
Hazelnuts		1	<6.0	19					7.8
Ovine muscle		2	<5.5	26		<0.35	<0.037		
Ovine muscle	max		6.0	29		<0.50	0.047		
Ovine offal		2	<6.5	35		<0.30	0.56		
Ovine offal	max		<7.0	39			0.97		
Potatoes		1	<4.0	24	0.60	<0.30		<0.30	<0.30
Runner beans		1	<4.0	<3.0	0.50	<0.30		<0.30	<0.30
Sloe berries		1	<3.0	34	<0.30	<0.20		<0.30	3.5

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}			
			Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples						
Milk	Near farms	1	0.17			
Milk	Far farms	1	0.16			
Blackberries		2		<0.00015	<0.00020	<0.00045
Blackberries	max	2		<0.00020		<0.00050
Chicken		1	0.70	0.0010	<0.00020	<0.00020
Eggs		1		<0.00020	<0.00010	<0.00020
Hazelnuts		1				
Ovine muscle		2	25	<0.00015	<0.00020	<0.00025
Ovine muscle	max		32	<0.00020		<0.00030
Ovine offal		2	2.2	<0.00020	<0.00030	0.00030
Ovine offal	max		2.5			
Potatoes		1		<0.00010	0.00030	<0.00020
Runner beans		1				
Sloe berries		1		<0.00020	0.00030	0.00030

** not detected by the method used*

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

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

[c] The concentration of ^{242}Cm was 0.000025 Bq kg^{-1}

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2001

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Gamma dose rates at 1 m over intertidal areas			
Footbridge	Rock	1	0.093
Nant Islyn Bay	Mud and stones	2	0.10
West of footbridge	Stones	1	0.10

Table 6.11(a). Radioactivity in food and the environment near Wylfa nuclear power station, 2001

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	19	<0.06		2.6			<0.13		
Brill	Red Wharf Bay	1		<25		<0.19	1.1	5.6			<0.14		
Anglerfish	Red Wharf Bay	1		<25		<0.09	0.35	0.56			<0.07		
Grey mullet	Red Wharf Bay	1				<0.06		2.6			<0.15		
Tub gurnard	Red Wharf Bay	1		<25		<0.13	1.8	4.5			<0.30		
Conger eel	Red Wharf Bay	1				<0.05		0.41			<0.14		
Crabs	Pipeline	2				<0.12	7.9	0.45	0.0055	0.027	0.10	0.00022	
Green crabs	Menai Straits	1				<0.16		0.60			<0.13		
Lobsters	Pipeline	2				<0.06	160	0.53			<0.12		150
Winkles[b]	Cemaes Bay	2	<25	<25	12	<0.07		0.30	0.014	0.083	0.12	0.00013	
Dog whelks[c]	Red Wharf Bay	1		<25		<0.05	8.5	0.29	0.018	0.099	0.11	0.00021	
Squid	Red Wharf Bay	1				<0.12		0.40			<0.09		
Fucus vesiculosus	Cemaes Bay	2				<0.09	110	0.37			<0.08		180

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	^{137}Cs
Terrestrial samples							
Milk	Near farms[e]	5	<3.9	18	<0.61	<0.27	<0.31
Milk	Near farms[e]	max	<4.0	21	<0.73	<0.30	<0.35
Apples		1	<4.0	14	<0.20	<0.30	<0.30
Blackberries		1	<4.0	16	0.50	<0.30	<0.30
Broad beans		1	<4.0	26	0.90	<0.30	<0.30
Cabbage		1	<4.0	<2.0	0.80	<0.30	<0.40
Carrots		1	<4.0	3.0	<0.20	<0.40	<0.40
Honey		1	<6.0	110	<0.20	<0.20	<0.20
Kale		1	4.0	6.0	0.30	<0.40	<0.40
Potatoes		1	<4.0	11	0.30	<0.20	<0.30
Swede		1	<3.0	10	0.50	<0.20	<0.40
Wheat		1	<6.0	94	2.3	<0.40	<0.40

[a] *Except for milk and seawater where units are Bq l^{-1}*
[b] *The concentration of ^{241}Pu was 2.3 Bq kg^{-1}*
[c] *The concentration of ^{242}Cm was 0.00027 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 'far' farms producing milk near this site.*

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2001

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

7. DEFENCE ESTABLISHMENTS

Surveillance by the Food Standards Agency and SEPA is undertaken routinely 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 a revised authorisation from 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 (DSTL, 2002**).** 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 2001 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 2001.

Special sampling was undertaken at Featherstone in Staffordshire in 2001 in relation to earlier fires at the munitions factory. The results are discussed in Section 7.7.

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. 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 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 2000. The most likely source of the radionuclides detected was natural background or weapon test fallout. The dose to consumers of local food in 2001, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

7.2 Devonport, Devon

Discharges of liquid radioactive waste are made by Devonport Royal Dockyard Ltd. (DML) under authorisation and the Ministry of Defence under administrative agreement into the Tamar Estuary. The DML authorisations have been revised (DEFRA and DoH, 2002) and a new authorisation took effect on 13 March 2002. The monitoring programme in 2001 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 2000 where comparisons can be drawn. However, no tritium activity was detected in grass and green crabs from the River Lyner as had been the case in 2000. 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 less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. The radiological significance of this, in common with other defence establishments, continued to be low.

7.3 Faslane and Coulport, Argyll and Bute

The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport.

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the Ministry of Defence. The discharges made during 2001 are shown in Appendix 1. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the Ministry of Defence. No disposals of solid waste were made from either site during 2001. This was due to the general embargo imposed by BNFL on the MOD(N) waste.

Habit surveys have been used to investigate exposure pathways. The most recent of which, conducted in 2000, identified fish consumption and external radiation from the shore as the major pathways of exposure. The scope of the monitoring programme reflects these pathways and included the analysis of seawater, sediment and fish samples. Results are shown in Tables 7.2(a) and (b). These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield and weapons testing and Chernobyl fallout. Additionally, measurements of gamma dose rates made in the surrounding area were difficult to distinguish from natural background. Taking into account occupancy and consumption rate data from the 2000 habit survey, the dose to the 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 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 and concentrations of caesium-137 were higher than in 2000 (Tables 7.2(a) and (b)). However, the external radiation dose to the most exposed group was 0.016 mSv in 2001 which was less than 2% of the dose limit for members of the public of 1 mSv.

7.5 Rosyth, Fife

Nuclear powered submarine refitting work at Rosyth Royal Dockyard continued throughout 2001 giving rise to the discharge of small quantities of liquid radioactive waste into the Forth Estuary. The discharges remained well within the authorised limits. There were no reported discharges of gaseous radioactive waste and no disposals of low level solid waste as the embargo placed by BNFL on MOD(N) remained in force.

In August 2001, SEPA served an Enforcement Notice on the company due to the failure to maintain adequately and keep in good repair the Low Active Effluent Discharge line. The company took adequate steps to comply with the notice.

In November 2001, the company notified SEPA of an unauthorised discharge of reactor coolant from HMS Spartan. A valve had failed under pressure allowing coolant to pass into the base entrance lock. The submarine had recently undergone a refit and consequently the coolant was relatively new and only mildly contaminated. The exact quantity discharged is not known but environmental monitoring supported the belief that the quantity of radioactive waste discharged was small. It is estimated that less than 17 MBq of tritium and 50 kBq of cobalt-60 had been discharged into the entrance lock. The design of the valve and pipework is believed to be the primary cause of the leak and the Ministry of Defence has instigated a programme of modification to prevent a re-occurrence of this incident. No enforcement action was taken against the company.

Sampling of resin wastes stored at the dockyard verified the existence of carbon-14 in gaseous form. This radionuclide had not previously been identified as a gaseous waste although a recent theoretical study predicted its production. Quantities are believed to be small, however, SEPA has asked the company to consider the implications of the findings.

Due to the construction of a new passenger ferry terminal adjacent to the dockyard, one environmental monitoring point is no longer accessible. The company has explored alternative locations and has identified a suitable replacement sampling point.

Following a report that cobalt-60 contamination had been observed in sediment taken from an area of shoreline below the Middle Jetty, samples were taken for analysis. This analysis did confirm the existence of the contamination but at very low levels (up to 10 Bq kg^{-1}), in an area not normally accessed by members of the public. Nonetheless SEPA intends to keep the situation under review.

The routine SEPA monitoring programme included sampling and analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 7.2(a) and 7.2(b). The radioactivity levels detected were low, and in most part due to the 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 2001 was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

7.6 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.

7.7 Featherstone, Staffordshire

The Royal Ordnance Factory at Featherstone manufactures munitions. Depleted uranium is used in some products. In the last four years, there have been two fires at the site, the most significant being in February 1999. At that time sampling of food-related samples was not thought to be necessary, as monitoring of smoke from the fire did not indicate that any radioactivity had been discharged. However, estimates of the amount of depleted uranium in the fire of approximately 3 GBq (250 kg) have now been made and sampling was undertaken in 2001 to confirm the initial findings.

Samples of grass and soil were taken from two locations near the site and analysed for uranium isotopes. The sample locations were chosen to be at points of peak deposition as calculated by an atmospheric dispersion model. The results are given in Table 7.3.

The concentrations of uranium isotopes are low and the isotopic ratios are those expected for uranium of natural origin. There is no evidence that depleted uranium (with a $^{234}U/^{238}U$ ratio of significantly less than 1) was present in the deposition from the fires.

Table 7.1. Radioactivity in food and the environment near Aldermaston, 2001

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	<25	<25	<0.03	<0.04	0.000026	0.000072	0.00035	
Pike	Outfall (Pangbourne)	1	<25	<25	<0.04	0.36	0.000076	0.00038	0.00048	
Pike	Staines	1	<25	<25	<0.05	0.21			<0.12	
Pike	Shepperton	1	<25	<25	<0.05	0.16			<0.18	
Pike	Teddington	1	<25	<25	<0.03	0.27			<0.15	
Flounder	Beckton	1		<25	<0.05	0.23			<0.14	
Nuphar lutea	Newbridge	1		<25	<0.03	0.05			<0.04	
Nuphar lutea	Staines	1		<25	0.05	0.19			<0.05	
Clay	Outfall (Pangbourne)	1			<0.23	4.1			<1.0	400

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	<5.1	<0.28	<0.0071	<0.00011	<0.00010	<0.00019
Milk	Near farms max		<8.0	<0.33	<0.0078	<0.00013		<0.00023
Apples		1	<3.0	<0.30	<0.036	0.00010	<0.00020	<0.00030
Carrots[c]		1	<4.0	<0.30	0.096	<0.00020	0.00020	<0.00030
Honey		1	<6.0	<0.20	<0.036	<0.00020	<0.00020	<0.00020
Plums		1	<4.0	<0.30	<0.034	<0.00030	<0.00030	<0.00040
Potatoes		1	<4.0	<0.30	0.046	0.00010	0.00020	0.00020
Rabbit		1	7.0	<0.30	<0.035	<0.00030	<0.00020	<0.00040
Runner beans		1	<4.0	<0.40	<0.034	<0.00010	<0.00020	<0.00030
Spinach		1	<4.0	<0.30	0.037	<0.00010	0.00010	<0.00030
Wheat		1	<6.0	<0.30	0.045	<0.00030	<0.00030	<0.00040
Soil					50			
Soil[d]	max				66			

* *Not detected by the method used*

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

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

[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.024, 0.0011 and 0.021 Bq kg^{-1} respectively*

[d] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 12, 0.46 and 11 Bq kg^{-1} respectively*

Table 7.2(a). Radioactivity in food and the environment near naval establishments, 2001

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{60}Co	^{110m}Ag	^{125}Sb	^{131}I	^{137}Cs	^{155}Eu	^{241}Am
Barrow											
Grass	Barrow	2		<4.5							
Grass	max			<5.0							
Devonport											
Spurdog	Plymouth Sound	1			<0.13	<0.26	<0.28	*	0.25	<0.19	<0.09
Crabs[c]	Plymouth Sound	1			<0.17	<0.31	<0.40	*	<0.16	<0.26	<0.13
Green crabs	River Lynher	1	<25	<25	<0.07	<0.17	<0.17	*	<0.07	<0.18	<0.22
Mussels	River Lynher	1	<25	<25	<0.14	<0.26	<0.31	*	<0.12	<0.20	<0.10
Oysters	River Lynher	1	<25	<25	<0.03	<0.06	<0.07	*	<0.03	<0.07	<0.07
Fucus vesiculosus[d]	Kinterbury	2			<0.07	<0.12	<0.13	*	<0.08	<0.17	<0.24
Mud[e]	Kinterbury	2			<0.25	<0.49	<0.61	*	2.8	2.0	0.092
Grass	Devonport	4		<4.0	<0.50				<0.48		
Grass	max				<0.60				<0.50		
Faslane											
Fish	Carnban boatyard	2			<0.10	<0.10	<0.10		<0.56	<0.12	<0.11
Sediment	Carnban boatyard	2			<0.19	<0.18	<0.23		11	0.75	<0.37
Seawater	Carnban boatyard	1		2.3							
Holy Loch											
Sediment	Mid Loch	1			0.19	<0.13	0.28		16	0.62	0.73
Rosyth											
Crabs	East of dockyard	2			<0.10	<0.10	<0.21		<0.29	<0.19	<0.11
Seaweed	East of dockyard	2			<0.10	<0.10	<0.12	1.5	0.25	<0.16	<0.18
Sediment	East of dockyard	2			<0.10	<0.10	<0.13		2.6	<0.29	<0.18
Sediment	Port Edgar	2			<0.10	<0.11	<0.26		29	<0.67	<1.3
Sediment	West of dockyard	2			<0.10	<0.10	<0.18		7.2	0.74	0.67
Sediment	Blackness Castle	1			<0.10	<0.11	<0.22		12	1.5	1.1
Sediment	Burntisland Bay	2			<0.10	<0.10	<0.11		0.64	<0.24	<0.14
Seawater	East of dockyard	1		<1.0							

* *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 5.0 Bq kg^{-1}*
[e] *The concentrations of ^{238}Pu, $^{239+240}Pu$, ^{242}Cm and $^{243+244}Cm$ were 0.011, 0.23, 0.0016 and 0.0017 Bq kg^{-1} respectively*

Table 7.2(b). Monitoring of radiation dose rates near naval establishments, 2001

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	0.072
Faslane	Gareloch Head	Mud, sand and stones	2	<0.052
Faslane	Gulley Bridge Pier	Sand and stones	2	0.052
Faslane	Rhu	Gravel	2	<0.061
Faslane	Rosneath	Sand and gravel	2	<0.059
Faslane	Carnban boatyard	Mud and sand	2	0.061
Holy Loch	North Sandbank	Mud and sand	1	0.082
Holy Loch	Kilmun Pier	Sand and stones	1	0.079
Holy Loch	Mid-Loch	Sand	1	0.062
Rosyth	Blackness Castle	Mud and sand	2	<0.048
Rosyth	Burntisland Bay	Sand	2	<0.047
Rosyth	East of Dockyard	Sand	2	<0.047
Rosyth	Port Edgar	Mud	2	0.051
Rosyth	West of Dockyard	Mud and sand	2	0.057

Table 7.3. Radioactivity in the environment near Featherstone, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1}		
			^{234}U	^{235}U	^{238}U
Grass[a]	Position A	1	0.51	0.024	0.50
Grass[a]	Position B	1	0.13	0.0080	0.14
Soil[b]	Position A	1	9.5	0.41	9.0
Soil[b]	Position B	1	7.3	0.34	7.5

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

8. AMERSHAM PLC

This company manufactures radioactively labelled materials for use in medicine, research and industry. The company's principal establishment is located in Amersham, Buckinghamshire and it also operates from Cardiff and on the Harwell site. The environmental effects of the Harwell facility are covered by general surveillance of the Harwell site (Section 5). From July 2001, the company changed its name from Nycomed Amersham plc to Amersham plc.

8.1 Amersham, Buckinghamshire[1]

Discharges of liquid radioactive wastes are made under authorisation to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Discharges of gaseous wastes are also authorised. The routine monitoring programme consists of analysis of fish, milk, crops 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. Supplementary monitoring of grass was undertaken in 2001 to investigate an overflow of Amersham's sewage discharges into the river Misbourne in winter 2000/2001.

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. Cobalt-57 was enhanced in mud close to the outfall but its levels were very low. Tritium concentrations in biota in the Thames and the Grand Union Canal were at the limit of detection.

The activity concentrations in milk and crops were generally lower than the limits of detection. However, low levels of tritium and sulphur-35 were detected in a few samples. Very low levels of activity were detected in grass taken from the area near the River Misbourne. There were no food safety concerns from the consumption of milk and beef from cattle grazing local fields after the overflow incident.

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 2001 was less than 0.005 mSv which was less than 0.5% of the 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 dose limit for members of the public.

8.2 Cardiff, South Glamorgan[2]

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

Routine monitoring, carried out on behalf of the Welsh Assembly Government 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 and grass provide additional

[1] *now renamed the Grove Centre*
[2] *now renamed the Maynard Centre*

information. Earlier monitoring and research has targeted organic tritium in foodstuffs (Food Standards Agency, 2001d, Swift, 2001, Leonard *et al*., 2001b and McCubbin *et al*., 2001a). This supplementary monitoring undertaken in 2000 was not repeated in 2001 and subsequently fewer samples have been analysed in 2001.

The results of both routine and supplementary monitoring in 2001 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 relatively high levels of total tritium in some local fish observed in 2000 were no longer detected in 2001 (Figure 8.1). The observations for 2000 could have been due to environmental variability or to changes in the nature of the discharge. There is no strong correlation with the overall discharge of tritium. The results of sample analyses show that over 90% of the total tritium was organically bound and the estimates of dose for members of the public take this into account. The trend in concentrations of carbon-14 in seafood is shown in Figure 8.2.

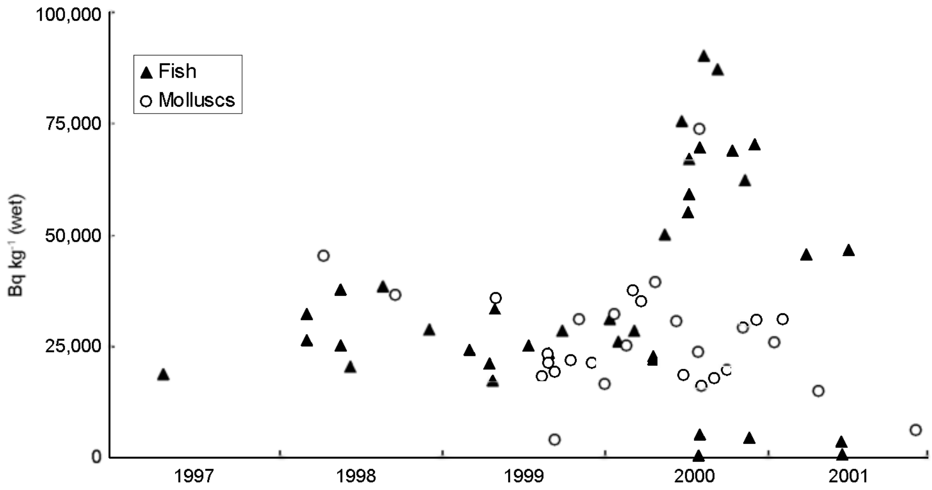

Figure 8.1 Tritium concentrations in fish and molluscs from Cardiff

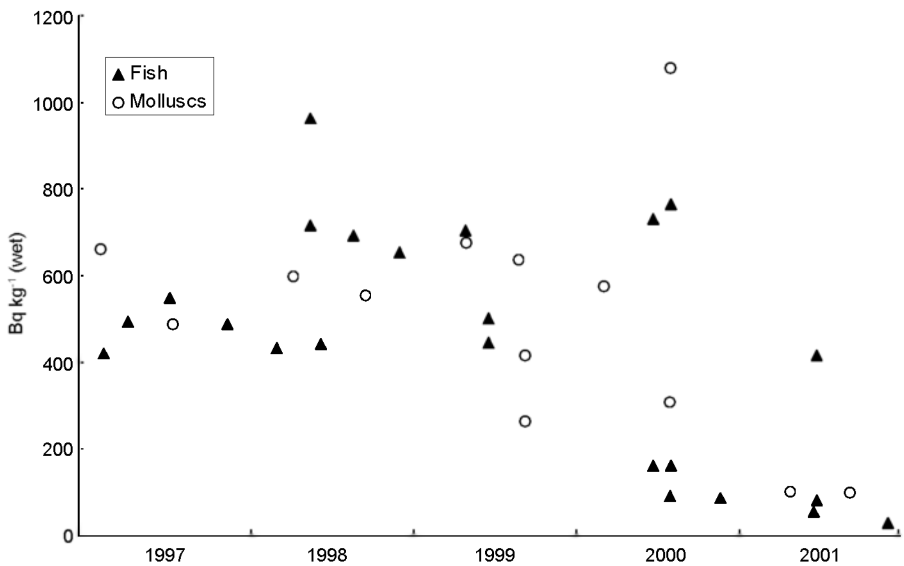

Figure 8.2 Carbon-14 concentrations in fish and molluscs from Cardiff

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 largely be explained by other sources such as Chernobyl and weapon test fallout and discharges from other establishments. Gamma and beta dose rates over sediment, as measured using portable instruments, were difficult to distinguish from those expected from the natural background. The dose to the most exposed group of fish and shellfish consumers based on the current ICRP recommended dose coefficient for organic tritium was 0.036 mSv which was less than 4% of the dose limit for members of the public of 1 mSv. This estimate includes a contribution due to external radiation. The dose in 2000 was 0.064 mSv. The apparent reduction in dose was largely due to a reduction in tritium in one species, sole. This observation is based on very few measurements and is not indicative of a generalised reduction in concentrations of tritium in seafood.

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 0.014 mSv which was less than 2% of the dose limit for members of the public of 1 mSv. The largest contribution was from carbon-14 in milk.

8. Amersham plc

Table 8.1. Radioactivity in food and the environment near Amersham, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{57}Co	^{137}Cs	$^{239}Pu+^{238}Pu$	^{240}Pu	^{241}Am
Aquatic samples										
Pike	Newbridge	1	<25	<25		<0.03	<0.04	0.000026	0.000072	0.00035
Pike	Outfall (Grand Union Canal)	1	<25	<25	19	0.04	0.26			<0.04
Pike	Staines	1	<25	<25		<0.05	0.21			<0.12
Pike	Shepperton	1	<25	<25		<0.05	0.16			<0.18
Pike	Teddington	1	<25	<25		<0.03	0.27			<0.15
Flounder	Beckton	1		<25		<0.05	0.23			<0.14
Nuphar lutea	Newbridge	1		<25		<0.03	0.05			<0.04
Nuphar lutea	Outfall (Grand Union Canal)	1		<25		<0.03	0.13			<0.04
Nuphar lutea	Staines	1		<25		0.05	0.19			<0.05
Mud[b]	Outfall (Grand Union Canal)	1				<0.29	21			<0.91

Material	Location or selection[c]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{57}Co	^{75}Se	^{125}I	^{131}I	^{137}Cs
Terrestrial samples									
Milk	Near farms	1	<4.0	<0.43		<0.30	<0.033	<0.025	<0.25
Milk	Far farms	1	<4.0	<0.50		<0.33	<0.038		<0.30
Apples		1	<4.0	0.80		<0.30	<0.064		<0.30
Beetroot		1	<4.0	0.30		<0.20	<0.12		<0.30
Blackberries		1	11	<0.40		<0.30	<0.17		<0.30
Courgettes		1	9.0	<0.40		<0.30	<0.078		<0.30
Plums		1	<3.0	<0.40		<0.20	<0.079		<0.30
Raspberries		1	8.0	<0.40		<0.30	<0.077		<0.30
Runner beans		1	8.0	0.80		<0.20	<0.080		<0.30
Spinach		1	<4.0	0.50		<0.30	<0.16		<0.30
Wheat		1	10	<0.80		<0.30	<0.23		<0.30
Grass[d]		7			<1.0	<1.3			<1.2
Grass[d]	max				1.7	<2.1			2.2

[a] *Except for milk where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *The concentration of beta activity was 460 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] *Taken as part of special investigations*

Table 8.2(a). Radioactivity in food and the environment near Cardiff, 2001

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am
Aquatic samples									
Flounder	East of new pipeline	2		46000	420	<0.05	0.23	<0.13	<0.29
Sole	East of new pipeline	1		3700	82	<0.04	0.21	<0.11	<0.10
Cod	East of new pipeline	1		6100	29	0.09	0.67	<0.10	<0.06
Mullet	East of new pipeline	1		720	57	<0.18	<0.17	<0.25	<0.13
Mussels	Orchard Ledges	3	25000	24000	100	<0.12	0.33	<0.20	<0.21
Winkles	Orchard Ledges	1			98	<0.06	0.25	<0.13	<0.08
Fucus vesiculosus	Orchard Ledges	2	650	640	7.3	<0.10	0.56	<0.22	<0.21
Mud	Orchard Ledges East	2	700	520	22	<0.47	15	<1.2	<1.9
Mud, sand and stones	Orchard Ledges East	1			12	<0.44	8.5	3.1	<1.3
Sea water	Orchard Ledges	2		4.8					
Sea water	Orchard Ledges East	2		6.0					

Material	Location or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
				Organic ^{3}H	^{3}H	^{14}C	^{35}S	^{125}I	^{134}Cs	^{137}Cs
Terrestrial samples										
Milk	Near farms[c]		5	<11	<25	20	<0.55	<0.034	<0.28	<0.29
Milk	Near farms[c]	max		20	57	25	<0.75	<0.040	<0.30	<0.30
Milk	Far farms		2	<4.1	<5.5	16	<0.53	<0.035	<0.28	<0.33
Milk	Far farms	max		<4.5		17	<0.58		<0.30	
Blackberries			1	51	230	33	<0.30	<0.11	<0.30	<0.30
Honey			1		23	95	<0.20	<0.030	<0.20	<0.20
Potatoes			1	4.0	7.0	28	1.0	<0.091	<0.20	<0.30
Rape oil			1		11	86	<0.70	<0.11	<0.40	<0.40
Raspberries			1	13	130	19	<0.40	<0.12	<0.30	<0.30
Runner beans			1	<23	190	13	0.50	<0.10	<0.30	<0.30
Wheat			1		10	85	0.90	<0.10	<0.30	<0.40
Grass			5	50	260	58			<0.30	<0.37
Grass	max			130	440	60				<0.40
Soil			3						<0.33	5.6
Soil	max								<0.40	6.5

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum.*
[c] *The concentration of ^{32}P was <0.34 Bq l^{-1} and the maximum was 0.40 Bq l^{-1}*

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 2001

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Gamma dose rates at 1m over intertidal areas			
Orchard Ledges East	Mud	2	0.076
Beta dose rates			µSv h^{-1}
Orchard Ledges East	Mud	2	<0.022

9. MINOR SITES

Four minor sites with very low levels of discharge are monitored using a small sampling programme of indicator materials. The results, given in the following sections, show that there was no detected impact on the environment in 2001 due to operation of these sites.

9.1 Imperial College Reactor Centre, Ascot, Berkshire

Two grass samples were analysed by gamma-ray spectrometry. All results in 2001 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 2001 were less than the limits of detection.

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

Results of monitoring at Derby are presented in Table 9.1. Routine sampling and analysis of uranium activity in grass and soil samples associated with gaseous releases showed similar levels to 2000. 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.

Rolls Royce also operates a low level solid waste disposal site at Hilts Quarry in Crich, Derbyshire. Cobalt-60 was reported as being present in stream water and other samples collected as part of the operator's environmental monitoring programme. As part of a special investigation, the Food Standards Agency took samples of food and indicator materials from various locations throughout the village linked to watercourses, including an area known to have been flooded by the stream. The results are also presented in Table 9.1. No cobalt-60, or any other fission-products, were detected in any of the samples except small quantities of Cs-137 in one grass sample at levels consistent with expected deposition from the Chernobyl accident. Uranium isotopic ratios were typical of natural sources. Subsequently the operator's contract laboratory was found to have cross-contaminated samples and the initial findings of the presence of cobalt-60 were inaccurate.

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, 2001

Material		No. of samples	Mean radioactivity concentration, Bq kg^{-1}				
			^{60}Co	^{232}Th	^{234}U	^{235}U	^{238}U
Grass[a]		4			0.049	<0.0020	0.046
Grass[a]	max				0.057	0.0024	0.049
Soil[b]		4			18	0.80	18
Soil[b]	max				30	1.3	29
Broccoli[a,c]		1	<0.20	0.023	0.020	0.0015	0.020
Cabbage[a,c]		1	<0.20	0.011	0.0089	0.0011	0.011
Grass[a,c]		5	<0.58	0.085	0.089	0.0045	0.093
Grass[a,c]	max		<0.90	0.18	0.18	0.0086	0.18
Herbage[a,c]		2	<0.35	0.051	0.053	0.0021	0.052
Herbage[a,c]	max		<0.40	0.072	0.073	0.0029	0.074

[a] *Fresh weight*
[b] *Dry weight*
[c] *Taken as part of special investigations*

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 2001 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 2001 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 (Young *et al.*, 2002; see also Appendix 6).

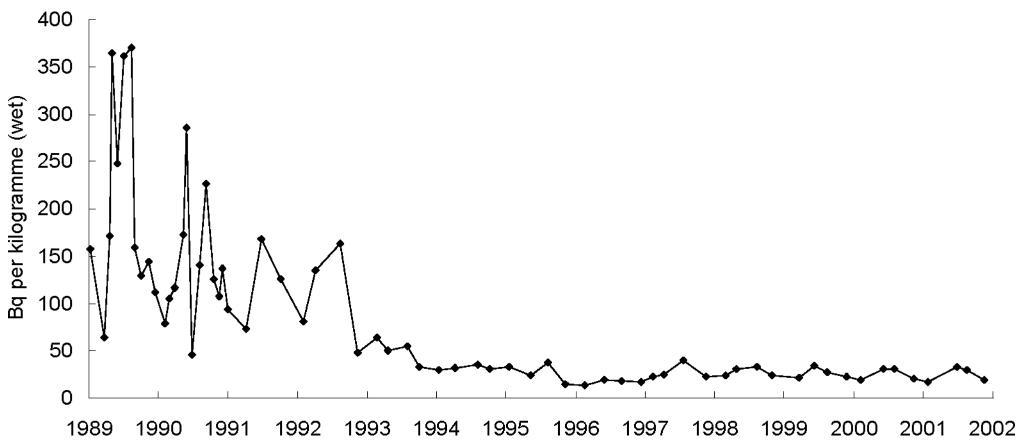

Figure 10.1 Polonium-210 in parton winkles

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 similar to those in 2000 (Food Standards Agency and SEPA, 2001) though there was a reduction in polonium-210 in crabs from Parton (2001: 16 Bq kg^{-1}; 2000: 26 Bq kg^{-1}). Following completion of a research study (Young *et al.*, 2002), estimates of background concentrations of natural radionuclides have been revised (Appendix 6). Taking into account the ranges of values observed, it is difficult to distinguish the measured total concentrations from those expected due to natural sources. However, there were small enhancements for some radionuclides and marine species, and it is these that form the basis of the dose assessment.

The critical radiation exposure pathway is internal irradiation, due to the ingestion of natural radioactivity in local fish and shellfish. Two groups of consumers are considered in this report. A group local to the discharge point who consume seafood collected from Saltom Bay and Parton are assessed in this Section. Another group, close to the discharge point from Sellafield to the south of Whitehaven, is covered in Section 4. Both groups are distinct from that associated with commercial fisheries at Whitehaven (Section 4). In both assessments, an estimated contribution due to background levels of natural radionuclides has been subtracted. Consumption rates of the Saltom Bay/Parton group were reviewed in 2001 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 Saltom Bay/Parton group dose fell from 0.42 mSv in 2000 (Food Standards Agency and SEPA, 2001) to 0.19 mSv in 2001. The fall was due to reduced concentrations of polonium-210 in crabs from Parton.

The fish and shellfish consumed also contained artificial radionuclides due to Sellafield discharges. The additional exposure due to artificial radionuclides has been calculated using data from Section 4. In 2001, these exposures added a further 0.057 mSv to the doses above resulting in a total dose to this group of up to 0.25 mSv. The total dose to the nearby Sellafield group of fish and shellfish consumers was 0.58 mSv. It was this group that was the most exposed in 2001. The estimated doses in 2001 are therefore well within the dose limit for members of the public of 1 mSv.

10.2 Other industrial sites

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

In 2001, SEPA repeated monitoring undertaken in 1998 (MAFF and SEPA, 1999) which involved the sampling of marine sediments from Aberdeen Bay. Samples were analysed for polonium-210, lead-210 and radium-226 and the results are given in Table 10.1. No enhancement in concentrations above those expected due to natural sources was found.

Levels of radionuclides in gaseous discharges from some other industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and waste incineration. Since 1991, a small rolling programme to examine the effects of these activities has been carried out. In 2001, six sites were chosen for study:

- Cambridge, Cambridgeshire (pharmaceuticals)
- Alconbury, Cambridgeshire (biological research)
- Immingham, North Lincolnshire (oil refinery)
- Langford, North Somerset (veterinary research)
- Weldon, Northamptonshire (tritium lighting manufacture)
- Wrexham, Wrexham County Borough (waste incineration services)

Following local concern unconnected with any specific industrial activity, samples were also obtained from a seventh location in Reading. The site at Alconbury has previously disposed of sewage sludge from its on-site operations to land. The sewage sludge is known to contain carbon-14. Blackberries and potatoes were obtained from fields known to have received sludge disposals and analysed for tritium and carbon-14. The results of the sampling of vegetables, grass, soil, indicator materials and animals in 2001 are given in Table 10.2 for all seven sites.

There is considerable variability in the concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the possible effects of man-made sources or enhancements of natural radionuclides. With this proviso, we conclude that in 2001 the concentration of natural radionuclides observed were within the ranges expected for natural sources. The concentrations of man-made radionuclides in samples were all low and of negligible radiological significance. Estimated doses from consumption of rabbit and apples sampled near the sites were all less than 0.005 mSv.

10.3 Landfill sites

Some organisations are authorised by SEPA in Scotland or the Environment Agency in England and Wales to dispose of solid wastes containing very low levels of radioactivity to approved landfill sites. Waste with very limited radioactivity can also be disposed of in general refuse. Radioactivity in wastes can migrate into leachate and in some cases can enter the groundwater. Monitoring of leachates in England and Wales is carried out by the Environment Agency (Environment Agency, 2002). 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. 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 0.002 mSv which was 0.2% of the dose limit for members of the public of 1 mSv.

In view of concerns raised about sheep grazing a former landfill site at Cefn-Bryn-Brain, Carmarthenshire, a small survey of grass samples was carried out to confirm that the site did not pose a radiological risk. Particular attention was paid to monitoring of radium-226, since a previous assessment by Carmarthenshire County Council had indicated the possibility of enhanced levels of this radionuclide. The results are shown in Table 10.4. There is no evidence for enhanced levels of natural radionuclides or unexpected levels of man-made radionuclides in the grass samples taken.

Table 10.1. Natural radioactivity in fish, shellfish and sediment, 2001

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	2	21	1.9							
Winkles	Parton	4	25	3.6	0.11	0.64	0.97	0.43	2.7	0.087	2.4
Winkles	North Harrington	1	32								
Winkles	Nethertown	4	23	4.9							
Winkles	Drigg	1				0.49	0.66	0.33			
Winkles	Tarn Bay	1	11								
Winkles	Ravenglass	1	25	2.6							
Mussels	Parton	2	51	3.5							
Mussels	Nethertown	4	45	4.0							
Limpets	St Bees	2	18								
Limpets	Tarn Bay	1	9.8	3.3							
Cockles	Ravenglass	2	21								
Whelks	Sellafield offshore area	2	4.4								
Crabs	Parton	4	16	0.15		0.12	0.024	0.016	0.056	0.0014	0.049
Crabs	Sellafield coastal area	4	10	0.75							
Lobsters	Parton	4	15	0.18		0.035	0.017	0.0072	0.027	0.00050	0.026
Lobsters	Sellafield coastal area	4	14	0.030							
Cod	Parton	2	0.87	0.060		0.019	0.0059	0.0028	0.010	0.00020	0.0084
Flounder	Whitehaven	1	3.2								
Scotoil, Aberdeen											
Sediment[b]	Aberdeen Harbour	3	8.0	7.8	<18						
Other samples											
Winkles	Bradwell	1	10	1.7							
Winkles	Cemaes Bay	1	21	1.2							
Winkles	Plymouth	1	8.7	2.0							
Winkles	Kirkcudbright	1		<1.1							
Mussels	Bradwell	1	38	0.68							
Mussels	Carbis Bay	1	46	5.9							
Mussels	Conwy	1	49	2.2							
Mussels	Ribble Estuary	1			0.024	0.38	0.57	0.17			
Mussels	Plymouth	1	33	6.8							
Mussels	The Wash	1	36	1.8							
Mussels	River Alde	1	42	1.7							
Mussels	Isle of Sheppey	1	33	0.93							
Cockles	Southern North Sea	2				0.43	0.24	0.31			
Cockles	The Wash	1	24	0.93							
Cockles	Dee Estuary	1	29	1.0							
Cockles	Middleton Sands	1	19	1.3							
Cockles	Ribble Estuary	1			0.012	0.32	0.37	0.14			
Cockles	Poole Bay	1	27	0.94							
Cockles	Flookburgh	2	16								
Whelks	Bradwell	1	3.1	0.38							
Whelks	Dungeness	1	7.6	0.39							
Whelks	Dunwich	1	9.0	0.61							
Whelks	Poole Bay	1	9.7	0.41							
Whelks	Weymouth Bay	1	11	0.18							
Whelks	Fleetwood	1	1.2								
Limpets	Lavernock Point	1	15	4.9							
Limpets	Lowestoft	1	13	2.5							
Limpets	Kirkcudbright	1	11								
Crabs	Chapman's Pool	1	19	0.23							
Crabs	Conwy	1	35	0.76							
Crabs	Cromer	1	8.6	0.69							
Crabs	Hastings	1	19	0.18							
Crabs	Padstow	1	15	0.56							
Crabs	Torness	1	4.1	0.12							
Crabs	Kirkcudbright	1		<0.97							
Lobsters	Plymouth	1	9.6	0.060							
Lobsters	Alderney	1	10	0.79							
Lobsters	Kilkeel	1	3.1	0.020							
Lobsters	Kirkcudbright	2	5.9	<0.29							
Shrimps	Ribble Estuary	2			0.045	0.0099	0.014	0.0044			
Shrimps	Dungeness	1	19	0.28							
Shrimps	Bognor Rocks	1	1.7	0.050							
Shrimps	Hinkley	1	7.3	0.31							
Shrimps	The Wash	1	30	0.060							
Shrimps	Cardigan Bay	1	5.9	0.050							
Shrimps	Lowestoft	1	17	0.080							

[a] *Except for sediment where dry concentrations apply*
[b] *The concentration of ^{228}Ac was <9.6 Bq kg^{-1}*

Table 10.2 Radioactivity in food and the environment near industrial sites, 2001

Site	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{3}H	^{7}Be	^{14}C	^{32}P	^{33}P	^{35}S	^{40}K	^{82}Br	^{90}Sr	^{99m}Tc	^{125}I	^{131}I
Alconbury,	Grass	4	<2.8	47	53	<0.28	<0.45	2.0	200	<0.53	0.27	<15	<0.012	<0.30
Cambridgeshire	Soil	4		<2.0	16			<2.2	530		1.0			
	Rabbit	1	7.7	<0.90	20	<0.50	<0.50	<1.0	86	<2.9	<0.20		<0.057	<0.18
	Blackberries[b]	1	<4.0		15									
	Potatoes[b]	1	<4.0		23									
Cambridge,	Grass	4	<3.2	47	45	<0.20	<0.48	2.5	190	<0.55	<0.15	<2.7	<0.021	<0.34
Cambridgeshire	Soil	4		<2.8	19			<4.0	220		1.4			
	Rabbit	1	3.4	<0.80	60	<1.0	<1.0	<1.0	100	<0.75	<0.10		<0.068	<0.14
Langford,	Grass	4	<4.8	75	43	<0.53	<1.2	1.6	200	<0.45	0.84	<1.9	<0.011	<0.29
North Somerset	Soil	4		<2.0	23			<1.3	670		2.2			
	Rabbit	1	13	<1.0	<50	<2.0	<2.0	<0.30	100		<0.20		<0.046	<2.3
Immingham,	Grass	4	<3.6	43	53	<0.38	<0.23	<0.43	220	<0.50	0.27	<13	<0.028	<0.28
North Lincolnshire	Soil	4		<3.5	<24			<1.6	620		1.6			
	Rabbit	1	3.9	<0.80	40	<1.0	<1.0	<1.0	90	<0.19	<0.20		<0.056	<0.11
Wrexham,	Grass	4	<4.1	22	25	<0.90	<0.42	<0.78	140	<0.38	<0.13	<10	<0.018	<0.19
Wrexham County	Soil	4		<2.0	<21			<5.2	380		1.7			
Borough	Rabbit	1	7.8	<0.80	30			<0.80	75	<0.28	<0.090		<0.043	<0.12
Weldon,	Grass	4	<9.2	19	30	<0.18	<0.48	1.9	150	<0.38	<0.11	<13	<0.021	<0.23
Northamptonshire	Soil	4		<2.5	<19			<1.7	420		<8.0			
	Rabbit	1	5.3	<0.80	50	<0.60	1.2	<1.0	76	<0.43	<0.10		<0.049	<0.13
Reading,	Apples[c]	1												<0.40
Berkshire	Mint[d]	1												<4.0

Site	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Alconbury,	Grass	4	<0.18	<0.20	2.0	1.3	0.13	0.040	<0.00027	<0.00080	<0.0019
Cambridgeshire	Soil	4	<0.32	5.7	<26	18	23	42	<0.043	0.14	0.063
	Rabbit	1	<0.09	<0.10	<0.020	0.015	0.0090	<0.0010	<0.00010	0.00030	0.00020
	Blackberries[b]	1	<0.20	<0.20							
	Potatoes[b]	1	<0.20	<0.25							
Cambridge,	Grass	4	<0.15	<0.15	1.8	1.6	0.13	0.064	<0.00055	0.0016	0.0021
Cambridgeshire	Soil	4	<0.30	8.7	29	17	13	12	<0.024	0.21	0.090
	Rabbit	1	<0.10	<0.10	0.050	0.032	0.010	<0.0030	<0.00050	<0.00030	0.0002
Langford,	Grass	4	<0.11	<0.19	1.1	1.2	0.34	0.077	<0.00048	0.0050	<0.0036
North Somerset	Soil	4	<0.32	15	40	31	19	21	<0.024	0.42	0.16
	Rabbit	1	<0.10	<0.10	<0.070	0.020	0.015	0.00080	<0.00020	<0.00030	<0.00060
Immingham,	Grass	4	<0.15	<0.18	3.1	1.8	0.16	0.10	<0.00029	0.0012	0.00053
North Lincolnshire	Soil	4	<0.41	11	34	23	29	27	<0.031	0.21	0.097
	Rabbit	1	<0.10	<0.10	0.020	0.013	0.010	0.00090	<0.00010	0.00040	0.00050
Wrexham,	Grass	4	<0.07	<0.31	2.6	1.1	0.21	0.16	<0.0014	0.0039	0.0021
Wrexham County	Soil	4	<0.27	12	23	18	17	15	<0.010	0.28	0.10
Borough	Rabbit	1	<0.09	<0.10	<0.030	<0.0080	0.0080	0.0030	<0.00020	0.00030	0.00020
Weldon,	Grass	4	<0.08	<0.08	1.2	0.88	0.15	0.064	<0.00036	<0.0012	0.0013
Northamptonshire	Soil	4	<0.33	6.2	28	23	23	29	0.0073	0.16	0.063
	Rabbit	1	<0.10	<0.10	0.010	0.050	0.0013	0.0040	<0.00030	0.00020	0.00020
Reading,	Apples[c]	1	<0.40	<0.40				<0.0020	<0.00080	0.00040	0.0018
Berkshire	Mint[d]	1	<2.6	<2.6				<0.047	0.00090	<0.0027	<0.0092

[a] *Except for soil where dry concentrations apply*
[b] *Special sampling site near Huntingdon Life Sciences (see Section 10.2)*
[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0063, 0.0019 and 0.0029 Bq kg^{-1} respectively*
[d] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.047, 0.020 and <0.037 Bq kg^{-1} respectively*

Table 10.3. Radioactivity in surface water leachate from landfill sites in Scotland, 2001

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	6700	<15	0.14	<0.05
City of Glasgow	Summerston Tip	1	290	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	2.0	<15	<0.05	<0.05
Dundee City	Riverside	1	21	<15	<0.05	<0.05
Fife	Balbarton	1	97	<15	<0.05	<0.05
Fife	Melville Wood	1	120	<15	<0.05	<0.05
Highland	Longman Tip	1	25	<15	<0.05	<0.07
North Lanarkshire	Dalmacoulter	1	2.6	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	2.3	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	7.0	<15	<0.05	<0.05

Table 10.4. Radioactivity in grass near Cefn-Bryn-Brain landfill site, 2001

Location	No. of sampling observ-ations	Mean radioactivity concentration[a], Bq kg^{-1}												
		^{60}Co	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th
Position A	1	<0.80	<0.90	<1.0	<0.60	<5.8	<0.90	<0.80	1.4	<3.2	6.0	2.0	0.10	0.064
Position B	1	<0.90	<1.4	<0.90	<0.90	<3.3	<0.70	<0.80	0.90	<3.1	6.4	1.9	0.15	0.19
Position C	1	<0.90	<1.2	<0.60	<0.60	<7.1	<0.70	<0.70	<0.80	<3.3	13	3.4	0.34	0.056

[a] *Fresh weight*

11. CHERNOBYL AND REGIONAL MONITORING

11.1 Chernobyl

Radiocaesium is still present 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 2001, the on-going programme of monitoring was suspended because of the limitations on access to farms caused by the foot and mouth outbreak. In all there were 386 farms, or parts of farms, and approximately 230,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of 96% since 1986 when approximately 8900 farms were under restriction. Limited mark and release and slaughterhouse monitoring was undertaken. The areas under restriction are shown in Figures 11.1 to 11.3.

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).

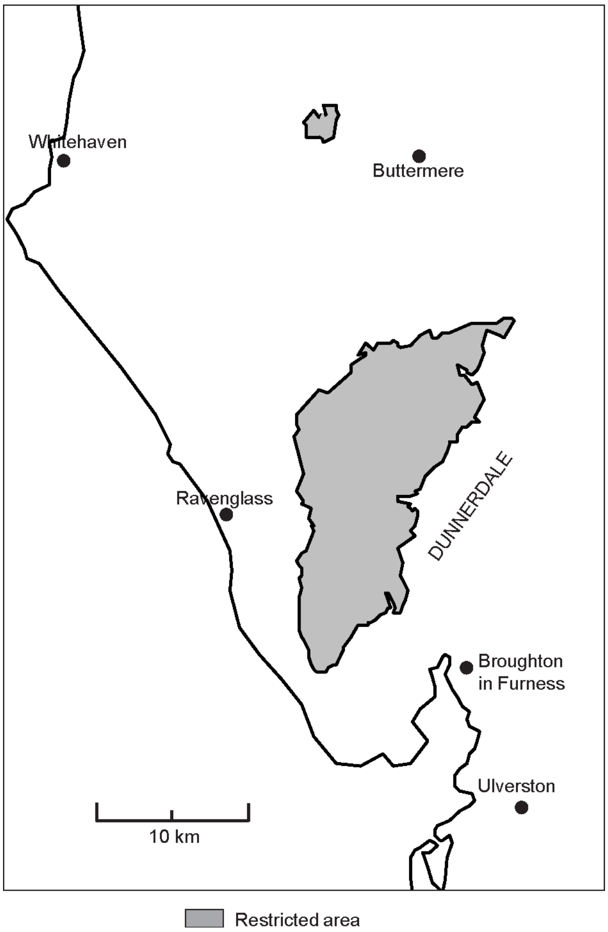

Figure 11.1. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - England

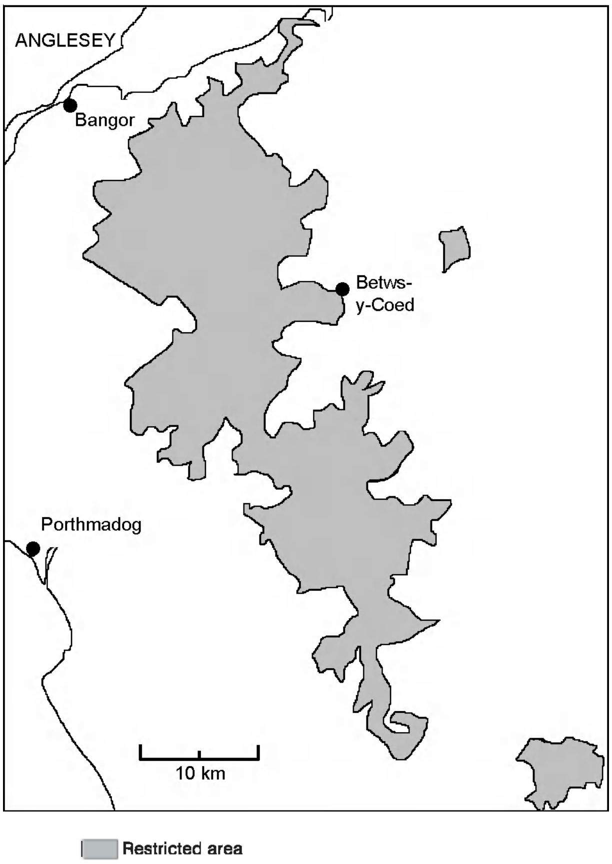

Figure 11.2 ***Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Wales***

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

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 were less than 1000 Bq kg^{-1}, the level attained shortly after the accident, and were generally similar in 2001 to those in 2000. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al.* 2000b)

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously. A consumption rate of fish of 37 kg $year^{-1}$, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is cautious (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish of much lower radiocaesium concentration may contribute to the diet. In 2001, estimated doses were less than 0.090 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 2001 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 close to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Levels of strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of United Kingdom dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. Low levels of tritium and sulphur-35 were detected, but taken as a whole, the results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2001.

The results are similar to those obtained in previous years. The dose to the most exposed group from consumption of Manx foodstuffs monitored in 2001 was 0.016 mSv or less than 2% of the 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 2001 are given in Table 11.3. Nuclides which can be attributed to routine releases from the nuclear industry were detected in some samples (cobalt-60, technetium-99, europium-154, europium-155). However, all concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the most exposed group of high-rate fish and shellfish consumers gives a dose of less than 0.005 mSv in 2001 or less than 0.5% of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands 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 2001. The results are provided in Tables 11.4 and 11.5.

There was some evidence for the effects of radioactive waste disposal into the environment reaching the general diet in the form of positively detected amounts of tritium and sulphur-35 being determined. However, all of the results for man-made radionuclides were low. Many were close to the limits of detection for the various analytical methods used. There was some variability from region to region, but no more than is usually detected from the programme. Within the normal variability observed, there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 11.4 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 2000 (Food Standards Agency and SEPA, 2001).

The mean dose due to consumption of natural radionuclides was 0.15 mSv, similar to the value for 2000. The most important radionuclides continued to be 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 2001. The aim is to collect samples and analyse them monthly for natural and man-made radionuclides. In some cases, less than 12 samples were analysed this year because of direct and indirect effects of the FMD outbreak. The programme, together with that for crops presented in the following section, provides useful information with which to compare data from farms close to nuclear sites and other establishments which may enhance concentrations above background levels. Some of this data is supplied to the European Commission as part of the requirements under the EURATOM treaty (e.g. JRC, 2001).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2001 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 12 and 15 Bq l^{-1} were found at Cambridgeshire and Dumfries and Galloway respectively, but this level of variability has been detected in previous years. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels. The mean concentration of strontium-90 was less than 0.04 Bq l^{-1}. In the past, the levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout, however, the levels are now very low and it is less easy to distinguish this trend.

The assessed doses from consumption of dairy milk at average rates were highest to the one-year-old infant age group. For the full range of radionuclides analysed, the average dose was 0.031 mSv which 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 2001 (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 2000.

Sampling of bread and meat continued in Scotland in 2001. 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 2000.

11.7 Air particulate and fresh water

Monitoring of radioactivity in air and rain took place in two locations in Scotland as part of a UK wide surveillance programme of background sampling under the Euratom Treaty. The results are given in Table 11.11. Results for England and Wales are also available (Environment Agency, 2002). Caesium-137 concentrations were all below the limits of detection. Both tritium and caesium-137 concentrations were similar to those observed elsewhere in the UK. Monitoring of air in Glasgow gave less than 2.0 mBq m^{-3} of beta activity.

Sampling and analysis of fresh water throughout Scotland continued in 2001. Analyses of tritium, strontium-90, caesium-137 and total alpha and beta activity were undertaken. The results, in Table 11.12, were generally similar to those found in England and Wales (Environment Agency, 2002). Detectable amounts of tritium were again observed in samples from the Winterhope reservoir (Dumfries and Galloway), however, they were of negligible radiological significance. 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 2001.

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. Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999b) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). 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 2001 cruises are presented in Figures 11.4 - 11.6. Data from shoreline sampling in the Irish Sea and Scottish waters in 2001 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 2001 data for the Irish 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 Irish Sea (Figure 11.5) were generally higher than those observed in the North Sea (Food Standards Agency and SEPA, 2001) due to the influence of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 11.6).

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) and McCubbin *et al.*, (2001b). 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 2001 gave results of less than 450 and less than 4330 mBq kg^{-1} respectively. These concentrations are similar to those for 2000.

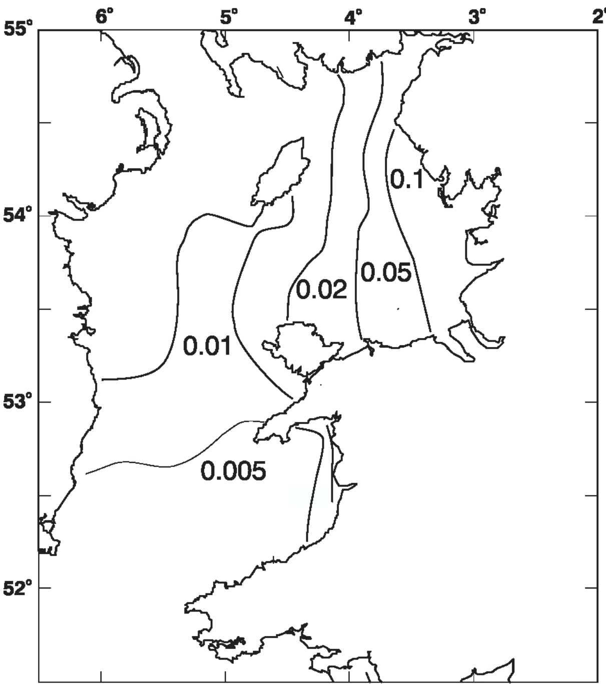

Figure 11.4 Concentrations (Bq l-1) of caesium-137 in filtered surface water from the Irish Sea, September 2001

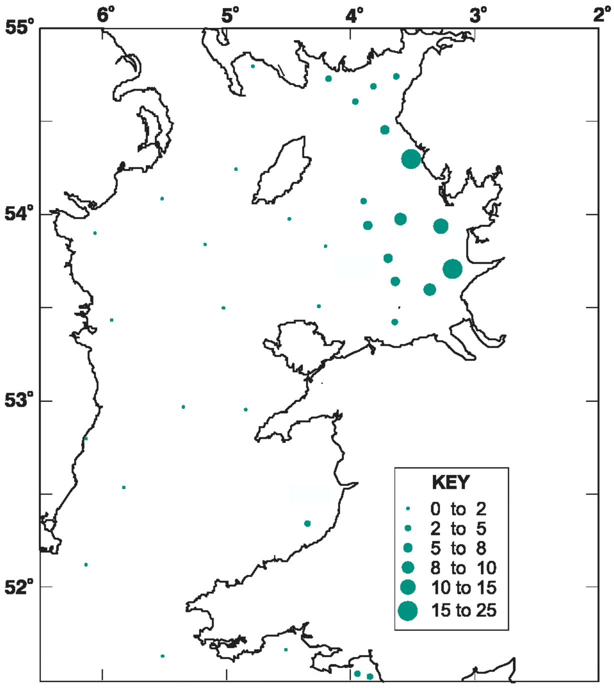

Figure 11.5 Concentrations (Bq l-1) of tritium in surface water from the Irish Sea, September 2001

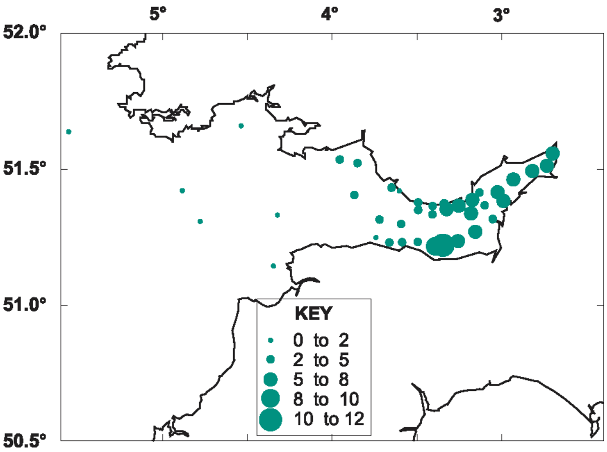

Figure 11.6 Concentrations (Bq l-1) of tritium in surface water from the Bristol Channel, September 2001

Table 11.1. Caesium radioactivity in the freshwater environment, 2001

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.10	0.16
Narborough[b]	Rainbow trout	1	<0.04	0.22
Ennerdale Water	Water	1	*	0.001
Devoke Water	Perch	1	0.87	180
Devoke Water	Water	1	*	0.01
Gilcrux	Rainbow trout	1	<0.08	0.41
Scotland				
Loch Dee	Water	3	*	0.01

* *not detected by the method used*

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

[b] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 30, 0.00010, 0.00059 and 0.0011 Bq kg^{-1} (wet) respectively*

Table 11.2. Radioactivity in terrestrial food from the Isle of Man, 2001

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	<4.0	22	<0.50	<0.31	0.037	<1.1	<1.4	0.0090	<2.2	<0.53
Milk	max			23		<0.35	0.041	<1.2	<1.5		<2.4	<0.65
Cabbage		1	10	11	0.70	<0.30	0.12	<0.50	<0.30	<0.034	<2.1	<0.60
Potatoes		1	5.0	25	<0.20	<0.30	0.044	<0.30	<0.30	<0.040	<1.7	<0.50
Strawberries		1	<4.0	12	0.40	<0.20	0.22	<0.40	<0.30		<1.5	<0.30

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	<0.011	0.12	<1.4	<0.20	<0.00020	0.00010	<0.040	0.00050
Milk	max			0.13	<1.5					
Cabbage		1	<0.044	0.11	<1.2	<0.50	<0.00030	<0.00030	<0.064	0.00030
Potatoes		1	<0.068	0.093	<0.80	<0.20	<0.00030	<0.00030	<0.061	0.00040
Strawberries		1		0.043	<0.80					

[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, 2001

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		<0.11			<1.0		0.19	<0.33
Mackerel	Guernsey	2		<0.23			<2.5		<0.27	<0.66
Pollack	Jersey	1		<0.19			<1.8		<0.16	<0.49
Edible crabs	Guernsey	1		<0.07			<0.53		<0.05	<0.18
Edible crabs	Jersey	1		<0.06			<0.53		<0.05	<0.15
Edible crabs[b]	Alderney	2	<25	<0.12		1.0	<0.79		<0.07	<0.23
Spiny spider crab	Jersey	1		0.25			<0.48		<0.04	<0.13
Spiny spider crab	Alderney	2		0.42			<1.5		<0.12	<0.39
Lobsters	Guernsey	1		<0.10			<1.1		<0.07	<0.27
Lobsters	Jersey	1		<0.14		1.9	<1.3		<0.11	<0.40
Lobsters[c]	Alderney	1		<0.15			<1.7		<0.13	<0.40
Oysters	Jersey	1		0.06			<0.35		<0.03	<0.12
Limpets	Guernsey	1		<0.04			<0.38		0.05	<0.12
Limpets	Jersey La Rozel	1		0.14			<0.53		<0.05	<0.15
Toothed winkle[d]	Alderney	1	<25	0.54	<0.098		<1.8		<0.14	<0.46
Scallops	Guernsey	2		<0.08			<0.79		<0.06	<0.22
Scallops	Jersey	1		<0.05			<0.48		0.08	<0.15
Ormers	Guernsey	1		<0.07			<0.58		<0.06	<0.20
Porphya	Guernsey Fermain Bay	4		<0.08			<0.74		<0.08	<0.21
Porphya	Jersey Plemont Bay	3		<0.11			<0.43		<0.03	<0.11
Porphya	Alderney Quenard Point	2		<0.03			1.4		<0.03	<0.09
Fucus vesiculosus	Jersey La Rozel	4		<0.24	0.027	4.0	<0.68		<0.09	<0.22
Fucus vesiculosus	Alderney Quenard Point	2						0.73		
Fucus serratus	Guernsey Fermain Bay	4		0.11	<0.039	2.6	<0.33		<0.04	<0.11
Fucus serratus	Alderney Quenard Point	4		0.27	<0.036	4.3	<0.44		<0.04	<0.15
Laminaria digitata	Jersey Verclut	4		<0.06			<0.53		<0.05	<0.16
Mud	Guernsey St. Sampson's Harbour	1		1.8			<2.1		2.7	<0.68
Mud	Jersey St Helier	1		15			<2.3		8.3	1.0
Sand	Alderney Lt. Crabbe Harbour	1		<0.67			<6.6		2.4	<1.9
Seawater	Guernsey	4							0.002	
Seawater	Jersey									
Seawater	Alderney East	4	<2.5						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	<0.17	<0.00016	<0.00016	<0.000097	*	*	77
Mackerel	Guernsey	2	<0.38	0.000026	0.000074	0.00014	*	0.000011	140
Pollack	Jersey	1	<0.24			<0.12			120
Edible crabs	Guernsey	1	<0.10	0.00025	0.00089	0.0021	*	0.00022	68
Edible crabs	Jersey	1	<0.16	0.00026	0.00067	0.0024	*	0.00036	72
Edible crabs[b]	Alderney	2	<0.14	0.00054	0.0011	0.0030	*	0.00044	47
Spiny spider crab	Jersey	1	<0.13			<0.13			82
Spiny spider crab	Alderney	2	<0.27	0.0012	0.0026	0.0041	*	0.00073	58
Lobsters	Guernsey	1	<0.14			<0.07			30
Lobsters	Jersey	1	<0.20	0.0013	0.0062	0.014	0.000036	0.00032	89
Lobsters[c]	Alderney	1	<0.34	0.00021	0.0011	0.0051	0.000073	0.00085	36
Oysters	Jersey	1	<0.07	0.0014	0.0051	0.0055	0.000034	0.00046	82
Limpets	Guernsey	1	<0.08			<0.05			86
Limpets	Jersey La Rozel	1	<0.16	0.0038	0.0094	0.017	0.000040	0.0019	85
Toothed winkle[d]	Alderney	1	<0.25	0.0076	0.021	0.026	0.00030	0.0041	46
Scallops	Guernsey	2	<0.21	0.0011	0.0034	0.0028	*	0.00035	110
Scallops	Jersey	1	<0.14	0.0026	0.0075	0.0055	*	0.00036	120
Ormers	Guernsey	1	<0.14			<0.18			110
Porphya	Guernsey Fermain Bay	4	<0.11	0.0030	0.010	0.014	0.000036	0.0017	110
Porphya	Jersey Plemont Bay	3	<0.08			<0.07			57
Porphya	Alderney Quenard Point	2	<0.09			<0.09			64
Fucus vesiculosus	Jersey La Rozel	4	<0.16	0.0088	0.022	0.011	0.000073	0.0014	190
Fucus serratus	Guernsey Fermain Bay	4	<0.10	0.0034	0.014	0.0063	0.000068	0.00081	120
Fucus serratus	Alderney Quenard Point	4	<0.11	0.0053	0.019	0.0054	0.00013	0.00077	160
Laminaria digitata	Jersey Verclut	4	<0.10			<0.08			130
Mud	Guernsey St. Sampson's Harbour	1	0.94	0.24	0.74	0.99	*	0.11	490
Mud	Jersey St Helier	1	2.3	1.6	4.0	6.7	0.018	0.81	630
Sand	Alderney Lt. Crabbe Harbour	1	<1.0			1.1			340
Seawater	Guernsey	4							
Seawater	Jersey								
Seawater	Alderney East	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 concentrations of organic tritium and ^{14}C were <25 and 18 Bq kg^{-1} respectively*
[c] *The concentrations of ^{210}Pb and ^{210}Po were 0.79 and 10 Bq kg^{-1} respectively*
[d] *The concentrations of organic tritium and ^{14}C were <25 and 17 Bq kg^{-1} respectively*

Table 11.4. Radioactivity in general diet (TDS survey), 2001

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
North	1	<2.1	46	<0.25	65	0.050	<0.04	0.082	0.043
Wales	1	<10	50	<1.0	70	<0.070	<0.06	0.14	<0.054
East Midlands	1	<2.1	39	<0.30	61	<0.090	0.02	<0.020	0.039
South West	1	<2.1	26	0.51	70	<0.060	<0.18	<0.030	0.030
North East	1	<20	44	<0.32	69	<0.15	<0.06	0.083	0.037
South East	1	16	55	<1.0	60	<0.070	0.04	0.046	0.057
West Midlands	1	2.6	58	<0.25	63	0.052	0.04	<0.020	0.037
East	1	6.9	44	<1.0	74	<0.070	0.08	<0.020	0.045
South	1	<20	48	<0.40	66	<0.10	<0.06	<0.040	<0.071
North West	1	<2.1	46	<0.23	68	0.056	0.04	<0.020	0.051
Northern Ireland	1	<20	37	2.9	63	0.74	0.06	0.076	0.039
Scotland (Perth)[b]	1	<20	58	1.3		<0.10	<0.15	0.11	0.073
Scotland (Glasgow)[c]	1	<20	110	1.2		<0.05	<0.07	0.029	0.086

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
North	1	0.023	0.0012	0.017	<0.00013	0.00016	<0.00048
Wales	1	0.031	<0.0020	<0.016	<0.00058	0.00071	0.00046
East Midlands	1	0.023	<0.0030	<0.016	<0.00077	0.00069	0.00021
South West	1	0.028	0.00080	0.019	<0.00046	0.0011	0.00037
North East	1	0.037	0.00047	0.024	<0.00041	<0.00031	0.0040
South East	1	0.030	0.00090	0.023	<0.00010	0.00015	0.0012
West Midlands	1	0.030	<0.00030	0.022	<0.00034	<0.00057	<0.00049
East	1	0.029	0.0013	0.023	0.00049	0.00091	0.00027
South	1	0.031	0.0014	0.021	<0.00025	0.00046	0.0018
North West	1	0.029	<0.00042	<0.016	<0.00030	<0.00037	<0.00029
Northern Ireland	1	0.015	0.00094	0.029	0.00039	0.0026	<0.000094
Scotland (Perth)[b]	1	0.031			<0.0015	<0.0015	<0.0010
Scotland (Glasgow)[c]	1	0.025	0.022		<0.00068	<0.00068	<0.00075

[a] *Results are available for other artificial nuclides detected by gamma spectrometry. All such results were less than the limit of detection.*
[b] *Supplied by SEPA. The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0093, <0.0032 and 0.0071 Bq kg^{-1} respectively.*
[c] *Supplied by SEPA. The concentrations of ^{228}Th, ^{230}Th and ^{234}U, ^{235}U, ^{238}U were 0.033, <0.023, 0.0094, <0.0033 and <0.0033 Bq kg^{-1} respectively.*

Table 11.5. Radioactivity in regional diet in Scotland, 2001

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{3}H	^{35}S	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	8	<6.2	<0.72	85	<0.10	<0.08
East Lothian (North Berwick)	12	<6.5	<0.74	82	<0.10	<0.07
Highland (Dingwall)	12	<5.8	<0.84	91	<0.10	<0.08
Renfrewshire (Paisley)	12	<5.7	<0.84	80	<0.10	<0.08

Table 11.6. Estimates of radiation exposure from radionuclides in regional diet, 2001

Nuclide[a]	Exposure, mSv[b]
Man-made radionuclides	
Tritium	0.0002
Sulphur-35	0.0008
Strontium-90	0.002
Caesium-137	0.0002
Plutonium-238	0.00004
Plutonium-239+240	0.00006
Americium-241	0.00006
Sub-total	0.003
Natural radionuclides	
Carbon-14	0.02
Lead-210	0.04
Polonium-210	0.09
Radium-226	0.005
Uranium	0.0003
Thorium-232	0.0003
Sub-total	0.15
Total	0.15

[a] *Tritium is also produced by natural means and carbon-14 by man. Levels of natural radionuclides may be enhanced by man's activities*

[b] *To a 1 year old child consuming at average rates. Exposures due to the potassium-40 content of food are not included here because they do not vary according to the potassium-40 content of food. Levels of potassium in the body are homeostatically controlled*

Table 11.7. Radioactivity in milk remote from nuclear sites, 2001

Location	Selection[a]	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$
Co. Antrim		7	<4.0	15		0.029	0.14	0.051	0.0074	<0.0067	<0.00010	<0.00010
	max			20		0.034	0.22					
Co. Armagh		8	<3.9	15		0.031	0.092	<0.029	0.0062	<0.0068	<0.00010	<0.00010
	max		<4.0	22		0.036	0.15					
Cambridgeshire[b]		12	<3.0			0.019	0.068	<0.033	0.0045	<0.0070	<0.00010	<0.00010
	max		12			0.026	0.11					
Cheshire		10	<3.9	15		0.024	0.13	<0.034	0.0060	<0.0073	<0.00010	<0.00010
	max		<4.0	19		0.035	0.26					
Clwyd		10	<4.5	15		0.028	0.072	<0.028	0.0064	<0.0071	<0.00010	<0.00010
	max		8.0	19		0.033	0.13					
Cornwall		10	<4.0	15		0.043	0.085	<0.036	0.011	<0.0072	<0.00010	<0.00020
	max			24		0.059	0.14					
Devon		10	<4.0	15		0.034	0.064	0.046	0.0042	<0.0072	0.00010	<0.00010
	max			19		0.060	0.10					
Co. Down		6	<4.0	16		0.035	0.18	0.096	0.0071	<0.0070	<0.00020	<0.00020
	max		4.0	24		0.055	0.32					
Dumfries and Galloway		7	<6.9	15	<0.50	<0.10	<0.053[c]					
	max		15	22			0.070[c]					
Co. Fermanagh		8	<4.1	13		0.033	0.095	0.077	0.0070	<0.0068	<0.00010	<0.00010
	max		6.0	17		0.052	0.12					
Gloucestershire		24	<4.0	15		0.021	0.059	<0.040	0.0072	<0.0071	<0.00010	<0.00010
	max		4.0	24		0.046	0.12	<0.043				
Gwent[b]		8	<2.4			0.035	0.084	<0.037	0.0055	0.0070	<0.00010	<0.00020
	max		5.0			0.043	0.11					
Gwynedd		12	<4.1	17		0.041	0.085	0.054	0.0078	<0.0067	<0.00010	<0.00010
	max		5.0	29		0.054	0.15					
Hampshire		9	<3.9	16		0.021	0.070	<0.038	0.0069	<0.0069	<0.00010	<0.00010
	max		<4.0	28		0.031	0.12					
Highland		11	<5.8	15	<0.56	<0.10	<0.068[c]					
	max		8.0	21	0.75		0.15[c]					
Humberside		10	<3.9	17		0.022	0.061	<0.034	0.0034	<0.0069	<0.00010	<0.00010
	max		4.0	26		0.035	0.092					
Lanarkshire		10	<5.3	14	<0.52	<0.10	<0.075[c]					
	max		6.2	18			0.13[c]					
Lancashire		10	<4.0	15		0.031	0.10	<0.040	0.0042	<0.0070	<0.00010	<0.00010
	max		4.0	35		0.044	0.19					
Leicestershire		9	<4.8	16		0.021	0.076	<0.026	0.0032	<0.0071	0.00010	<0.00020
	max		7.0	22		0.035	0.12					
Lincolnshire		11	<4.1	16		0.015	0.053	<0.028	0.0033	0.0077	<0.00010	<0.00010
	max		5.0	25		0.022	0.10					

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	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$
Co. Londonderry		7	<3.9	13		0.037	0.13	<0.033	0.012	<0.0069	<0.00010	0.00010
	max		<4.0	19		0.046	0.18					
Middlesex		10	<4.1	16		0.029	0.068	0.055	0.0067	<0.0068	<0.00010	<0.00020
	max		5.0	24		0.044	0.11					
Midlothian		10	<5.2	17	<0.50	<0.10	<0.050[c]					
	max		6.1	18								
Norfolk		9	<3.8	14		<0.019	0.084	<0.028	0.0047	<0.0071	<0.00040	<0.00030
	max		<4.0	17		0.047	0.19					
North Yorkshire		11	<4.2	16		0.023	0.071	<0.034	0.0043	<0.0069	0.00010	<0.00010
	max		5.0	21		0.033	0.14					
Oxfordshire		9	<4.0	15		0.019	0.057	<0.029	0.0051	<0.0071	<0.00010	<0.00010
	max		4.0	19		0.027	0.097					
Renfrewshire		12	<5.6	12	<0.50	<0.10	<0.11[c]					
	max		7.3	17			0.18[c]					
Shropshire		8	<3.9	12		0.027	0.070	<0.042	0.0066	<0.010	<0.00010	<0.00010
	max		<4.0	18		0.038	0.099		0.0081		0.00010	
Somerset		11	<4.2	11		0.033	0.078	<0.030	0.0048	<0.0067	<0.00010	<0.00010
	max		6.0	16		0.058	0.16					
Suffolk		10	<4.0	14		0.015	0.060	<0.031	0.0061	<0.0068	<0.00010	<0.00010
	max			18		0.023	0.092					
Tyneside		10	<5.0	17		0.032	0.073	<0.042	0.010	<0.0069	<0.00010	<0.00010
	max		10	21		0.043	0.13	<0.047				
Co. Tyrone[b]		12	<2.3			0.029	0.18	<0.030	0.0057	<0.0071	<0.00010	<0.00010
	max		5.0			0.036	0.28					
Yorkshire		10	<4.0	14		0.025	0.074	0.054	0.0057	<0.0070	<0.00010	<0.00010
	max			21		0.037	0.12					
Mean Values												
England			<4.0	15		<0.025	0.073	<0.037	0.0058	<0.0074	<0.00011	<0.00012
Northern Ireland			<3.5	15		0.032	0.14	<0.053	0.0075	<0.0069	<0.00012	<0.00012
Wales			<3.8	16		0.035	0.080	<0.040	0.0066	<0.0069	<0.00010	<0.00013
Scotland			<5.7	15	<0.54	<0.10	<0.073					
United Kingdom			<4.2	15		<0.038	<0.083	<0.041	0.0062	<0.0072	<0.00011	<0.00012

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

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

[c] *^{137}Cs only*

Table 11.8. Radioactivity in crops remote from nuclear sites, 2001[b]

Location	Material	No of samples[a]	Mean radioactivity concentration (wet), Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total Alpha
Cornwall																
St Austell	Cabbage	1	<4.0	17		0.36	<0.037	0.050	0.0088	<0.0060	<0.0017	<0.033	0.00020	<0.00030	<0.00020	
	Potatoes	1	<4.0	24		0.078	0.032	<0.042	0.011	0.0070	0.0058	<0.035	<0.00010	<0.00010	<0.00010	
Denbighshire																
Denbigh	Blackcurrants	1	<3.0	15		0.14	<0.032	0.14	0.042	<0.0030	<0.0026	<0.035	<0.00010	<0.00010	<0.00040	
	Carrots	1	4.0	7.0		0.17	<0.028	0.064	0.017	0.037	0.0081	0.038	<0.00010	0.00010	<0.00020	
	Lettuce	1	<4.0	<2.0		0.20	<0.046	0.22	0.13	0.012	0.0085	0.067	<0.00010	<0.00010	<0.00020	
Devon																
Exeter	Cabbage	1	<4.0	13		0.64	0.13	0.048	0.024	<0.037	0.0027	<0.035	0.00010	<0.00020	<0.00020	
	Strawberries	1	<4.0	10		0.23	<0.031	<0.037	0.019	0.033	<0.00090	<0.035	<0.00020	<0.00010	<0.00040	
Dorset																
Christchurch	Asparagus	1	<4.0	11		0.053	0.075	<0.044	0.034	<0.018	0.0078	<0.035	<0.00010	0.00010	<0.00020	
	Gooseberries	1	<4.0	7.0		0.11	0.040	<0.038	0.033	0.026	<0.0016	<0.032	<0.00010	<0.00010	<0.00020	
Dumfries and Galloway																
Dumfries	Leafy Green Veg	3	<6.2	5.8	<0.50	<0.10	<0.050[c]									<0.41
East Lothian																
North Berwick	Leafy Green Veg	4	<5.4	5.3	<0.50	<0.10	<0.053[c]									<2.8
Essex																
Southend on Sea	Potatoes	1	<4.0	12		0.026	<0.028	<0.079	0.0054	0.0040	0.0054	<0.028	<0.00020	0.00020	0.00010	
	Strawberries	1	<4.0	11		0.017	<0.028	<0.037	0.0052	0.011	<0.0018	<0.034	<0.00010	0.00010	0.00020	
Gloucestershire																
Frampton Cotterell	Asparagus	1	<4.0	16		0.041	0.058	0.067	0.038	0.013	0.0084	<0.034	<0.00020	0.00010	0.00020	
	Strawberries[d]	1	<4.0	14		<0.016	0.053	<0.043	0.0066	0.0060	<0.0012	<0.035	0.00010	0.00010	0.00040	
Highland																
Dingwall	Leafy Green Veg	4	<5.8	6.1	<0.50	<0.10	<0.050[c]									<0.26
Kent																
Ashford	Cabbage	1	<4.0	<3.0		0.19	<0.032	0.21	0.016	0.014	0.0036	<0.033	<0.00010	<0.00010	<0.00020	
	Potatoes	1	<4.0	20		0.045	<0.038	0.34	0.014	0.012	0.010	0.047	<0.00010	0.00020	0.0014	
Lancashire																
St Helens	Cabbage	1	<4.0	7.0		0.25	0.068	0.11	0.022	<0.021	0.00070	<0.034	<0.00010	<0.00020	<0.00040	
	Raspberries	1	<4.0	11		0.097	0.027	<0.040	0.024	0.015	0.0024	<0.033	<0.00020	0.00010	<0.00020	
Leicestershire																
Market Harborough	Potatoes	1	<4.0	17		0.036	<0.034	<0.035	0.0050	0.011	0.0018	<0.034	<0.00010	0.00010	<0.00020	
	Runner Beans	1	4.0	8.0		0.056	0.083	0.051	0.0029	0.0040	0.0033	<0.035	<0.00010	<0.00030	<0.00040	
	Strawberries	1	<4.0	11		0.024	0.22	<0.041	0.012	0.0050	<0.0010	<0.033	<0.00010	0.00010	0.00010	
Lincolnshire																
Bourne	Cabbage	1	<4.0	4.0		0.12	<0.031	0.099	0.049	0.019	0.037	0.049	<0.00010	0.00010	0.00010	
	Potatoes	1	5.0	15		0.023	<0.029	<0.035	0.011	0.013	0.0071	<0.034	<0.00010	0.00020	<0.00030	

Table 11.8. continued

Location	Material	No of samples[a]	Mean radioactivity concentration (wet), Bq kg⁻¹ ^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total Alpha
Norfolk																
Norwich	Cabbage	1	4.0	8.0		0.21	<0.026	0.053	0.015	0.015	0.0015	<0.034	0.00010	0.00010	0.00020	
	Raspberries	1	<4.0	6.0		0.051	<0.034	<0.040	0.035	0.0080	<0.0012	<0.034	<0.00020	0.00010	<0.00020	
North Yorkshire																
Knaresborough	Lettuce	1	<3.0	<3.0		0.12	0.058	0.076	0.038	0.010	<0.0028	<0.035	<0.00020	0.00010	<0.00030	
	Potatoes	1	5.0	4.0		0.029	<0.033	<0.044	0.016	0.0070	<0.0044	<0.035	<0.00010	0.00010	<0.00010	
Thirsk	Cabbage	1	<4.0	<3.0		0.18	<0.033	<0.039	0.011	<0.0050	<0.0017	<0.033	<0.00020	<0.00020	<0.00030	
	Carrots	1	<4.0	13		0.12	<0.027	<0.049	0.014	0.068	<0.0030	0.040	<0.00010	0.00010	<0.00020	
	Raspberries	1	<4.0	19		0.091	<0.027	<0.043	0.033	0.015	<0.0028	<0.033	<0.00010	0.00010	<0.00020	
Northumberland																
Bedlington	Lettuce	1	<4.0	3.0		0.45	<0.035	0.11	0.066	0.020	0.0048	<0.035	<0.00020	<0.00020	<0.00080	
Morpeth	Raspberries	1	<4.0	14		0.062	0.057	<0.038	0.017	0.0090	<0.0023	<0.034	0.00010	<0.00010	<0.00020	
Ponteland	Cabbage	1	<4.0	9.0		0.18	<0.033	0.075	0.012	0.013	<0.0014	<0.035	<0.00030	<0.00020	<0.00040	
	Swede	1	<4.0	10		0.23	0.033	<0.042	0.008	<0.0090	0.0017	<0.033	<0.00010	<0.00010	<0.00020	
Powys																
Brecon	Cabbage	1	<4.0	8.0		0.26	<0.031	<0.037	0.008	0.015	<0.0013	<0.035	<0.00010	<0.00020	<0.00030	
	Strawberries/ Raspberries	1	<4.0	4.0		0.17	<0.026	<0.068	0.034	0.023	0.0026	<0.035	<0.00020	0.00010	0.00020	
Renfrewshire																
Paisley	Leafy Green Veg	3	<5.8	5.1	<0.50	<0.10	<0.050[c]									<0.21
Staffordshire																
Lichfield	Cabbage	1	<4.0	3.0		0.11	<0.035	0.060	0.009	<0.0050	0.00090	<0.034	<0.00020	<0.00020	<0.00050	
	Potatoes	1	<4.0	18		0.020	0.035	<0.064	0.011	0.0050	0.0038	<0.035	<0.00010	0.00020	0.00010	
Surrey																
Addlestone	Spinach	1	<4.0	5.0		0.42	0.13	<0.060	0.068	0.045	0.020	0.052	<0.00010	0.00020	0.00030	
	Strawberries	1	<4.0	9.0		0.042	0.087	0.11	0.010	0.024	0.0040	<0.032	<0.00020	<0.00010	<0.00040	
Warwickshire																
Rugby	Cabbage	1	<4.0	2.0		0.12	<0.032	<0.048	0.016	0.0090	0.0047	<0.031	<0.00020	<0.00020	<0.00070	
	Carrots	1	<4.0	7.0		0.18	<0.047	<0.041	0.015	0.034	0.015	<0.035	<0.00010	0.00010	<0.00030	
Wiltshire																
Chippenham	Cabbage	1	<4.0	3.0		0.19	0.032	0.070	0.024	0.015	<0.0050	<0.035	<0.00010	0.00010	0.00050	
	Carrots	1	<4.0	<3.0		0.13	0.056	<0.040	0.016	0.020	0.0080	<0.034	<0.00010	0.00020	0.00030	
Mean Values																
England			<4.0	<9.9		<0.14	<0.051	<0.070	0.020	<0.016	<0.0056	<0.035	<0.00014	<0.00015	<0.00031	
Wales			<3.8	<7.0		0.19	<0.032	<0.097	0.042	<0.018	<0.0042	<0.041	<0.00013	<0.00013	<0.00026	
Scotland			<5.8	5.5	<0.50	<0.10	<0.051[c]									<0.92
Great Britian			<4.3	<8.9	<0.50	<0.14	<0.049	<0.073	0.023	<0.016	<0.0054	<0.036	<0.00013	<0.00014	<0.00031	<0.92

[a] *See section 3 for definition*

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

[c] *^{137}Cs only*

[d] *The concentration of ^{60}Co was 0.30 Bq kg⁻¹*

Table 11.9. Radioactivity in bread in Scotland, 2001

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
		^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	3	<5.0	69	2.8	60	<0.10	<0.11	<0.93
East Lothian (North Berwick)	4	<5.3	78	<3.1	59	<0.10	<0.05	<0.72
Highland (Dingwall)	4	<5.0	64	<4.7	66	<0.11	<0.05	<0.81
Renfrewshire (Paisley)	4	<5.6	90	<2.5	64	<0.10	<0.08	<0.33

Table 11.10. Radioactivity in meat in Scotland, 2001

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
		^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	3	<7.9	52	1.7	92	<0.10	<0.09	<0.28
East Lothian (North Berwick)	4	14	46	<1.5	98	<0.10	<0.15	<0.44
Highland (Dingwall)	4	<8.1	39	<3.6	100	<0.10	0.70	<0.20
Renfrewshire (Paisley)	4	<11	39	<5.9	110	<0.10	0.38	<0.16

Table 11.11. Radioactivity in air and rain in Scotland, 2001

Location	No. of sampling observ-ations	Mean radioactivity concentration Air, Bq kg^{-1}	Rain, Bq l^{-1}	
		^{137}Cs	^{3}H	^{137}Cs
Eskdalemuir	4	$<3.1\ 10^{-7}$	<2.5	<0.01
Lerwick	4	$<2.3\ 10^{-7}$	NA	<0.017

NA not available

Table 11.12. Radioactivity in freshwater in Scotland, 2001

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	10	<1.7	<0.0050	<0.010		
Argyll and Bute	Auchengaich	1	<1.5	0.0058		<0.016	0.029
Argyll and Bute	Helensburgh Reservoir	3			<0.010	<0.010	<0.023
Argyll and Bute	Loch Ascog	3			<0.010	<0.014	0.099
Argyll and Bute	Loch Eck	1	<1.5	0.0071		<0.010	0.026
Argyll and Bute	Loch Finlas	3			<0.010	<0.010	0.025
Argyll and Bute	Lochan Ghlas	3			<0.010	<0.012	0.026
Clackmannanshire	Gartmorn	1	<1.5	0.0079		0.046	0.19
Dumfries and Galloway	Black Esk	1	3.0			<0.011	0.015
Dumfries and Galloway	Purdomstone	3			<0.010	<0.012	0.070
Dumfries and Galloway	Winterhope	1	21	<0.0050		<0.010	0.040
East Lothian	Hopes Reservoir	1	<1.5	<0.0050		<0.011	0.035
East Lothian	Thorters Reservoir	1	<1.5	0.0069		<0.010	0.022
East Lothian	Whiteadder	3			<0.010	<0.011	0.045
Fife	Holl Reservoir	1	<1.5	<0.0050		<0.013	0.032
Highland	Loch Baligill	1	<1.5	0.0051		<0.010	0.047
Highland	Loch Calder	3			<0.010	<0.020	0.058
Highland	Loch Glass	11	<1.5	<0.0053	<0.010		
Highland	Loch Shurrerey	1	<1.5	<0.0050		0.010	0.048
North Ayrshire	Camphill	1	<1.5	<0.0050		<0.010	0.066
North Ayrshire	Knockendon Reservoir	1			<0.010	<0.010	0.041
North Ayrshire	Munnoch Reservoir	1	<1.5	<0.0050		<0.011	0.037
North Ayrshire	Outerwards	1	<1.5	0.0068		<0.010	0.024
Orkney Islands	Heldale Water	1	<1.5	<0.0050		<0.017	0.055
Perth and Kinross	Castlehill	3			<0.010	<0.010	<0.024
Scottish Borders	Knowsdean	11	<1.7	<0.0051	<0.010		
Stirling	Loch Katrine	11	<1.3	<0.012	<0.010		
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.5	0.0068		<0.010	0.027
West Lothian	Morton No. 2	1	<1.5	0.0052		<0.013	0.034

Table 11.13. Radioactivity in sea water from the Irish Sea and Scottish waters, 2001

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
		^{3}H	^{99}Tc	^{134}Cs	^{137}Cs
Seascale	4			0.004	0.16
St. Bees	12	<14	0.29	0.005	0.13
Whitehaven	1			*	0.13
Maryport	1			*	0.19
Silloth	1			0.003	0.24
Silecroft	1			*	0.09
Walney- west shore	4	<11		*	0.10
Isle of Whithorn	1			*	0.03
Drummore	1			*	0.03
Half Moon Bay	1			0.002	0.17
Rossal (Fleetwood)	1			0.001	0.11
Ainsdale	1			0.002	0.09
New Brighton	1			*	0.07
Ross Bay	1			*	0.04
North of Larne	12		0.024	*	0.01
Seafield	3	19		<0.10	<0.17
Seafield (high water)	2	8.4		<0.10	0.12
Southerness[a]	3	8.2		<0.10	<0.14
Carsethorn	2	7.2			
North Solway	3	7.7			
Knock Bay	4	<2.3		*	0.03
Castltown Harbour	3	<1.5		<0.10	<0.13
Prestatyn	1			*	0.03
Llandudno	1			*	0.02
Holyhead	4	<1.5		*	0.01

** not detected by the method used*

[a] The concentrations of ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 0.00042, 0.0012 and 0.0022 Bq l^{-1} respectively

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

The Food Standards Agency and SEPA have programmes of special surveillance investigations and supporting research and development studies to complement the routine surveillance undertaken. This additional work is primarily directed at 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, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000).

A list of related research projects completed in 2001 is presented in Table 12.1. Those sponsored by the Food Standards Agency are also listed on the internet (www.food.gov.uk). Copies of the final reports for each of those projects funded by the Food Standards Agency are available from the Radiological Protection and Research Management Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by SEPA and the Scotland and Northern Ireland Forum for Environmental Research is available from SEPA, Erskine Court, The Castle Business Park, Stirling FK9 4TR. 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.

Assessment of contaminated land – AIR (98) 09

This work was commissioned by the Environment Agency, with support from DETR and SNIFFER (Scottish and Northern Ireland Forum for Environmental Research) to provide information on the techniques available to allow the Environment Agencies to fulfil their envisaged regulatory requirements, and to assist DETR in the preparation of Statutory Guidance. The work was carried out by Entec UK Ltd., in conjunction with the NRPB.

Seasonal variations in radionuclides in crabs and lobsters – R02011

As described in Section 4, the Sellafield reprocessing plant discharges technetium-99 into the Irish Sea. Previous work has shown that lobsters are very effective at concentrating technetium in flesh while other crustaceans such as crab are less effective (Swift and Nicholson, 2001). This study investigated whether there were any seasonal factors which might influence the degree of uptake (Copplestone et al., 2002). Monthly samples of crab, lobster and seaweed were taken from the south coast of the Isle of Man and analysed for radioactivity. Physical data such as size and weight were also recorded. Statistical analysis of the data showed no clear significant seasonal or short term variation in technetium-99 concentrations. The results from this work show that lobsters and crabs may be sampled for the radioactivity surveillance programme throughout the year. No seasonal bias will be introduced by such sampling.

Use of censored data – R02004

Whilst the surveillance programme reported in RIFE offers a substantial set of data of radioactivity concentrations and dose rates around nuclear sites, it is necessarily limited and provides an incomplete picture of the distributions in food and the environment. In particular the data include values at the limits of detection (LoD). This study explored options available to the Food Standards Agency to improve the use of such data and to calculate better estimates of representative concentrations (Daniels and Higgins, 2002).

Effects of radiation on aquatic organisms – AIR (98) 20

Most studies of the effects of radioactivity on the living world have been aimed at understanding the human response. It is argued that with man being protected, so is the environment. This experimental project reflected growing interest in direct protection of the environment. Groups of fish were exposed to alpha and gamma radiation in controlled conditions and their reproduction output was measured (Knowles, 2002). The data derived may be used as part of the basis for new rules for protection of the environment.

Development of ^{36}Cl method – R02014

A more sensitive method has been developed that offers an alternative to scintillation techniques for the determination of chlorine-36 in foods. This radionuclide is produced naturally by cosmic rays and as a by-product of the nuclear energy industry. Accelerator mass spectrometry (AMS) was the analytical technique chosen and problems of potential interference of sulphur-36 were overcome by reducing the sulphur content by chemical separation prior to the AMS analysis. Subsequent analysis of food samples showed that chlorine-36 was present at very low concentrations and that there is insignificant risk to consumers from the presence of this radionuclide (Rose and Baxter, 2002).

Natural radionuclides in seafood – R03010

There is relatively little UK information available on the concentration of naturally-occurring radionuclides, such as polonium-210, in fish and shellfish. This project was undertaken to gain a better understanding of the extent of natural variation in seafood obtained from UK waters. Samples of commonly consumed seafood were obtained over a three year period from a number of locations around the UK, avoiding areas where natural radioactivity might be enhanced by various industrial processes. The report confirms that there is large variation in natural radionuclide concentrations between the same species (typically 4 fold and up to 26 fold) and different sites (Young et al., 2002). The results show that the practice of using single generic UK wide values for background concentrations of naturally occurring radionuclides in seafood to calculate doses to consumers is questionable and a range of values would be more appropriate. Accurate assessments would need to rely on a detailed site-specific interpretation.

Uncommon seafoods – R02013

During the annual surveillance programme for RIFE, field workers often report minor or novel food pathways in local fishing communities. These usually involve one person or occasionally a family, eating one or more uncommon, non-commercial seafoods. There is the potential for these seafoods to be overlooked by the mainstream surveillance programme which targets commercial fishery products. In order to establish what was eaten, historical records of uncommon seafoods were reviewed and approximately 40 different species targeted for sampling and analysis. The results were reassuring and revealed that no important pathways for the accumulation of radionuclides were being missed (Swift, 2002). The surveillance programme will therefore continue to rely on commonly eaten species.

Surveillance of farmed fish – R02015

The annual production of farmed fish in the UK is about 200,000 tonnes, mainly Scottish salmon. A recent theoretical study of farmed fish showed that enhanced levels of polonium might be expected as a consequence of feeding with fishmeal (Smith and Jeffs, 1999). Polonium-210 is a naturally occurring radionuclide that can be accumulated in fish and shellfish, and levels in seawater vary around the world. Feeding farmed fish with fishmeal could potentially enhance or concentrate the polonium levels depending on where the fishmeal was sourced. This project involved the sampling and analysis of both farmed fish and fish meal-based feeds in order to demonstrate whether such an enhancement was taking place. Within the limits of the sampling exercise, the authors concluded that there was no significant enhancement of polonium-210, or other natural radionuclides (lead-210 and carbon-14) which were also studied. Consequential radiation doses were all well within limits (Smith, 2002b).

UK laboratory performance: ^{99}Tc, Cs and ^{241}Am in food – R02010

As part of continuing checks on the performance of analytical laboratories, the Food Standards Agency sponsored this study which compared results for technetium-99, caesium isotopes and americium-241 in various foodstuffs. Seventeen laboratories participated in the scheme providing 405 analytical results. The best agreement was found for caesium isotopes and americium-241. In the case of technetium-99, there were fewer results and a wider spread. The results for technetium-99 ranged over a factor of 3 for low to medium activity levels but differed by less than 40% for high levels. With few exceptions, the performance of the analytical laboratories was satisfactory for the purposes of the Food Standards Agency (Toole, 2001).

Table 12.1. Extramural projects in support of the monitoring programmes

Topic	Reference	Further details	Target completion date
RIFE Trend studies	R03011	F	Ongoing
Assessment of contaminated land	AIR (98)09	S	Complete
Seasonal variations in radionuclides in crabs and lobsters	R02011	F	Complete
Effects of radiation on aquatic organisms	AIR (98)20	S	Complete
^{36}Cl method development	R02014	F	Complete
Natural radionuclides in seafood	R03010	F	Complete
Uncommon seafoods	R02013	F	Complete
Airborne survey	AIR (98)07	S	Complete
Assessment of UK laboratory performance: ^{99}Tc, Cs, ^{241}Am in food	R02010	F	Complete
Use of censored data	R02004	F	Complete
Surveillance of farmed fish	R02015	F	Nov-02
Assessment of UK laboratory performance: tritium in fish and milk	R02012	F	Nov-02
Development of TRAMS database	R03017	F	Sep-02
Natural radionuclides in wildfood	R03009	F	Dec-02
Cs, Am and Pu in Northern Irish waters	AIR (99) 01	S	Dec-02
Enhancement to Optimon-T software	R02004	F	Dec-02
Bottled waters	R03021	F	Jan-03
Tritium and carbon-14 in seafood	R03014	F	Mar-03
Soil and herbage survey	UKRSR01	S	Jun-03
Dietary and occupancy surveys	230/2350	S	Mar-04
Total diet studies	R03019	F	Mar-04
Industrial site surveillance	R03020	F	Mar-04

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

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ACKNOWLEDGEMENTS

The Food Standards Agency and Scottish Environment Protection Agency would like to express their thanks for the hard work and dedication shown during the recent foot and mouth outbreak by the organisations responsible for collecting the samples for the programme covered in this report. These groups include:

- Centre for Environment, Fisheries and Aquaculture Science
- National Milk Records
- National Radiological Protection Board
- Veterinary Laboratories Agency
- ADAS Wales

In addition they would like to thank everyone who provided samples for the 2001 programmes. The provision of suitable samples is essential in maintaining the standard of the programmes.

APPENDIX 1. DISPOSALS OF RADIOACTIVE WASTE*

Table A1.1. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2001

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Capenhurst[r]				
Rivacre Brook	Tritium	87.5	0.124	<1
	Uranium	0.02	0.0015	7.5
	Uranium daughters	0.02	0.0022	11
	Non-uranic alpha	0.003	$2.1\ 10^{-5}$	<1
	Technetium-99	0.1	0.0013	1.3
Chapelcross	Alpha	0.1	$7.3\ 10^{-5}$	<1
	Beta[e]	25	0.026	<1
	Tritium	5.5	0.167	3.0
Drigg				
Sea pipeline	Alpha	0.1	$6.57\ 10^{-5}$	<1
	Beta[e]	0.3	0.00137	<1
	Tritium	120	0.365	<1
Stream[f]	Alpha	$9.0\ 10^{4}$	$2.53\ 10^{3}$	2.8
	Beta[e]	$1.2\ 10^{6}$	$4.10\ 10^{4}$	3.4
	Tritium	$6.0\ 10^{8}$	$1.79\ 10^{6}$	<1
Sellafield[u]	Alpha	1	0.196	20
Sea pipelines	Beta	400	123	31
	Tritium	$3.0\ 10^{4}$	2560	8.5
	Carbon-14	20.8	9.47	46
	Cobalt-60	13	1.23	9.0
	Strontium-90	48	26.1	54
	Zirconium-95+Niobium-95	9	0.272	3.0
	Technetium-99	90	79.4	88
	Ruthenium-106	63	3.89	6.0
	Iodine-129	2.0	0.629	31
	Caesium-134	6.6	0.483	7.0
	Caesium-137	75	9.57	13
	Cerium-144	8	0.789	10
	Plutonium alpha	0.7	0.155	22
	Plutonium-241	27	4.58	17
	Americium-241	0.3	0.038	13
	Uranium[d]	2040	387	19
Sellafield				
Factory sewer	Alpha	0.0033	$3.1\ 10^{-5}$	<1
	Beta	0.0135	$3.8\ 10^{-4}$	2.8
	Tritium	0.132	0.0253	19
Springfields	Alpha	4	0.16	4.0
	Beta	240	85.1	36
	Technetium-99	0.6	0.0177	3.0
	Thorium-230	2	0.0694	3.5
	Thorium-232	0.2	0.0047	2.4
	Neptunium-237	0.04	$3.0\ 10^{-4}$	<1
	Uranium	0.15	0.0478	32

* *These data are supplied by site operators to 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. All sites in England and Wales have been sent draft copies of the disharge tables for comment. Where comments have been returned, alterations have been made as necessary to the Tables.*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq[a]	% of limit[b]
United Kingdom Atomic Energy Authority				
Dounreay	Alpha[c]	0.27	0.0014	<1
	Beta[e]	49	0.309	<1
	Tritium	30.8	0.0972	<1
	Cobalt-60	0.46	$7.38\ 10^{-4}$	<1
	Strontium-90	7.7	0.161	2.1
	Zirconium-95+Niobium-95	0.4	$6.38\ 10^{-4}$	<1
	Ruthenium-106	4.1	0.00145	<1
	Silver-110m	0.13	$2.36\ 10^{-4}$	<1
	Caesium-137	23	0.0149	<1
	Cerium-144	0.42	0.00102	<1
	Plutonium-241	2.3	$7.37\ 10^{-4}$	<1
	Curium-242	0.04	$5.13\ 10^{-7}$	<1
Harwell (pipeline)	Alpha	0.001	$1.22\ 10^{-5}$	1.2
	Beta[e]	0.02	$6.06\ 10^{-4}$	3.0
	Tritium	4	0.0155	<1
	Cobalt-60	0.007	$9.35\ 10^{-6}$	<1
	Caesium-137	0.007	$6.26\ 10^{-5}$	<1
Harwell (Lydebank Brook)	Alpha	$5\ 10^{-4}$	$1.41\ 10^{-5}$	2.8
	Beta[e]	0.002	$6.27\ 10^{-5}$	3.1
	Tritium	0.1	0.0142	14
Winfrith (inner pipeline)	Alpha	0.3	$1.14\ 10^{-4}$	<1
	Tritium	650	2.38	<1
	Cobalt-60	10	0.0013	<1
	Zinc-65	6	$2.39\ 10^{-4}$	<1
	Other radionuclides	80	0.0127	<1
Winfrith (outer pipeline)	Alpha	0.004	$4.29\ 10^{-5}$	1.1
	Tritium	1	0.00653	<1
	Other radionuclides	0.01	$6.83\ 10^{-5}$	<1
Magnox Electric[h]				
Berkeley	Tritium	8	$7.4\ 10^{-4}$	<1
	Caesium-137	0.2	0.00229	1.2
	Other radionuclides	0.4	0.00392	<1
Bradwell	Tritium	30	1.8	6.0
	Caesium-137	0.75	0.469	63
	Other radionuclides	1	0.31	31
Dungeness 'A' Station	Tritium	35	2.42	6.9
	Caesium-137	1.2	0.108	9.0
	Other radionuclides	1.4	0.212	15
Hinkley Point 'A' Station	Tritium	25	1.09	4.4
	Caesium-137	1.5	0.428	29
	Other radionuclides	1	0.15	15
Hunterston 'A' Station[k]	Alpha	0.04	0.14	350
	Beta	0.6	0.0246	4.1
	Tritium	0.7	0.00405	<1
	Plutonium-241	1.0	$8.25\ 10^{-4}$	<1
Oldbury	Tritium	25	0.344	1.4
	Caesium-137	0.7	0.482	69
	Other radionuclides	1.3	0.320	25

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001 TBq[a]	% of limit[b]
Sizewell				
'A' Station	Tritium	35	2.01	57
	Caesium-137	1.0	0.759	76
	Other radionuclides	0.7	0.317	45
Trawsfynydd	Total activity[e,i,j]	0.72	0.00179	<1
	Tritium	12	0.0292	<1
	Strontium-90	0.08	$9.2\ 10^{-4}$	1.2
	Caesium-137	0.05	0.00185	3.7
Wylfa	Tritium	40	6.43	16
	Other radionuclides	0.15	0.0553	37
British Energy Generation Ltd				
Dungeness				
'B' Station	Tritium	650	356	55
	Sulphur-35	2	0.58	26
	Cobalt-60	0.03	0.00241	8.0
	Other radionuclides	0.25	0.0271	11
Hartlepool	Tritium	1200	386	32
	Sulphur-35	3	1.72	57
	Cobalt-60	0.03	0.00196	6.5
	Other radionuclides	0.3	0.00836	2.8
Heysham				
Station 1	Tritium	1200	399	33
	Sulphur-35	2.8	0.179	6.4
	Cobalt-60	0.03	$7.9\ 10^{-4}$	2.6
	Other radionuclides	0.3	0.0211	7.0
Station 2	Tritium	1200	330	28
	Sulphur-35	2.3	0.0558	2.4
	Cobalt-60	0.03	$2.29\ 10^{-4}$	<1
	Other radionuclides	0.3	0.0159	5.3
Hinkley Point				
'B' Station	Tritium	620	419	68
	Sulphur-35	5	0.483	9.7
	Cobalt-60	0.033	$4.5\ 10^{-4}$	1.4
	Other radionuclides	0.235	0.0188	8.0
Sizewell				
'B' Station	Tritium	80	64.1	80
	Other radionuclides	0.2	0.0529	27
British Energy Generation (UK) Ltd				
Hunterston				
'B' Station	Alpha	0.001	$6.09\ 10^{-5}$	6.1
	Beta[e,g,p]	0.45	0.0058	1.3
	Tritium	800	478	60
	Sulphur-35	10	2.31	23
	Cobalt-60	0.03	$4.1\ 10^{-4}$	1.4
Torness	Alpha	0.001	$6.01\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	$1.19\ 10^{-3}$	<1
	Tritium	800	274	34
	Sulphur-35	10	0.0185	<1
	Cobalt-60	0.03	$1.48\ 10^{-4}$	<1

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq[a]	% of limit[b]
Ministry of Defence				
Aldermaston (pipeline)	Alpha	$6.0\ 10^{-5}$	$5.91\ 10^{-6}$	10
	Tritium	0.05	0.00184	3.7
	Plutonium-241	$2.4\ 10^{-4}$	$2.36\ 10^{-5}$	10
	Other radionuclides	$6.0\ 10^{-5}$	$5.91\ 10^{-6}$	10
Aldermaston (Silchester)	Alpha	$4.0\ 10^{-5}$	$3.05\ 10^{-6}$	7.6
	Beta	$1.2\ 10^{-4}$	$8.02\ 10^{-6}$	6.7
	Tritium	0.05	$4.6\ 10^{-4}$	<1
Aldermaston (stream)	Tritium	0.01	0.00199	20
Barrow [l]	Tritium	0.02	$8.13\ 10^{-5}$	<1
	Manganese-54	$2.5\ 10^{-7}$	$6.98\ 10^{-10}$	<1
	Cobalt-58	$7.0\ 10^{-7}$	$4.45\ 10^{-10}$	<1
	Cobalt-60	$7.0\ 10^{-8}$	$1.31\ 10^{-9}$	1.9
	Tin-113	$2.5\ 10^{-7}$	$1.39\ 10^{-9}$	<1
	Antimony-124	$2.0\ 10^{-6}$	$1.03\ 10^{-9}$	<1
	Other radionuclides	$3.5\ 10^{-6}$	Nil	
Devonport[m,n] (sewer)	Beta		$8.71\ 10^{-6}$	
	Tritium		$8.53\ 10^{-6}$	
	Cobalt-60		$6.89\ 10^{-7}$	
Devonport[m,n] (river)	Beta		Nil	
	Tritium		"	
	Cobalt		"	
Devonport[n,o] (sewer)	Total activity		$4.98\ 10^{-4}$	
	Cobalt-60		$4.68\ 10^{-4}$	
Devonport[o] (pipeline)	Total activity[e,p]	0.001	$3.67\ 10^{-4}$	37
	Tritium	0.12	0.0762	63
	Cobalt-60	0.006	$3.76\ 10^{-5}$	<1
Faslane	Alpha activity	$2.0\ 10^{-4}$	$2.14\ 10^{-6}$	1.1
	Beta activity[e,p]	$5.0\ 10^{-4}$	$8.41\ 10^{-7}$	<1
	Tritium	1	0.0397	4.0
	Cobalt-60	$5.0\ 10^{-4}$	$2.85\ 10^{-5}$	5.7
Rosyth[q]	Alpha	$1\ 10^{-6}$	$4.8\ 10^{-8}$	4.8
	Beta[e,p]	$5\ 10^{-4}$	$1.25\ 10^{-4}$	25
	Tritium	0.04	0.00162	4.1
	Cobalt-60	0.005	$3.53\ 10^{-4}$	7.1
Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$3.1\ 10^{-5}$	10
	Beta >0.4 MeV	0.1	0.00422	4.2
	Tritium	0.2	0.00211	1.1
	Iodine-125	0.2	$4.51\ 10^{-4}$	<1
	Caesium-137	0.005	$3.5\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0233	7.8

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq[a]	% of limit[b]
Cardiff	Tritium	900	67.2	7.5
	Carbon-14	2	0.222	11
	Phosphorus-32/33	0.01	$2.59\ 10^{-6}$	<1
	Iodine-125	0.05	0.00712	14
	Others	$5.0\ 10^{-4}$	$4.81\ 10^{-7}$	<1
Imperial College Reactor Centre				
Ascot	Tritium	$1.0\ 10^{-4}$	$2.74\ 10^{-5}$	27
	Other radioactivity	$4.0\ 10^{-5}$	$3.2\ 10^{-6}$	8.0
Imperial Chemical Industries plc				
Billingham	Beta/gamma	0.36	$6.56\ 10^{-7}$	<1
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha[s]	0.00666	$3.93\ 10^{-4}$	5.9
	Alpha and beta[t]	0.0072	$5.07\ 10^{-5}$	<1
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] *Discharge authorisation was revised with effect from August 2000*
[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 and Radioactive Components Facility*
[u] *Some limits are related to the throughput of the THORP plant and may thus vary from year to year.*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2001

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq	% of limit
British Nuclear Fuels plc				
Capenhurst	Tritium	1600	0.04	<1
	Uranium[d]		1.0 10^{-6}	
Chapelcross	Tritium	5000	844	17
	Sulphur-35	0.05	0.0195	39
	Argon-41	4500	2140	48
Sellafield[a,b]	Alpha	0.00196	6.7 10^{-5}	3.4
	Beta	0.328	5.55 10^{-4}	<1
	Tritium	1440	241	17
	Carbon-14	7.30	0.953	13
	Sulphur-35	0.21	0.115	55
	Argon-41	3700	1930	52
	Cobalt-60	9.2 10^{-4}	3.0 10^{-5}	3.3
	Krypton-85	4.7 10^{5}	1.04 10^{5}	22
	Strontium-90	0.0094	5.3 10^{-5}	<1
	Ruthenium-106	0.056	0.00102	1.8
	Antimony-125	0.005	5.40 10^{-4}	11
	Iodine-129	0.070	0.0199	28
	Iodine-131	0.055	0.00228	4.1
	Caesium-137	0.0183	3.34 10^{-4}	1.8
	Plutonium (alpha)	0.00122	3.27 10^{-5}	2.7
	Plutonium-241	0.0174	1.78 10^{-4}	1.0
	Americium-241 and curium-242	7.40 10^{-4}	3.56 10^{-5}	4.8
Springfields	Uranium	0.006	4.21 10^{-4}	7.0
United Kingdom Atomic Energy Authority[h]				
Dounreay (Fuel Cycle Area)	Alpha[e]	9.8 10^{-4}	3.63 10^{-5}	3.7
	Beta[k]	0.045	2.04 10^{-4}	<1
	Tritium	2	0.339	17
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	4.05 10^{-4}	9.6
	Ruthenium-106	0.0039	1.29 10^{-5}	<1
	Iodine-129	0.0011	6.72 10^{-5}	6.1
	Iodine-131	1.5 10^{-4}	2.62 10^{-5}	18
	Caesium-134	8.4 10^{-4}	1.61 10^{-6}	<1
	Caesium-137	0.007	5.99 10^{-5}	<1
	Cerium-144	0.007	1.01 10^{-5}	<1
	Plutonium-241	0.0033	3.28 10^{-5}	<1
	Curium-242	2.7 10^{-4}	8.84 10^{-8}	<1
	Curium-244[i]	5.4 10^{-5}	9.89 10^{-8}	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	1.66 10^{-9}	<1
	Beta	0.0015	9.54 10^{-9}	<1
	Tritium	4.5	6.88 10^{-4}	<1
	Krypton-85	4.0 10^{-4}	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha	6 10^{-6}	3.82 10^{-8}	<1
	Beta	5.1 10^{-5}	4.71 10^{-7}	<1
	Tritium	22.5	0.062	<1
	Krypton-85	4	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq	% of limit
Dounreay (East minor sources)	Alpha[l]	1.37 10^{-5}	1.84 10^{-7}	1.3
	Beta[k]	3.71 10^{-4}	3.63 10^{-7}	<1
	Krypton-85	1	Nil	Nil
Dounreay (West minor sources)	Alpha[l]	3 10^{-7}	9.98 10^{-11}	<1
	Beta[k]	7.5 10^{-5}	4.65 10^{-9}	<1
	Tritium	2.25 10^{-5}	2.97 10^{-7}	1.3
Harwell	Alpha	7.0 10^{-6}	1.03 10^{-7}	1.5
	Beta	4.5 10^{-4}	2.32 10^{-6}	<1
	Tritium	150	1.56	1.0
Windscale	Alpha	1.2 10^{-5}	2.54 10^{-7}	2.1
	Beta	0.005	5.15 10^{-6}	<1
	Tritium	2.3	7.7 10^{-4}	<1
	Krypton-85	14	0.041	<1
	Iodine-131	0.0012	3.48 10^{-6}	<1
Winfrith	Alpha	2.0 10^{-6}	Nil	Nil
	Beta	2.5 10^{-5}	Nil	Nil
	Tritium	5	0.127	2.5
	Carbon-14	0.3	6.5 10^{-4}	<1
	Krypton-85	150	8.0 10^{-4}	<1
Magnox Electric[o]				
Berkeley	Alpha and beta[m]	2.0 10^{-4}	5.8 10^{-7}	<1
	Tritium	2	4.3 10^{-3}	<1
	Carbon-14	0.2	2.0 10^{-4}	<1
	Sulphur-35	0.006	Nil	Nil
Bradwell	Beta	0.001	3.26 10^{-4}	33
	Tritium	1.5	0.901	60
	Carbon-14	0.6	0.464	77
	Sulphur-35	0.2	0.083	42
	Argon-41	1000	622	62
Dungeness 'A' Station	Beta	0.001	2.2 10^{-4}	22
	Tritium	2	0.69	35
	Carbon-14	5	3.0	60
	Sulphur-35	0.4	0.036	9
	Argon-41	2000	860	43
Hinkley Point 'A' Station	Beta	0.001	2.15 10^{-6}	<1
	Tritium	25	0.632	2.5
	Carbon-14	4	0.00206	<1
	Sulphur-35	0.2	4.86 10^{-4}	<1
	Argon-41	4500	Nil	Nil
Hunterston 'A' Station[p]	Beta[j]	6.0 10^{-5}	3.6 10^{-7}	<1
	Tritium	0.02	Nil	Nil
	Carbon-14	0.002	"	"
Oldbury	Beta	0.001	1.44 10^{-4}	15
	Tritium	5	2.13	43
	Carbon-14	6	4.73	79
	Sulphur-35	0.75	0.334	45
	Argon-41	500	224	45

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			TBq	% of limit
Sizewell				
'A' Station	Beta	0.001	$1.9\ 10^{-4}$	19
	Tritium	7	2.06	29
	Carbon-14	1.5	1.02	68
	Sulphur-35	0.6	0.164	27
	Argon-41	3000	1840	61
Trawsfynydd	Beta	0.002	$1.76\ 10^{-6}$	<1
	Tritium	10	0.108	1.1
	Carbon-14	5	$2.87\ 10^{-3}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta	0.001	$2.27\ 10^{-5}$	2.3
	Tritium	20	1.61	8.0
	Carbon-14	2.4	0.404	17
	Sulphur-35	0.5	0.035	6.9
	Argon-41	120	12.7	11
British Energy Generation Ltd				
Dungeness				
'B' Station	Beta	0.001	$8.85\ 10^{-6}$	<1
	Tritium	15	0.809	5.4
	Carbon-14	5	0.523	11
	Sulphur-35	0.45	$9.98\ 10^{-3}$	2.2
	Argon-41	150	23.1	15
	Iodine-131	0.005	$2.02\ 10^{-6}$	<1
Hartlepool	Beta	0.001	$4.72\ 10^{-6}$	<1
	Tritium	6	1.82	30
	Carbon-14	5	2.09	42
	Sulphur-35	0.16	0.0637	40
	Argon-41	60	19.8	33
	Iodine-131	0.005	$2.25\ 10^{-5}$	<1
Heysham				
Station 1	Beta	0.001	$7.72\ 10^{-6}$	<1
	Tritium	6	1.39	23
	Carbon-14	4	1.23	31
	Sulphur-35	0.12	0.0212	18
	Argon-41	60	5.48	9.1
	Iodine-131	0.005	$1.11\ 10^{-4}$	2.2
Heysham				
Station 2	Beta	0.001	$1.11\ 10^{-5}$	1.1
	Tritium	15	1.7	11
	Carbon-14	3	1.16	39
	Sulphur-35	0.3	0.0185	6.2
	Argon-41	85	17.6	21
	Iodine-131	0.005	$4.06\ 10^{-5}$	<1
Hinkley Point				
'B' Station	Beta	0.001	$3.32\ 10^{-5}$	3.3
	Tritium	30	5.04	17
	Carbon-14	8	1.14	14
	Sulphur-35	0.4	0.136	34
	Argon-41	300	12.7	4.2
	Iodine-131	0.005	$5.66\ 10^{-5}$	1.1
Sizewell				
'B' Station (outlets 1-3)	Noble gases	295	4.93	1.7
	Halogens	0.0027	$9.28\ 10^{-5}$	3.4
	Beta	0.01	$7.34\ 10^{-6}$	<1
	Tritium	7.8	1.82	23
	Carbon-14	0.59	0.179	30

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001	
			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	$4.84\ 10^{-5}$	2.4
	Tritium	20	7.34	37
	Carbon-14	3	1.9	63
	Sulphur-35	0.8	0.0582	7.3
	Argon-41	220	64.2	29
Torness	Beta[j]	0.002	$1.13\ 10^{-5}$	<1
	Tritium	20	2.4	12
	Carbon-14	3	0.561	19
	Sulphur-35	0.8	0.0283	3.5
	Argon-41	220	5.70	2.6
Ministry of Defence				
Aldermaston[a,n]	Alpha	$4.5\ 10^{-7}$	$7.1\ 10^{-8}$	16
	Other beta and gamma emitters[f]	$5.0\ 10^{-6}$	$8.05\ 10^{-8}$	1.6
	Tritium	170	5.58	3.3
	Krypton-85	1.0	$4.1\ 10^{-3}$	<1
	Plutonium-241	$1.68\ 10^{-6}$	$2.1\ 10^{-7}$	13
Barrow[g]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.08	"	"
Burghfield[a,n]	Alpha	$2.0\ 10^{-8}$	$8.1\ 10^{-10}$	4.1
	Tritium	0.05	Nil	Nil
Coulport	Tritium	0.05	0.00148	3.0
Dounreay				
(Vulcan)	Alpha[j]	10^{-6}	$1.09\ 10^{-7}$	11
	Beta[j]	10^{-4}	$1.6\ 10^{-6}$	1.6
	Noble gases	0.027	Nil	Nil
	Iodine-131	$3.7\ 10^{-4}$	$2.84\ 10^{-5}$	7.7
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	"	"
Amersham plc				
Amersham	Alpha	$2.0\ 10^{-6}$	$1.0\ 10^{-7}$	5.0
	Other (penetrating)	0.05	$7.80\ 10^{-5}$	<1
	Other (non-penetrating)	0.5	0.0084	1.7
	Tritium	40	Nil	Nil
	Selenium-75	0.03	$2.9\ 10^{-4}$	<1
	Iodine-125	0.1	$2.8\ 10^{-3}$	3.0
	Iodine-131	0.05	$5.2\ 10^{-4}$	1.0
	Radon-222	10	2.8	28
Cardiff	Soluble tritium	400	112	28
	Insoluble tritium	1000	442	44
	Carbon-14	6	1.37	23
	Phosphorus-32/33	$2.0\ 10^{-4}$	$3.19\ 10^{-6}$	1.6
	Iodine-125	$5.0\ 10^{-4}$	$1.55\ 10^{-4}$	31
	Other activity	0.04	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2001 TBq	% of limit
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$6.2\ 10^{-5}$	12
	Argon-41	2.5	0.427	17
Imperial Chemical Industries plc				
Billingham	Tritium	2	$3.0\ 10^{-8}$	<1
	Argon-41	2	Nil	Nil
Ortho-Clinical Diagnostics Ltd				
Cardiff	Iodine-125	0.015	$8.01\ 10^{-4}$	5.3
	Other activity	$5.0\ 10^{-4}$	Nil	Nil
Rolls Royce Marine Power Operations Ltd				
Derby	Alpha	[d]	$1.43\ 10^{-6}$	
Scottish Universities Research and Reactor Centre				
East Kilbride	Tritium	19.2	$5.54\ 10^{-5}$	<1
	Argon-41	3.33	Nil	Nil
Urenco (Capenhurst) Ltd				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$1.2\ 10^{-7}$	4.8

[a] *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location. Limits for carbon-14, ruthenium-106 and iodine-129 were revised with effect from 1 January 2001. The limits for these radionuclides apply to the whole site.*
[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 BAE SYSTEMS Marine Ltd*
[h] *Data includes contributions from tenants*
[i] *Data includes any curium-243 present*
[j] *Particulate activity*
[k] *Excluding tritium and krypton-85*
[l] *Excluding radon and daughter products*
[m] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[n] *Discharges were made by AWE plc*
[o] *Magnox Electric is a wholly owned subsidiary of BNFL plc*
[p] *Discharge limits were revised with effect from August 2000*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2001

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2001	
			TBq	% of limit
Drigg	Tritium	10	1.8	18
	Carbon-14	0.05	0.0061	12
	Cobalt-60	2	0.072	3.6
	Iodine-129	0.05	$3.7\ 10^{-5}$	<1
	Radium-226 plus thorium-232	0.03	$8.8\ 10^{-4}$	2.9
	Uranium	0.3	0.019	6.2
	Other alpha[a]	0.3	0.034	12
	Others[a,b]	15	1.9	13
Dounreay[c]	Alpha		$1.6\ 10^{-4}$	
	Beta/gamma		$3.3\ 10^{-4}$	

[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]	$2.60\ 10^{-4}$	$5.38\ 10^{-3}$	[b]	$6.10\ 10^{-6}$
	Ravenglass	[a]	$3.82\ 10^{-4}$	$3.36\ 10^{-3}$	[b]	$1.80\ 10^{-5}$
	Drigg	[a]	$3.68\ 10^{-4}$	[b]	$1.04\ 10^{-1}$	$1.91\ 10^{-5}$
	Isle of Man	[a]	$3.64\ 10^{-4}$	$4.16\ 10^{-3}$	$1.73\ 10^{-3}$	$1.11\ 10^{-5}$
Beef	Sellafield	[a]	$2.60\ 10^{-1}$	[b]	[b]	$6.10\ 10^{-4}$
	Ravenglass	[a]	$3.82\ 10^{-1}$	$1.68\ 10^{-1}$	[b]	$1.38\ 10^{-3}$
Lamb	Sellafield	[a]	$3.00\ 10^{-1}$	[b]	[b]	$4.14\ 10^{-4}$
	Ravenglass	[a]	$4.41\ 10^{-1}$	$1.59\ 10^{-1}$	[b]	$6.35\ 10^{-4}$
Beef offal	Sellafield	[a]	$2.60\ 10^{-1}$	[b]	[b]	[a]
	Ravenglass	[a]	$3.82\ 10^{-1}$	[a]	[b]	[a]
Lamb offal	Sellafield	[a]	$3.00\ 10^{-1}$	[b]	[b]	$2.11\ 10^{-2}$
	Ravenglass	[a]	$4.41\ 10^{-1}$	[a]	[b]	$4.76\ 10^{-2}$

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

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
DoENI	Department of Environment Northern Ireland
DoH	Department of Health
DS	Discharge Strategy
DSTL	Defence Science and Technology Laboratory
DTI	Department of Trade and Industry
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
NDAWG	National Dose Assessment Working Group
NEA	Nuclear Energy Agency
NGO	Non-governmental Organisation
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
QNL	Quarterly Notification Level
RIFE	Radioactivity in Food and the Environment
RNAD	Royal Naval Armaments Depot
RSA 93	Radioactive Substances Act 1993
RWMAC	Radioactive Waste Management Advisory Committee
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 (Year of last survey)	Group[a]	Rates
Aldermaston (1991)		1 kg y^{-1} pike 360 h y^{-1} over riverbank
Amersham (1991)		1 kg y^{-1} pike 1600 h y^{-1} over riverbank
Berkeley and Oldbury (2001)		18 kg y^{-1} salmonids and other fish 2.3 kg y^{-1} shrimps 520 h y^{-1} over mud
Bradwell (1999)		44 kg y^{-1} fish 3.1 kg y^{-1} crustaceans 6.5 kg y^{-1} molluscs 2900 h y^{-1} over mud[b]
Capenhurst (NA)		0.0025 kg y^{-1} sediment 2.5 l y^{-1} water
Cardiff (1998)		34 kg y^{-1} fish 1.4 kg y^{-1} prawns 990 h y^{-1} over mud and sand
Channel Islands (1997)		62 kg y^{-1} fish 30 kg y^{-1} crustaceans 30 kg y^{-1} molluscs 1400 h y^{-1} over mud and sand

Table A4.2. continued

Site	Group[a]	Rates
Chapelcross (2000)	A	20 kg y^{-1} salmonids (80%) and other fish (20%)
		12 kg y^{-1} shrimps
		3.0 kg y^{-1} mussels
		1000 h y^{-1} over mud and sand
	B	500 h y^{-1} over salt marsh
	C	1100 h y^{-1} handling nets
Devonport (1992)		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay (1999)	A	1800 h y^{-1} handling pots
	B	19 kg y^{-1} fish
		14 kg y^{-1} crab and lobster
		2.2 kg y^{-1} winkles
	C	430 h y^{-1} over sand and rock
	D	25 h y^{-1} in a Geo
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (1999)		59 kg y^{-1} fish
		17 kg y^{-1} crustaceans
		15 kg y^{-1} molluscs
		1500 h y^{-1} over mud and sand
Faslane (2000)	A	200 h y^{-1} over mud
	B	9.9 kg y^{-1} fish
		1400 h y^{-1} over mud and sand
Hartlepool (2000)		59 kg y^{-1} fish
		35 kg y^{-1} crab
		9.4 kg y^{-1} winkles
		520 h y^{-1} over sand[b]
Harwell (1991)		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham (2001)		36 kg y^{-1} fish
		18 kg y^{-1} shrimps
		19 kg y^{-1} cockles and other molluscs
		1200 h y^{-1} over mud and sand
Hinkley Point (2000)		43 kg y^{-1} fish
		9.8 kg y^{-1} shrimps and prawns
		1.8 kg y^{-1} whelks
		960 h y^{-1} over mud
Holy Loch (1989)		900 h y^{-1} over mud
Hunterston (2001)	A	29 kg y^{-1} fish
		22 kg y^{-1} Nephrops and squat lobsters
		2 kg y^{-1} queen scallops
	B	1200 h y^{-1} over mud and sand
Rosyth (1999)	A	21 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		5.6 kg y^{-1} molluscs
	B	1100 h y^{-1} over mud and sand
Sellafield	A (2001)	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 (1998)	1200 h y^{-1} handling nets and pots

Table A4.2. continued

Site	Group[a]	Rates
Sellafield (cont.)		
	C (bait diggers) (1998)	950 h y^{-1} handling sand
	D (Whitehaven commercial) (1998)	40 kg y^{-1} plaice and cod
		9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	E (Morecambe Bay)	See Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	G (Dumfries and Galloway) (1996)	38 kg y^{-1} plaice, cod and salmon
		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) (1972)	47 kg y^{-1} laverbread
	I (Trout) (2001)	6.8 kg y^{-1} rainbow trout
	J (typical fish consumer) (NA)	15 kg y^{-1} cod and plaice
	K (Isle of Man) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	L (Northern Ireland) (2000)	99 kg y^{-1} haddock and other fish
		34 kg y^{-1} Nephrops and crabs
		7.7 kg y^{-1} mussels and other molluscs
		1100 h y^{-1} over mud and sand
	M (North Wales) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	N (Sellafield 1997-2001) (NA)	39 kg y^{-1} fish
		14 kg y^{-1} crabs
		6.3 kg y^{-1} lobsters
		1.1 kg y^{-1} Nephrops
		8.1 kg y^{-1} winkles
		7.5 kg y^{-1} other molluscs
		1000 h y^{-1} over sand and mollusc beds
Sizewell (2001)		40 kg y^{-1} fish
		8.4 kg y^{-1} crab and lobster
		6.4 kg y^{-1} Pacific oysters and mussels
		1000 h y^{-1} over mud
Springfields (2000)	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 (2001)	A	41 kg y^{-1} fish
		17 kg y^{-1} Nephrops, crab and lobster
		5.9 kg y^{-1} mussels
		490 h y^{-1} over sand
	B	1800 h y^{-1} handling fishing gear
Trawsfynydd (1994)		1.8 kg y^{-1} brown trout
		22 kg y^{-1} rainbow trout
		0.93 kg y^{-1} perch
		1000 h y^{-1} over lake shore
Upland lake (NA)		37 kg y^{-1} fish
Whitehaven (2001)		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 (1987)		77 kg y^{-1} cod
		26 kg y^{-1} crab
		39 kg y^{-1} whelks
Wylfa (1988)		94 kg y^{-1} fish
		23 kg y^{-1} crab
		1.8 kg y^{-1} molluscs
		370 h y^{-1} over sand

[a] *Where more than one group exists at a site the groups are denoted A, B, etc.*
[b] *Not assessed in this report for 2001*
NA not applicable

APPENDIX 5. DOSIMETRIC DATA [ICRP 72]

Radionuclide	Half Life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology (Sv.Bq^{-1})			
				Adults	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 (Young *et al*., 2002 and unpublished studies). Data for lead-210 and polonium-210 are from a detailed study and are quoted as medians with minimum and maximum values given in brackets.. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background. Similarly, natural levels of carbon-14 are subtracted when assessing exposures due to man-made sources of this radionuclide. The natural concentrations of carbon-14 are determined by measuring the carbon concentration in each sample and applying a specific activity of 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	0.042 (0.0030-0.55)	0.02 (0.013-2.4)	0.24 (0.043-0.76)	0.080 (0.02-0.79)	1.2 (0.18-6.8)	1.5 (0.69-2.6)	1.6 (0.68-6.8)	0.94 (0.59-1.3)	0.39 (0.18-0.61)	1.5 (0.68-4.9)
Polonium-210	0.82 (0.18-4.4)	9.1 (1.1-35)	19 (4.1-35)	5.3 (1.9-10)	17 (1.2-69)	13 (6.1-25)	42 (19-69)	18 (11-36)	6.5 (1.2-11)	8.4 (5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

6.2 Terrestrial foodstuffs

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

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

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