RIFE - 3

Radioactivity in Food and the Environment, 1997

Ministry of Agriculture, Fisheries and Food

SCOTTISH ENVIRONMENT PROTECTION AGENCY

1998

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Preface

This report presents the results of surveillance programmes for radioactivity carried out by the Joint Food Safety and Standards Group, Ministry of Agriculture, Fisheries and Food and the Scottish Environment Protection Agency in 1997. Measurements of radioactivity have been carried out in a range of foodstuffs and other materials close to nuclear sites throughout the United Kingdom. These measurements have been used to estimate the doses that could be received via ingestion of foodstuffs and external radiation by members of the "critical group" or people likely to be the most exposed at these sites.

In addition measurements have also been made at locations remote from nuclear sites and near other industries which may cause elevated levels of radioactivity in food. The impact of both natural and man-made radionuclides has been considered.

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

EXECUTIVE SUMMARY

The report demonstrates that foodstuffs and seafood produced in and around the United Kingdom in 1997 are radiologically safe to eat and that the exposure of consumers to artificially produced radioactivity via the foodchain remains well below UK and EU limits.

Natural radionuclides are the most important source of exposure in the average diet of consumers. Man-made radionuclides contributed less than 5% of the dose.

Estimated doses to high-rate fish and shellfish consumers, in the vicinity of Sellafield, from artificial radionuclides in the diet have decreased from 14% (in 1996) to 10% (in 1997) of the EU dose limit of 1 millisievert. The decrease was largely due to changes in the consumption of shellfish by these people.

The highest dose to members of the public in the UK from both artificial and natural radioactivity was estimated to be 0.49 millisieverts to high-rate fish and shellfish consumers in the Whitehaven area.

The highest doses in Scotland were also attributable to liquid wastes from Sellafield and were received by a group of high-rate fish and shellfish consumers in Dumfries and Galloway. Their dose was 0.047 millisievert. Technetium-99 contributed the single largest dose to this group, 0.010 millisievert in 1997, a reduction from 0.019 millisievert in 1996 due to a decrease in the detected levels in *Nephrops*.

Levels of technetium-99 in lobsters from the vicinity of Sellafield were again above those specified in the EU post-accident intervention levels and were comparable to 1996 levels. The assessed dose to the most exposed group of seafood consumers from technetium-99 discharges was less than 5% of the EU dose limit.

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RESUME OF MAIN FINDINGS

Radiation doses at nuclear sites

- Doses were all within the 1 mSv (millisievert) limit for the public.
- The highest doses were due to liquid wastes from the reprocessing plant at Sellafield where high-rate fish and shellfish consumers received 0.10 mSv in 1997 as compared with 0.14 mSv in 1996. The decrease was largely due to changes in consumption rates of shellfish. This critical group also received a dose of up to 0.28 mSv from natural radioactivity discharged from the Albright and Wilson Ltd works at Whitehaven.
- The highest doses in Scotland were also attributable to liquid wastes from Sellafield and were received by a group of high-rate fish and shellfish consumers in the Dumfries and Galloway area. Their radiological dose was 0.047 mSv. Technetium-99 contributed the single largest dose to this group, 0.010 mSv in 1997, a reduction from 0.019 mSv in 1996 due to a decrease in the detected levels of this radionuclide in *Nephrops.*
- External exposure resulting from discharges was highest for a person living on a boat in Whitehaven harbour whose dose was 0.16 mSv. Those most exposed to external radiation further afield from Sellafield were people on a houseboat in the Ribble estuary and their dose was 0.13 mSv in 1997, a small reduction from the value for 1996.
- The highest doses from gaseous wastes were also seen at Sellafield. High-rate consumers of milk, vegetables, fruit and meat received a dose of 0.044 mSv, similar to the value for 1996.
- Doses at all major sites in the UK are shown in Figures S1 and S2 and are detailed below.

Radioactivity levels at nuclear sites

- There were no changes in radionuclide concentrations in food and radiation dose rates in 1997 which had significant dose implications.
- Near Sellafield the higher levels of technetium-99 in seafood typical of recent years were maintained.
- Dose rates in Whitehaven harbour increased due to the redistribution of sediment-associated activity as a result of dredging.
- Incident monitoring was carried out after a release of ruthenium-106 from Sellafield in November. Localised contamination in adjacent fields was found but no intervention in the food supply was required.
- Two contaminated seagulls were found and removed from local beaches near Sellafield. Their contamination may have come from the open spent fuel storage ponds. Contaminated pigeons were also found in February 1998 (see section 4.1.5).
- Sea-to-land transfer of technetium-99 took place on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser.
- The report includes the results of analysis of tritium in seafood near Cardiff for the first time. Relatively high levels were found though the doses due to consumption were relatively small because of the low toxicity of this radionuclide.

Radiation doses and levels at other locations in the UK

- Analyses of food throughout the UK demonstrated that natural radionuclides are by far the most significant source of exposure remote from nuclear sites.
- Monitoring of artificial radioactivity on the Isle of Man and in Northern Ireland showed that doses were all less than 3% of the 1 mSv EU limit.
- A habits 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 2% of the EU limit.
- Concentrations of natural radionuclides in fish and shellfish near Whitehaven Works (Albright and Wilson Ltd) continued to be enhanced above normal levels. Doses to high-rate seafood consumers, including the effects of artificial radionuclides from the Sellafield site nearby, were 0.49 mSv.
- No evidence was found for enhancement of natural radionuclides near other non-nuclear industrial sites.
- Tritium was found to leach from some landfill sites but the radiological significance of the levels was negligible.

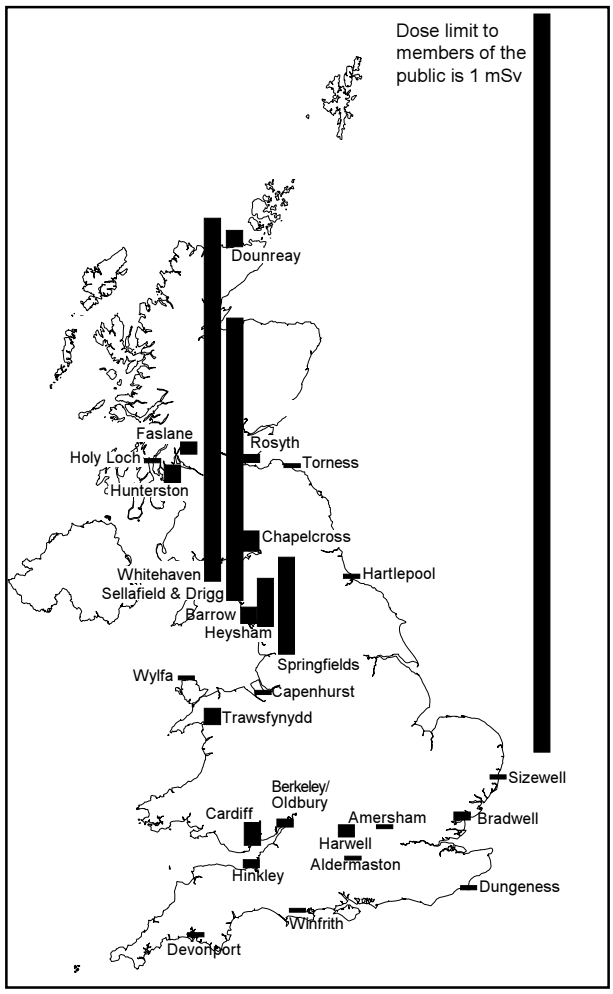

Figure S.1. Radiation exposures in the UK due to liquid radioactive waste discharges, 1997.
(Historic discharges from Sellafield have a significant effect on exposures throughout the Irish Sea. Exposures at Whitehaven and Sellafield include the effects of enhanced concentrations of natural radionuclides)

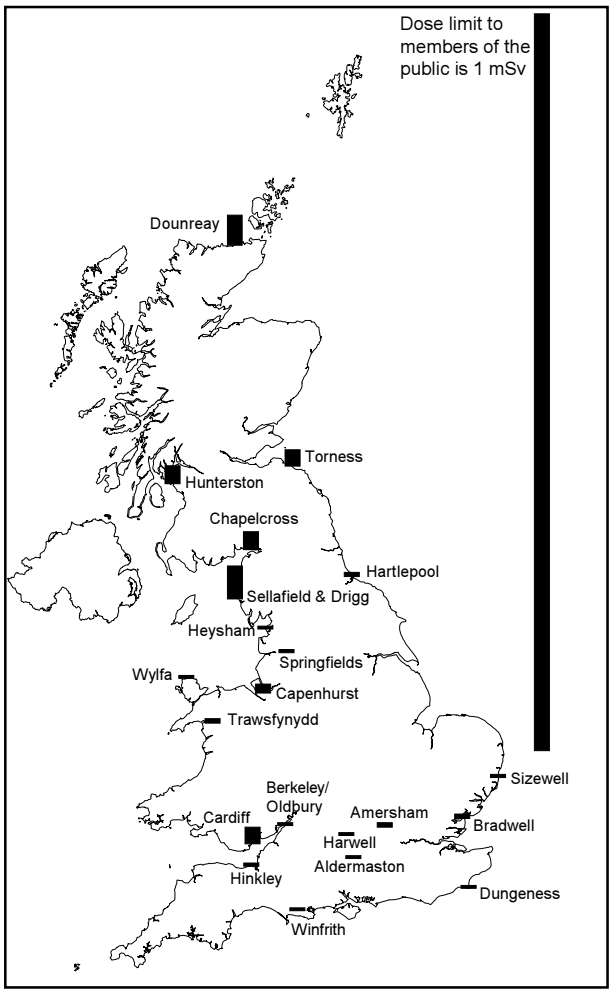

Figure S.2. Radiation exposures in the UK due to gaseous radioactive discharges, 1997

The surveillance programmes

- The programmes involved the collaboration of six specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the UK.

- They were organised independently of the industries discharging wastes by MAFF on behalf of the Channel Island States, the Environment and Heritage Service for Northern Ireland, the Manx Government and the Welsh Office, and by SEPA.

- This year's programmes required the collection of 1800 food samples and 3900 other samples as indicators of environmental levels. 18000 analyses or dose rate measurements were completed.

- From January 1998 onwards, measurements of dose rates in England and Wales and concentrations in sediments have been undertaken and will be reported by the Environment Agency as part of their responsibility for the environment.

- There will be less sampling of grass and soil close to nuclear sites. However there will be an expansion in surveillance of tritium and technetium-99 in foodstuffs.

- Results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries on the internet (www.maff.gov.uk.)

- Further details of all programmes described in this report can be obtained by 'phoning MAFF on **0171 238 6476** or SEPA on **01786 457 700**.

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 1997

Establishment	Radiation exposure pathway[h]	Critical group	Exposure, mSv[a]
British Nuclear Fuels plc			
Sellafield and Drigg[b]	All foodstuffs	Local consumers at Sellafield	0.035
	Fish and shellfish consumption	Local fishing community	0.10
	Terrestrial foods	Local consumers at Sellafield	0.044
	"	" " " Drigg	0.018
	"	" " " Ravenglass	0.031
	External	Farmers	0.081
	"	Houseboat dwellers (River Ribble)	0.13
	External[c]	Yachtsman (Whitehaven)	0.16
	"	Anglers	0.057
	External (skin)	"	0.88[d]
	Handling of fishing gear	Local fishing community	0.13[d]
	Porphyra/laverbread consumption	Consumers in South Wales	<0.005
	Trout consumption	Local consumers at Sellafield	<0.005
	Seaweed/crops	" " " "	0.093
Springfields	All foodstuffs	Local consumers	0.011
	External	Houseboat dwellers (River Ribble)	0.13
	"	Farmers	0.024
	"	Bird warden	0.058
	" (skin)	"	3.1[d]
	"	Anglers	0.014
	" (skin)	"	0.70[d]
	" "	Local fishermen	0.24[d]
	Fish and shellfish consumption and external	Local fishing community	0.051
	Terrestrial foods	Local consumers[g]	<0.005[f]
	Wildfowl consumption and external	Wildfowlers	0.035
	Exterial (skin)	"	1.2[d]
Capenhurst	Inadvertent ingestion of water and sediment	Local community	<0.005
	Terrestrial foods	Local consumers	0.013
Chapelcross	All foodstuffs	Local consumers	0.022
	Fish and shellfish consumption and external	Local fishing community	0.029
	External	Wildfowlers	0.021
	Terrestrial foods	Local consumers	0.025
United Kingdom Atomic Energy Authority			
Dounreay	All foodstuffs	Local consumers	0.020
	Handling of fishing gear	Local fishermen	<0.16[d]
	Fish and shellfish consumption	Local fishing community	<0.005
	Mollusc consumption and external	Mollusc collectors	0.020
	External	Local community	0.007
	Terrestrial foods	Local consumers[j]	0.040
Harwell	Fish consumption and external	Anglers	0.014
	Terrestrial foods	Local consumers	<0.005
Winfrith	All foodstuffs	Local consumers	<0.005
	Fish and shellfish consumption	Local fishing community	<0.005
	Terrestrial foods	Local consumers[j]	<0.005
Electricity Companies			
Berkeley and Oldbury	All foodstuffs	Local consumers	0.020
	Fish and shellfish consumption and external	Local fishing community	0.013
	Terrestrial foods	Local consumers	<0.005
Bradwell	All foodstuffs	Local consumers	<0.005
	Fish and shellfish consumption and external	Houseboat dwellers	0.012
	Terrestrial foods	Local consumers	0.006
Dungeness	All foodstuffs	Local consumers	0.005
	Fish and shellfish consumption and external	Bait diggers	0.008
	Terrestrial foods	Local consumers[g]	<0.005
Hartlepool	All foodstuffs	Local consumers	<0.005
	Fish and shellfish consumption	Local fishing community	<0.005
	Terrestrial foods	Local consumers	0.006
Heysham	All foodstuffs	Local consumers	0.013
	Fish and shellfish consumption and external	Local fishing community	0.073
	Terrestrial foods	Local consumers	<0.005

Summary Table: continued

Establishment	Radiation exposure pathway[h]	Critical group	Exposure, mSv[a]
Electricity Companies *continued*			
Hinkley Point	All foodstuffs	Local consumers	<0.005
	External	Local fishing community	0.013[i]
	Terrestrial foods	Local consumers	<0.005
Hunterston	All foodstuffs	Local consumers	0.017
	Fish and shellfish consumption and external	Local fishing community	0.027
	Terrestrial foods	Local consumers[j]	0.025
Sizewell	All foodstuffs	Local consumers	<0.005
	Fish and shellfish consumption and external	Local fishing community	<0.005
	Terrestrial foods	Local consumers	<0.005
Torness	All foodstuffs	Local consumers	0.014
	Fish and shellfish consumption	Local fishing community	0.008
	External	Local community	<0.005
	Terrestrial foods	Local consumers	0.023
Trawsfynydd	Fish consumption and external	Local fishing community	0.023
	Terrestrial foods	Local consumers[g]	0.006
Wylfa	All foodstuffs	Local consumers	<0.005
	Fish and shellfish consumption and external	Local fishing community	0.006
	Terrestrial foods	Local consumers	<0.005
Defence Establishments			
Aldermaston	Fish consumption and external	Anglers	<0.005
	Terrestrial foods	Local consumers[g]	<0.005[f]
Barrow	External	Local community	0.023
Devonport	Fish and shellfish consumption and external	Local community	<0.005
Faslane	External	Local community	0.015
Holy Loch	External	Local community	0.005
Rosyth	External	Local community	0.010
Amersham International plc			
Amersham	Fish consumption and external	Anglers	<0.005
	Terrestrial foods	Local consumers	0.006
Cardiff	All foodstuffs	Local consumers	0.052
	Fish and shellfish consumption and external	Local fishing community	0.032
	Terrestrial foods	Local consumers	0.023
Albright and Wilson Ltd			
Whitehaven[e]	Fish and shellfish consumption	Local fishing community	0.40

[a] *Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv (see section 6). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. All exposures for terrestrial pathways include a component from radionuclides which were found to be below the limits of detection. Unless stated otherwise, the critical group for terrestrial pathways is represented is represented by the 1 year old age group*

[b] *The estimates for marine pathways include the effects of liquid discharges from Drigg, but exclude the effects of natural radionuclides. The contribution due to Drigg is negligible. The exposure due to enhanced concentrations of natural radionuclides for seafood consumers in 1997 was 0.28 mSv*

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

[d] *Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see section 6)*

[e] *These estimates include the effects of enhanced concentrations of natural radionuclides but exclude a small contribution from the effects of artificial radionuclides from other sites. They assume a gut uptake factor of 0.8 for polonium which is based on studies of seafood consumption (see section 6). The exposure due to artificial radionuclides in 1997 was 0.091 mSv*

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

[g] *Adults*

[h] *The exposure from ingestion of all foodstuffs is based on the INTAKE methods and data (Section 6) and includes components due to liquid and gaseous discharges*

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

[j] *15 y old*

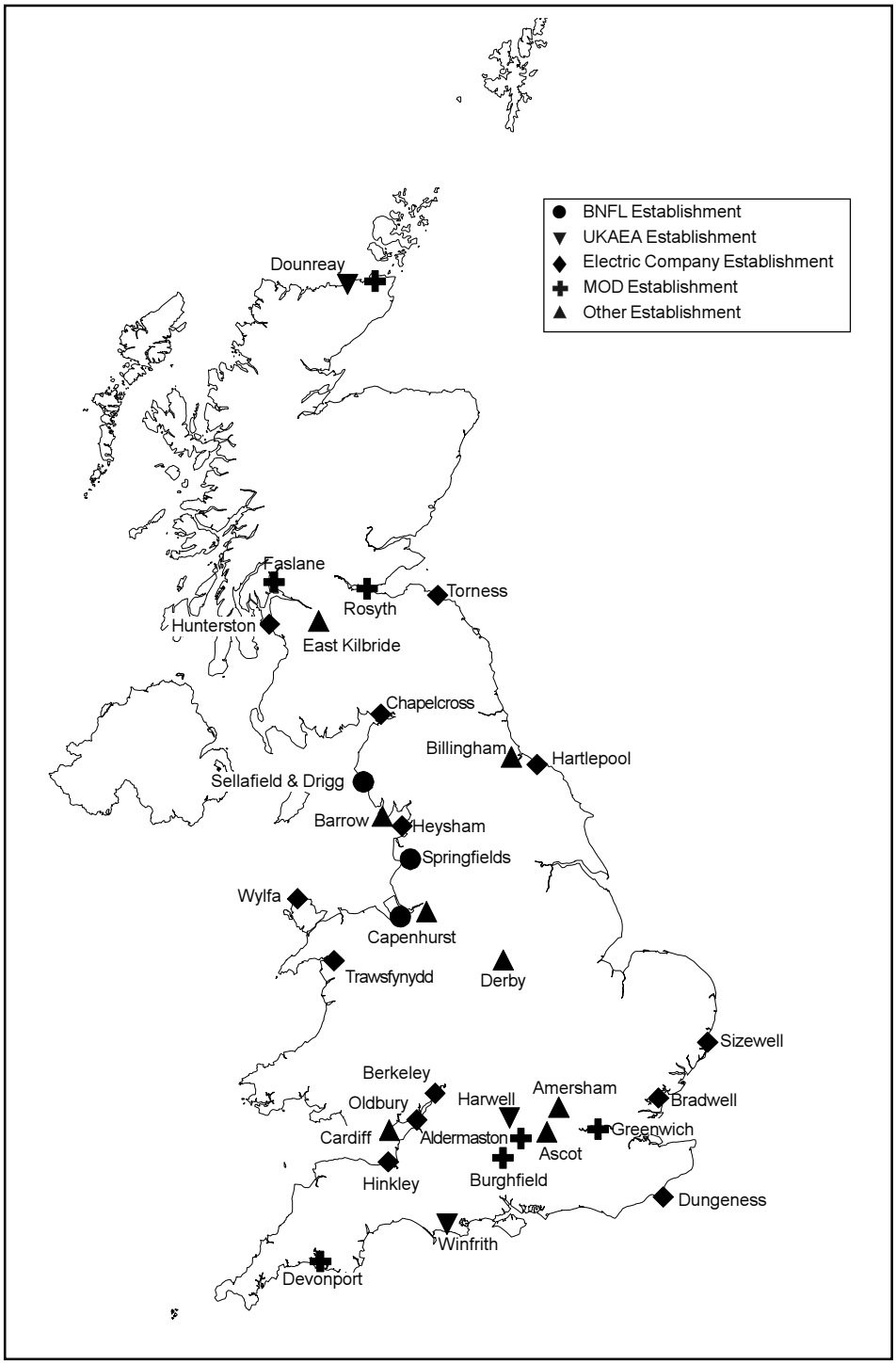

Figure 1.1. Principal sources of radioactive waste disposal in the UK

1. INTRODUCTION

1.1 Background

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

Since the publication of the previous report, the Food Safety and Standards Group of MAFF has become part of the Joint Food Safety and Standards Group of the Ministry of Agriculture, Fisheries and Food and the Department of Health. It is envisaged that this group will form the basis of the proposed Food Standards Agency and that the Agency will continue MAFF's radiological surveillance activities.

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

This report is jointly published by MAFF and SEPA.

The data in this report are for 1997 and the results of the programmes are assessed by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of MAFF, SEPA, the Welsh Office, the Environment and Heritage Service (Northern Ireland), the Manx Government and the Channel Island States. Additional monitoring is sponsored by the Environment Agency (e.g. Environment Agency, 1998) and the Environment and Heritage Service (e.g. EHS, 1996). The purpose of the programme is to verify that the levels of radioactivity present within foodstuffs are acceptable and to ensure that public radiation exposure from the consumption of these foods is within UK and internationally accepted limits. In Scotland SEPA has a broader responsibility (under the Environment Act 1995) for protecting (and determining general levels of pollution in) the environment. The monitoring is independent of similar programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. The bulk of the report concerns the local effects of disposals from nuclear sites in the United Kingdom. However, data on the marine environment of the whole of the British Isles and further afield together with information on the levels of radioactivity in foodstuffs in areas of the UK remote from nuclear sites is included. Where appropriate, the monitoring data for nuclear sites are supplemented by results from other projects related to the behaviour of radioactivity in the environment. A summary of the scope of all radioactivity monitoring programmes as undertaken by nuclear site operators and local and central government can be found in Cotter *et al*. (1992).

To set the monitoring results from the programme in context, radioactive waste disposals from nuclear establishments in the United Kingdom in 1997 are first summarised in section 1.2. Before the results are presented, an explanatory section gives details of methods of sampling, analysis and presentation and explains how results are interpreted in terms of public radiation exposures. A glossary of terms and abbreviations is provided at Appendix 2.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from, and in, sites on land

Data on radioactive waste disposals are published annually by the Department of Environment, Transport and the Regions (DETR, 1997), the latest available publication being for the year 1995. Details of the disposals from individual sites are available from public registers held by the Environment Agency and SEPA. A summary of 1997 disposals is included here and this enables the results of monitoring presented in this report to be considered in the context of the relevant disposals. The sites which are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. Our programme includes monitoring at each of these sites. For completeness, it should be noted that disposals of radioactive waste are also authorised from other sites such as hospitals, chemical works and research establishments. Occasionally the impact of such disposals is detected within this programme, for example, iodine-131 originating from hospitals is detected in some marine samples. Small amounts of solid waste are also disposed of in specified landfill sites. In general these disposals are so insignificant that environmental monitoring of their effects is not required. However, this situation is reviewed from time to time, and small surveys are included in the programme where relevant.

Tables 1.1, 1.2 and 1.3 list the principal disposals of liquid, gaseous and solid radioactive waste respectively from nuclear establishments in the United Kingdom during 1997. The Tables also list the disposal limits which are authorised or, in the case of Crown operators, 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 very much lower than the levels of activities which would equate to the dose limits which are recommended by the International Commission on Radiological Protection (ICRP), and embodied in national policy (United Kingdom - Parliament, 1995a). The percentages of the authorised (or agreed) limits taken up in 1997 are also stated in the tables.

Where changes in the rates of disposal in 1997 have materially affected the levels of radioactivity in the environment, comments are made to this effect in the relevant part of the subsequent text.

1.2.2 Radioactive waste disposal at sea

In addition to receiving most of the discharges of liquid radioactive effluents , the marine environment has also, in the past, received packaged solid waste of low specific activity, mainly disposed of in an area of the deep Atlantic Ocean. Such disposals no longer take place, the last being in 1982. In 1997 the Government announced that it would be relinquishing its opt-out from the ban on dumping radioactive waste at sea. The Government formally withdrew this option at the OSPAR Ministerial meeting held in Portugal in July 1998. The environmental impact of the deep ocean disposals is determined by 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 1997 are presented in Section 11.3, which confirms the negligible radiological significance of these disposals.

During the period of the preparation of last year's report searches of archive records relating to dumping of radioactive waste at sea were undertaken. These identified several previously unrecognised sites around the UK where small amounts of radioactive waste were dumped in the past, details of which were given in Parliamentary replies (United Kingdom – Parliament, 1997a). These wastes were from a variety of industrial and university sources and not the nuclear power industry.

The Government asked the National Radiological Protection Board (NRPB) to carry out an independent assessment of the radiological significance of the disposals. The assessment (Titley *et al*, 1997) concluded that the estimated doses from the dispersion of radionuclides in marine waters were not significant in radiological protection terms and that there was no need for additional environmental monitoring in connection with the disposals. The results of the assessment were given in a written Parliamentary reply (United Kingdom – Parliament, 1997b).

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

In addition to solid waste disposal at sea and discharges from United Kingdom installations, there are several other possible sources of radioactivity which may affect the marine foodchain and the environment. These include transport incidents, satellite re-entry, release from overseas installations and the operation of nuclear powered submarines. Submarine berths in the UK are monitored by the Ministry of Defence (DRPS, 1996). 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 1997.

Table 1.1. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 1997

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq[a]	% of limit[b]
British Nuclear Fuels plc				
Sellafield	Alpha	1	0.185	18
Sea pipelines	Beta	400	138	35
	Tritium	$2.5\ 10^{4}$	2560	10
	Carbon-14	20.8	4.42	21
	Cobalt-60	13	1.47	11
	Strontium-90	48	37.3	78
	Zirconium-95+Niobium-95	9	0.364	4.0
	Technetium-99	200	84.2	42
	Ruthenium-106	63	9.81	16
	Iodine-129	1.6	0.519	32
	Caesium-134	6.6	0.299	4.5
	Caesium-137	75	7.94	11
	Cerium-144	8	0.494	6.2
	Plutonium alpha	0.7	0.147	21
	Plutonium-241	27	3.26	12
	Americium-241	0.3	0.0505	17
	Uranium[d]	2040	759	37
Factory sewer	Alpha	0.0033	$8.1\ 10^{-5}$	2.5
	Beta	0.0135	$5.4\ 10^{-4}$	4.0
	Tritium	0.132	0.0124	9.4
Drigg				
Sea pipeline	Alpha	0.1	$2.18\ 10^{-4}$	<1
	Beta[e]	0.3	0.00738	2.5
	Tritium	120	1.69	1.4
Stream[f]	Alpha	$9.0\ 10^{4}$	57.1	<1
	Beta[e]	$1.2\ 10^{6}$	881	<1
	Tritium	$6.0\ 10^{8}$	$9.2\ 10^{4}$	<1
Springfields	Alpha	4	0.121	3.0
	Beta	240	142	59
	Technetium-99	0.6	0.0329	5.5
	Thorium-230	2	0.0522	2.2
	Thorium-232	0.2	0.0011	<1
	Neptunium-237	0.04	$2.10\ 10^{-4}$	<1
	Uranium	0.15	0.0568	38
Capenhurst				
Rivacre Brook	Uranium	0.02	$5.6\ 10^{-4}$	2.8
	Uranium daughters	0.02	0.0029	15
	Non-uranic alpha	0.003	$1.4\ 10^{-5}$	<1
	Technetium-99	0.1	0.00133	1
Chapelcross	Alpha	0.1	$3.19\ 10^{-4}$	<1
	Beta[e]	25	0.0397	<1
	Tritium	5.5	0.198	3.6
United Kingdom Atomic Energy Authority				
Dounreay	Alpha[c]	0.75	0.0255	3.4
	Beta[e]	110	0.952	<1
	Tritium	130	0.824	<1
	Cobalt-60	1	0.0217	2.2
	Strontium-90	12	0.223	1.9
	Zirconium-95+Niobium-95	6	0.0120	<1
	Ruthenium-106	12	0.0145	1.2
	Silver-110m	0.4	0.0060	1.5
	Caesium-137	50	0.326	<1
	Cerium-144	12	0.0076	<1
	Plutonium-241	15	0.252	1.7
	Curium-242	1	$5.0\ 10^{-4}$	<1
Harwell (pipeline)	Alpha	0.001	$2.11\ 10^{-5}$	2.1
	Beta[e]	0.02	0.00101	5.1
	Tritium	4	0.0305	<1
	Cobalt-60	0.007	$9.53\ 10^{-5}$	1.4
	Caesium-137	0.007	$2.23\ 10^{-4}$	3.2
Harwell (Lydebank Brook)	Alpha	$5\ 10^{-4}$	$2.54\ 10^{-5}$	5.1
	Beta[e]	0.002	$2.09\ 10^{-4}$	10
	Tritium	0.1	0.0195	19
Winfrith (inner pipeline)	Alpha	0.3	0.00179	<1
	Tritium	650	3.90	<1
	Cobalt-60	10	$8.55\ 10^{-4}$	<1
	Zinc-65	6	$4.10\ 10^{-4}$	<1
	Other radionuclides	80	0.0342	<1

Table 1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq[a]	% of limit[b]
Winfrith (outer pipeline)	Alpha	0.004	$9.50\ 10^{-5}$	2.4
	Tritium	1	0.0142	1.4
	Other radionuclides	0.01	$1.49\ 10^{-4}$	1.5
Magnox Electric plc				
Berkeley	Tritium	8	0.0552	<1
	Caesium-137	0.2	0.0173	8.7
	Other radionuclides	0.4	0.0544	14
Bradwell	Tritium	30	1.46	4.9
	Caesium-137	0.75	0.466	62
	Other radionuclides	1	0.383	38
Dungeness 'A' Station	Tritium	35	0.135	<1
	Caesium-137	1.2	0.520	43
	Other radionuclides	1.4	0.272	19
Hinkley Point 'A' Station	Tritium	25	0.810	3.2
	Caesium-137	1.5	0.484	32
	Other radionuclides	1	0.223	22
Hunterston 'A' Station	Total activity[e]	2	0.165	8.3
	Tritium	5	0.00990	<1
Oldbury	Tritium	25	0.178	<1
	Caesium-137	0.7	0.0417	6.0
	Other radionuclides	1.3	0.231	18
Sizewell 'A' Station	Tritium	35	5.06	14
	Caesium-137	1.0	0.0980	10
	Other radionuclides	0.7	0.135	19
Trawsfynydd	Total activity[e,i,j]	0.72	0.00902	1.3
	Tritium	12	0.298	2.5
	Strontium-90	0.08	0.00194	2.4
	Caesium-137	0.05	0.00701	14
Wylfa	Tritium	40	7.02	18
	Other radionuclides	0.15	0.0461	31
Nuclear Electric Ltd				
Dungeness 'B' Station	Tritium	650	247	38
	Sulphur-35	2	0.357	18
	Cobalt-60	0.03	0.00159	5.3
	Other radionuclides	0.25	0.0250	10
Hartlepool	Tritium	1200	367	31
	Sulphur-35	3	0.804	27
	Cobalt-60	0.03	0.00483	16
	Other radionuclides	0.3	0.00637	2.1
Heysham Station 1	Tritium	1200	465	39
	Sulphur-35	2.8	0.262	9.4
	Cobalt-60	0.03	$6.87\ 10^{-4}$	2.3
	Other radionuclides	0.3	0.00698	2.3
Station 2	Tritium	1200	351	29
	Sulphur-35	2.3	0.0486	2.1
	Cobalt-60	0.03	$5.64\ 10^{-4}$	1.9
	Other radionuclides	0.3	0.0101	3.4
Hinkley Point 'B' Station	Tritium	620	385	62
	Sulphur-35	5	0.868	17
	Cobalt-60	0.033	$7.1\ 10^{-4}$	2.0
	Other radionuclides	0.235	0.0149	6.3

Table 1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq[a]	% of limit[b]
Sizewell				
'B' Station[h]	Tritium	80	44.2	55
	Other radionuclides	0.2	0.0213	11
Scottish Nuclear Ltd				
Hunterston				
'B' Station	Alpha	0.001	$6.0\ 10^{-5}$	6.0
	Beta[e,g,p]	0.45	0.00412	<1
	Tritium	800	413	52
	Sulphur-35	10	1.36	14
	Cobalt-60	0.03	0.00110	3.7
Torness	Alpha	0.001	$7.09\ 10^{-6}$	<1
	Beta[e,g,p]	0.45	0.00375	<1
	Tritium	800	324	41
	Sulphur-35	10	0.077	<1
	Cobalt-60	0.03	$4.52\ 10^{-4}$	1.5
Ministry of Defence				
Aldermaston (pipeline)[k]	Alpha	$1.5\ 10^{-4}$	$1.85\ 10^{-5}$	12
	Tritium	0.05	0.00175	3.5
	Plutonium-241	$6.0\ 10^{-4}$	$7.42\ 10^{-5}$	12
	Other radionuclides	$1.5\ 10^{-4}$	$1.11\ 10^{-5}$	7.4
Aldermaston (Silchester)[k]	Alpha	$1.0\ 10^{-4}$	$7.28\ 10^{-6}$	7.3
	Beta	$3.0\ 10^{-4}$	$3.64\ 10^{-5}$	12
Barrow[l]	Tritium	0.02	Nil	
	Manganese-54	$2.5\ 10^{-7}$	"	
	Cobalt-58	$7.0\ 10^{-7}$	"	
	Cobalt-60	$7.0\ 10^{-8}$	"	
	Tin-113	$2.5\ 10^{-7}$	"	
	Antimony-124	$2.0\ 10^{-6}$	"	
	Other radionuclides	$3.5\ 10^{-6}$	"	
Burghfield[k]	Alpha	$2.0\ 10^{-6}$	$4.27\ 10^{-8}$	2.1
	Other radionuclides	$1.2\ 10^{-5}$	$8.54\ 10^{-8}$	<1
Devonport[m,n] (sewer)	Beta		$1.97\ 10^{-9}$	
	Tritium		$2.22\ 10^{-9}$	
	Cobalt-60		$5.60\ 10^{-10}$	
Devonport[m,n] (river)	Beta		Nil	
	Tritium		"	
	Cobalt		"	
Devonport[n,o] (sewer)	Total activity		$5.33\ 10^{-4}$	
	Cobalt-60		$4.82\ 10^{-4}$	
Devonport[o] (pipeline)	Total activity[e,p]	0.001	$2.67\ 10^{-5}$	2.6
	Tritium	0.12	0.0656	55
	Cobalt-60	0.006	$5.36\ 10^{-5}$	<1
Faslane	Alpha activity	$2.0\ 10^{-4}$	$1.68\ 10^{-5}$	8.4
	Beta activity[e,p]	$5.0\ 10^{-4}$	$8.27\ 10^{-6}$	1.7
	Tritium	1	0.0728	7.3
	Cobalt-60	$5.0\ 10^{-4}$	$5.5\ 10^{-5}$	11
Greenwich	Alpha and beta	$4.44\ 10^{-6}$	$4.17\ 10^{-7}$	9.4
Rosyth[q]	Alpha	10^{-6}	$8.8\ 10^{-8}$	8.8
	Beta[e,p]	$5\ 10^{-4}$	$2.19\ 10^{-4}$	44
	Tritium	0.01	0.00774	77
	Cobalt-60	0.01	$5.25\ 10^{-4}$	5.3
Nycomed Amersham plc				
Amersham	Alpha	$3.0\ 10^{-4}$	$4.63\ 10^{-5}$	15
	Beta >0.4 MeV	0.1	0.00798	8.0
	Tritium	0.2	0.00320	1.6
	Iodine-125	0.2	0.00106	<1
	Caesium-137	0.005	$1.26\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0514	17
Cardiff	Tritium	900	473	53
	Carbon-14	2	1.33	67
	Phosphorus-32/33	0.01	$3.26\ 10^{-5}$	<1
	Iodine-125	0.05	0.0115	23
	Others	$5.0\ 10^{-4}$	$8.23\ 10^{-5}$	16

Table 1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq[a]	% of limit[b]
Imperial College Reactor Centre				
Ascot	Tritium	$1.0\ 10^{-4}$	$1.96\ 10^{-6}$	2.0
	Other radioactivity	$4.0\ 10^{-5}$	$1.38\ 10^{-6}$	3.5
Imperial Chemical Industries plc				
Billingham	Beta/gamma	0.36	$9.69\ 10^{-8}$	<1
Rolls Royce plc				
Derby	Alpha	0.00666	$3.60\ 10^{-4}$	5.4
Scottish Universities Research and Reactor Centre				
East Kilbride	Total activity	$1.56\ 10^{-3}$	$4.30\ 10^{-7}$	<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] *Authorisation was revised with effect from 1 October 1997. The discharges presented are for 1997. The limits are the annual limits in effect from the date of revision*
[i] *Excluding caesium-137*
[j] *Excluding strontium-90*
[k] *Discharges are made by Hunting-BRAE Ltd*
[l] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges are made by Vickers Shipbuilding and Engineering 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 plc. Authorisation was revised with effect from 13 March 1997. The discharges presented are for 1997. The limits are the annual limits in effect from the date of the revision*
[p] *Excluding cobalt-60*
[q] *Discharges are made by Rosyth Royal Dockyard plc*

Table 1.2. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 1997

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq	% of limit
British Nuclear Fuels plc				
Sellafield[a,b]	Alpha	0.0017	$2.1\ 10^{-4}$	1.2
	Beta	0.048	0.00172	3.6
	Tritium	1400	164	12
	Carbon-14	8.4	1.57	18
	Sulphur-35	0.21	0.09	43
	Argon-41	3700	2540	69
	Cobalt-60	$9.2\ 10^{-4}$	$8.20\ 10^{-5}$	8.9
	Krypton-85	$3.5\ 10^{5}$	$9.6\ 10^{4}$	27
	Strontium-90	0.0016	$9.8\ 10^{-5}$	6.1
	Ruthenium-106	0.046	$7.07\ 10^{-3}$	15
	Antimony-125	0.005	$2.20\ 10^{-4}$	4.4
	Iodine-129	0.052	0.0252	48
	Iodine-131	0.055	0.00262	4.8
	Caesium-137	0.0073	$6.20\ 10^{-4}$	8.5
	Plutonium (alpha)	$8.4\ 10^{-4}$	$1.0\ 10^{-4}$	12
	Plutonium-241	0.0051	$7.90\ 10^{-4}$	15
	Americium-241 and curium-242	$3.6\ 10^{-4}$	$6.40\ 10^{-5}$	18
Springfields	Uranium	0.006	$1.96\ 10^{-3}$	33
Capenhurst[d]	Tritium			
	Uranium		$1.16\ 10^{-6}$	
Chapelcross	Tritium	5000	1030	21
	Sulphur-35	0.05	0.0232	46
	Argon-41	4500	2730	61
United Kingdom Atomic Energy Authority[h]				
Dounreay (Fuel Cycle Area)	Alpha	0.001	$6.36\ 10^{-5}$	6.4
	Beta	0.045	$8.42\ 10^{-4}$	1.9
	Tritium	40	0.0383	<1
	Krypton-85	1000	Nil	Nil
	Strontium-90	0.005	$1.05\ 10^{-3}$	21
	Ruthenium-106	0.007	$3.61\ 10^{-5}$	<1
	Iodine-129	0.004	$1.25\ 10^{-5}$	<1
	Iodine-131	0.003	$1.45\ 10^{-5}$	<1
	Caesium-134	0.001	$5.20\ 10^{-6}$	<1
	Caesium-137	0.007	$1.71\ 10^{-4}$	2.4
	Cerium-144	0.007	$1.91\ 10^{-5}$	<1
	Plutonium-241	0.005	$2.29\ 10^{-3}$	46
	Curium-242	0.001	$4.86\ 10^{-7}$	<1
	Curium-244[i]	10^{-4}	$1.09\ 10^{-6}$	1.1
Dounreay (Fast Reactor)	Beta	0.0015	$1.12\ 10^{-6}$	<1
	Tritium	130	0.0188	<1
	Krypton-85	$4.0\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Tritium	18	0.573	3.2
	Argon-41	1.5	Nil	Nil
	Krypton-85m	10	"	"
	Krypton-87	20	"	"
	Krypton-88	20	"	"
	Xenon-133	3750	"	"
	Xenon-133m	75	"	"
	Xenon-135	350	"	"
Harwell	Alpha	$7.0\ 10^{-6}$	$2.39\ 10^{-7}$	3.4
	Beta	$4.5\ 10^{-4}$	$5.20\ 10^{-6}$	1.2
	Tritium	150	2.50	1.7
Windscale	Alpha	$1.2\ 10^{-5}$	$3.15\ 10^{-7}$	2.6
	Beta	0.005	$5.59\ 10^{-6}$	< 1
	Tritium	2.3	0.00653	<1
	Krypton-85	14	0.273	2.0
	Iodine-131	0.0012	$4.10\ 10^{-6}$	<1
Winfrith	Alpha	$2.0\ 10^{-6}$	$6.76\ 10^{-9}$	<1
	Beta	$2.5\ 10^{-5}$	Nil	Nil
	Tritium	15	0.366	2.4
	Carbon-14	0.3	$6.90\ 10^{-4}$	<1
	Krypton-85	150	$4.20\ 10^{-4}$	<1
Magnox Electric plc[e]				
Berkeley Technology Centre	Alpha and beta	$2.0\ 10^{-5}$	$1.59\ 10^{-6}$	8
Power Station and Technology Centre	Alpha and beta	$2.0\ 10^{-4}$	$3.72\ 10^{-6}$	1.9
	Tritium	2	0.0107	<1
	Carbon-14	0.2	$3.05\ 10^{-4}$	<1
	Sulphur-35	0.006	Nil	Nil

Table 1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq	% of limit
Bradwell	Beta	0.001	$1.98\ 10^{-4}$	20
	Tritium	1.5	1.10	73
	Sulphur-35	0.2	0.0751	38
	Carbon-14	0.6	0.276	46
	Argon-41	1000	510	51
Dungeness 'A' Station	Beta	0.001	$3.00\ 10^{-4}$	30
	Tritium	2	0.57	29
	Carbon-14	5	3.2	64
	Sulphur-35	0.4	0.0715	18
	Argon-41	2000	977	49
Hinkley Point 'A' Station	Beta	0.001	$1.68\ 10^{-4}$	17
	Tritium	25	2.98	12
	Carbon-14	4	1.91	48
	Sulphur-35	0.2	0.0707	35
	Argon-41	4500	3030	67
Hunterston 'A' Station	Beta[j]	10^{-4}	$2.00\ 10^{-7}$	<1
	Tritium	1	$4.94\ 10^{-3}$	<1
	Carbon-14	0.2	$1.79\ 10^{-4}$	<1
Oldbury	Beta	0.001	$1.01\ 10^{-4}$	10
	Tritium	5	1.48	30
	Carbon-14	6	3.87	65
	Sulphur-35	0.75	0.266	35
	Argon-41	500	111	22
Sizewell 'A' Station	Beta	0.001	$7.34\ 10^{-5}$	7.3
	Tritium	7	0.639	9.1
	Carbon-14	1.5	0.530	35
	Sulphur-35	0.6	0.0357	6.0
	Argon-41	3000	1230	41
Trawsfynydd	Beta	0.002	$2.30\ 10^{-6}$	<1
	Tritium	10	0.277	2.8
	Carbon-14	5	$8.02\ 10^{-3}$	<1
	Sulphur-35	0.4	Nil	Nil
	Argon-41	3500	"	"
Wylfa	Beta	0.001	$7.35\ 10^{-5}$	7.4
	Tritium	20	5.29	26
	Carbon-14	2.4	1.33	55
	Sulphur-35	0.5	0.21	42
	Argon-41	120	51.4	43
Nuclear Electric plc[e]				
Dungeness 'B' Station	Beta	0.001	$3.45\ 10^{-5}$	3.5
	Tritium	15	4.78	32
	Carbon-14	5	0.473	9.5
	Sulphur-35	0.45	0.0119	2.6
	Argon-41	150	19.3	13
	Iodine-131	0.005	$4.40\ 10^{-6}$	<1
Hartlepool	Beta	0.001	$2.53\ 10^{-5}$	2.5
	Tritium	6	1.61	27
	Carbon-14	5	1.61	32
	Sulphur-35	0.16	0.0312	20
	Argon-41	60	37.8	63
	Iodine-131	0.005	$1.93\ 10^{-4}$	3.9
Heysham Station 1	Beta	0.001	$4.76\ 10^{-5}$	4.8
	Tritium	6	0.636	11
	Carbon-14	4	1.30	33
	Sulphur-35	0.12	0.0144	12
	Argon-41	60	7.92	13
	Iodine-131	0.005	0.00111	22
Heysham Station 2	Beta	0.001	$5.17\ 10^{-5}$	5.2
	Tritium	15	2.08	14
	Carbon-14	3	0.817	27
	Sulphur-35	0.3	0.0147	4.9
	Argon-41	85	21.0	25
	Iodine-131	0.005	$2.46\ 10^{-4}$	4.9
Hinkley Point 'B' Station	Beta	0.001	$7.53\ 10^{-5}$	7.5
	Tritium	30	1.96	6.5
	Carbon-14	8	1.41	18
	Sulphur-35	0.4	0.0731	18
	Argon-41	300	16.7	5.2
	Iodine-131	0.005	$2.05\ 10^{-5}$	<1

Table 1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq	% of limit
Sizewell				
'B' Station (outlets 1-3)	Noble gases	295	4.36	1.5
	Halogens	0.0027	$3.42\ 10^{-5}$	1.3
	Beta	0.01	$4.97\ 10^{-6}$	<1
	Tritium	7.8	0.565	7.2
	Carbon-14	0.59	0.0759	13
" (Approved places)	Noble gases	5	Nil	Nil
	Halogens	$3.0\ 10^{-4}$	"	"
	Tritium	0.2	$2.61\ 10^{-5}$	<1
	Carbon-14	0.01	$4.66\ 10^{-7}$	<1
Scottish Nuclear Ltd[e]				
Hunterston				
'B' Station	Beta[j]	0.002	$3.43\ 10^{-5}$	1.7
	Tritium	20	2.81	14
	Carbon-14	3	1.67	56
	Sulphur-35	0.8	0.127	16
	Argon-41	220	66.1	30
Torness	Beta[j]	0.002	$1.49\ 10^{-5}$	<1
	Tritium	20	1.81	9.1
	Carbon-14	3	0.497	17
	Sulphur-35	0.8	0.0385	4.8
	Argon-41	220	12.2	5.5
Ministry of Defence				
Aldermaston[a]	Alpha	$9.0\ 10^{-7}$	$1.44\ 10^{-7}$	16
	Beta[f]	$4.6\ 10^{-6}$	$1.91\ 10^{-7}$	4.2
	Tritium	340	4.09	1.2
	Krypton-85	0.4	$5.66\ 10^{-3}$	1.4
Barrow[g]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.08	"	"
Burghfield[a]	Alpha	$2.0\ 10^{-8}$	$2.80\ 10^{-10}$	1.4
	Tritium	0.35	$1.72\ 10^{-4}$	< 1
	Krypton-85	1	Nil	Nil
Dounreay				
(Vulcan)	Noble gases	9.25	Nil	Nil
	Iodine	$1.85\ 10^{-3}$	$2.94\ 10^{-5}$	<1
	Fission products	0.0592	$1.3\ 10^{-6}$	<1
Greenwich	Argon-41	[d]	Nil	
Rosyth[c]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	"	"
Nycomed Amersham plc				
Amersham	Alpha	$2.0\ 10^{-6}$	$2.40\ 10^{-7}$	12
	Other (penetrating)	0.05	$1.30\ 10^{-4}$	<1
	Other (non-penetrating)	0.5	0.026	5.2
	Tritium	40	$5.70\ 10^{-4}$	<1
	Selenium-75	0.03	$3.50\ 10^{-4}$	1.2
	Iodine-125	0.1	0.011	11
	Iodine-131	0.05	0.0018	3.6
	Radon-222	10	1.4	14
Cardiff	Soluble tritium	400	160	40
	Insoluble tritium	1000	480	48
	Carbon-14	6	3.02	50
	Phosphorus-32/33	$2.0\ 10^{-4}$	$2.94\ 10^{-6}$	1.5
	Iodine-125	$5.0\ 10^{-4}$	$1.11\ 10^{-4}$	22
	Other activity	0.04	$8.17\ 10^{-5}$	<1
Imperial College Reactor Centre				
Ascot	Tritium	$5.0\ 10^{-4}$	$1.91\ 10^{-4}$	38
	Argon-41	2.5	0.823	33
Imperial Chemical Industries plc				
Billingham	Tritium	2	$8.40\ 10^{-6}$	<1
	Argon-41	2	Nil	Nil
Johnson and Johnson Clinical Diagnostics Ltd				
Cardiff	Iodine-125	0.015	0.00166	11
	Other activity	$5.0\ 10^{-4}$	$1.65\ 10^{-5}$	3.3
Rolls Royce plc				
Derby	Alpha	[d]	$9.53\ 10^{-7}$	

Table 1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 1997	
			TBq	% of limit
Scottish Universities Research and Reactor Centre				
East Kilbride	Tritium Argon-41	19.2 3.33	Nil "	
URENCO				
Capenhurst	Uranium	$2.5\ 10^{-6}$	$6.80\ 10^{-8}$	2.7

[a] *Discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location.*
[b] *Some limits are related to the operation of the THORP plant and may thus vary from year to year*
[c] *Discharges are made by Rosyth Royal Dockyard plc*
[d] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[e] *Discharges may also be authorised from incinerators at these sites*
[f] *Excluding tritium and plutonium-241*
[g] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges are made by Vickers Shipbuilding and Engineering Ltd*
[h] *Data includes contributions from tenants*
[i] *Data includes any curium-243 present*
[j] *Particulate activity*

Table 1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 1997

Establishment	Radioactivity	Disposal limit, TBq	Disposals during 1997	
			TBq	% of limit
Drigg	Tritium	10	0.266	2.7
	Carbon-14	0.05	0.00455	9.1
	Cobalt-60	2	0.165	8.3
	Iodine-129	0.05	$4.0\ 10^{-5}$	<1
	Radium-226 plus thorium-232	0.03	0.00589	20
	Uranium	0.3	0.0658	22
	Other alpha[a]	0.3	0.064	21
	Others[a,b]	15	3.16	21
Dounreay[c]	Alpha			
	Beta/gamma			

[a] *With half-lives greater than three months*
[b] *Other beta emitting radionuclides but including iron-55 and cobalt-60*
[c] *Limits exist for concentrations of activity, activity per unit area and dose rate. Data for 1997 not available at time of report preparation*

2. SAMPLING AND MEASUREMENT

2.1 Sampling programme

The primary purpose of the MAFF programme is to monitor the safety of the food-chain. In order to assess the total radiation dose received by a member of the public, for comparison with dose limits, samples from the environment are also taken. In this context the term sampling includes the collection of samples from the environment for laboratory analysis (which is mainly directed at food pathways), and also 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 the programme has the further aim of determining environmental levels of radioactivity and ensuring the protection of the environment as well as the foodchain.

Sampling is focussed at nuclear sites licensed by the Health and Safety Executive under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965). Here the programme also serves to provide information to assist the Environment Agency to fulfil its statutory duties under the Radioactive Substances Act, 1993. Additional sampling is carried out remote from nuclear sites to establish the general safety of the foodchain and the environment. This can be affected by disposals of radioactive waste from nuclear sites abroad and shows the legacy of atmospheric fallout from past nuclear weapon testing and the reactor accident at Chernobyl.

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

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

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

2.1.1 Nuclear sites

Nuclear sites are the prime focus of the programme as they are responsible for the largest disposals of radioactive waste. Monitoring is carried out close to each of the sites shown in Figure 1.1. Most sampling and direct monitoring is conducted in the site's immediate vicinity. However, because of the ability to detect the effects of disposals of liquid effluent from BNFL Sellafield in many parts of north-European waters, the programme for this site extends beyond national boundaries.

The main aim of the programme is to monitor the diet of consumers who live near nuclear sites and to estimate exposures for those small groups of people who are most at risk from disposals of radioactive waste. In the aquatic environment, the pathways which are most relevant to such a programme are ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. In the terrestrial environment they are 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, 1998). Inhalation of airborne activity and external exposure from airborne material and surface deposition are difficult to assess by direct measurement and are more amenable to assessment using environmental models. The main thrust of the monitoring is therefore directed at foodstuffs of all kinds and measurements of external exposures on the shores of seas, rivers and lakes.

This report contains the results of foodstuff and dose rate monitoring throughout the United Kingdom in 1997. From January 1998 onwards, the responsibility for the bulk of surveillance of external exposure in England and Wales passed to the Environment Agency who will publish their results in a separate report. However, the RIFE report will continue to provide external exposure information in Scotland, and in England and Wales where it has foodchain implications.

2.1.1.1 The aquatic programme

The general scope of the aquatic programme in 1997 is summarised in Table 2.2. The main components were sampling and laboratory analysis of a wide range of seafood and indicator materials and direct measurements of external dose rates in areas of known or suspected contamination and where public occupation occurs or is likely to occur. In both cases the frequency of measurement depends on the level of environmental impact from the source under scrutiny, the intervals between measurements varying between 1 week and 1 year. In addition, large-area contamination monitoring is carried out along beaches at selected sites. This is to establish whether there is any unusual localised radioactivity which may be missed by the sediment sampling and measurement regime which is by definition selective.

The types of material sampled and the locations where samples are taken from are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from local habits surveys and other sources. As a consequence the programme varies from site to site and indeed from year to year, according to local circumstances. For example, shrimps are an important fishery at Hinkley Point and are a key foodstuff in the programme at this site. At Springfields commercial fishing is limited and the bulk of the monitoring addresses external exposure pathways.

Measurements of indicator materials, such as sediments and seaweeds, whilst less directly relevant to dose, still perform an important function by, for example, providing information on trends in contamination levels in the environment. These materials can concentrate particular radionuclides and offer a cost-effective means of determining levels of activity. In the case of sediments, there is an immediate use for activity concentration data in assessments. Such data can also be used to help distinguish contributions to the overall dose rates from artificial and natural radionuclides and different sources of artificial radioactivity.

Data from the aquatic programme is also used to aid the development of models for assessment of prospective doses.

2.1.1.2 The terrestrial programme

The general scope of the terrestrial programme in 1997 is summarised in Table 2.2. The main focus of this programme is the sampling and analysis of foodstuffs which may be affected by gaseous disposals, although in some cases where food availability is limited, environmental indicator materials such as grass are monitored in place of food. Grass and soil were also sampled and analysed in 1997 in relation to the Euratom Treaty (see section 9.5). The results from this part of the programme are due to cease in 1998 in response to changing requirements under articles 35 and 36 of the Euratom treaty.

The types of foodstuff sampled are chosen on a site-by-site basis to reflect local availability, however the basis of the choice is to provide information on the main components of diet; milk, meat and cereals, and on products most likely to be contaminated by disposals, such as leafy green vegetables or soft fruit. Minor foods such as mushrooms and honey, which are known to accumulate radioactivity in some circumstances, are also sampled when available.

For monitoring purposes cows' milk is generally the most important foodstuff as grass is an efficient collector of atmospheric contaminants and many of the more important radionuclides are rapidly passed from grass into milk. Milk is also a convenient product to regularly sample and analyse and is an important part of the diet, especially for young children and infants. In addition cows graze a large area of pasture and therefore the monitoring of milk provides a method of carrying out surveillance of large areas. For most analyses of milk, weekly or monthly collections are bulked to provide four quarterly samples for analysis each year, although some analyses may be carried out more frequently. The frequency of analysis of other foodstuffs is generally annual in order to allow for as wide a range of sample types as possible. Samples are collected from locations as close to the sites as practicable as these are the most sensitive to the effects of disposals. In the case of milk, sampling may take place at several farms and these are labelled either as 'near' or 'far' in the tables of results depending on their distance from the site. The threshold for distinguishing between near and far farms is 8 km.

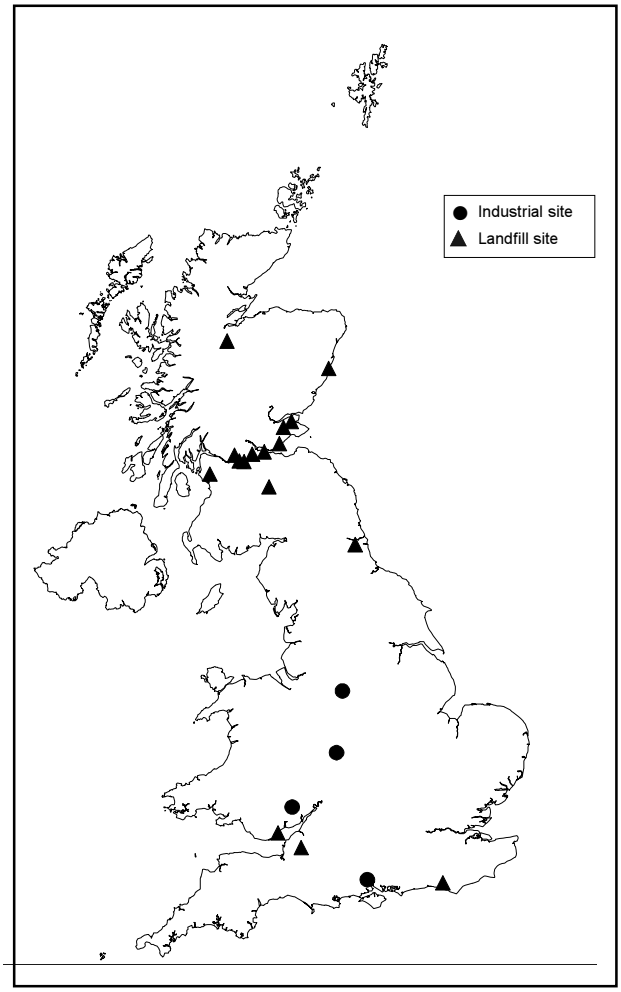

Figure 2.1. Industrial and landfill sites studied in 1997

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

2.1.2 Industrial and landfill sites

Whilst the main focus of the combined 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 1997 are shown in Figure 2.1.

A limited number of industrial sites are chosen for study because either they are known from previous research to have a measurable impact on the foodchain or they represent a type of industrial activity which has potential effects on the environment. These sites do not require licensing under the Nuclear Installations Act. In 1997, the industrial sites studied were:

- Whitehaven, Cumbria (a phosphate plant)
- Buxton, Derbyshire (a lime kiln)
- Llanwern, Newport (steel works)
- Southampton, Hampshire (industrial waste incinerator)
- Redditch, Hereford and Worcester (hospital waste incinerator)

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

Four landfill sites were monitored in England and Wales and twelve in Scotland. These sites are amongst those that have been approved for disposal of very low levels of radioactivity. They are studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment and hence the foodchain.

2.1.3 Chernobyl fallout

The main effort to monitor the effects of the 1986 Chernobyl accident was in relation to the continuing restrictions on the movement 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 since the accident, but there remains a small scale survey of caesium radionuclides in freshwater fish taken from a few upland lakes.

2.1.4 Additional monitoring

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

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

2.1.4.1 Isle of Man and the Channel Islands

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

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

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

2.1.4.2 General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information which is useful in interpreting site-related data and also helps ensure that all significant sources of contamination form part of the site-related programme. Representative mixed diet samples are collected from thirteen regions throughout the United Kingdom. Each diet sample is prepared as for consumption and combined in amounts which reflect the relative importance of each food in the average UK diet. These samples are analysed for a range of components including radionuclides. Part of this data is also supplied to the European Commission as part of the 'Euratom monitoring' detailed later in this report in section 9.5.

2.1.4.3 Specific foods, freshwater and air 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 environmental indicators.

The milk sampling carried out within the United Kingdom in 1997 was in two networks: a 'sparse' network of 3 dairies where samples are determined to a significantly lower limit of detection than is routine; and a 'dense' network of 25 dairies which affords nation-wide coverage at higher limits of detection. Samples are taken monthly and are reported to the EU to allow comparison of results with those from other European countries.

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

Drinking water was sampled from 27 locations throughout Scotland. The results of monitoring of drinking water in England and Wales have been published by the Department of the Environment, Transport and the Regions (DETR, 1997) and are summarised in the Environment Agency's Annual Report (Environment Agency, 1998). Air particulates are sampled monthly in Glasgow by NRPB.

2.1.4.4 Seawater surveys

Seawater surveys are carried out in the Irish Sea, Scottish waters and the North Sea to provide information on radionuclide levels and fluxes in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the aegis of the Oslo and Paris Conventions (OSPAR, 1993a) to which the United Kingdom is a signatory. These surveys are mounted using government research vessels and are supplemented by a programme of spot sampling of seawater at coastal locations.

2.2 Methods of measurement

There are two basic types of measurement made: (i) samples are collected from the environment and analysed for their radionuclide content in a laboratory; and (ii) dose rates are measured directly in the environment.

2.2.1 Sample analysis

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

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

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

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

Corrections are made for the radioactive decay of radionuclides between the time of sample collection and measurement in the laboratory. This is particularly important for radionuclides with relatively short half-lives such as sulphur-35 and iodine-131. Where bulking (combining) 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 ingrowth of activity from their parent radionuclides after sample collection is also considered. Corrections to the activity present at the time of measurement are made to take this into account for protactinium-233 and thorium-234.

The analysis of foodstuffs is carried out on that part of the sampled material which is normally eaten. The shells of shellfish and the pods of legumes are usually discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish 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. However, these losses are to be expected in the normal cooking process for the foodstuff.

2.2.2 Measurement of dose rates

Measurements of gamma dose in air over intertidal areas are normally made at 1 m above the ground using Mini Instruments [a] environmental radiation meters type 6-80 with compensated Geiger-Muller tubes type MC-71. When the human activity resulting in exposure justifies it, for example for people living on boats 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 [a] LB 1210B contamination monitors. These portable instruments are calibrated against recognised reference standards.

2.2.3 Dry Cloths

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

** Abbreviations are explained in Appendix 2.*

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

Table 2.1. Scope of the monitoring programmes

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

[a] *The terrestrial parts of this programme in England and Wales, excluding most grass and soil sampling and all drycloth sampling, are known as TRAMP (Terrestrial Radioactivity Monitoring Programme)*

[b] *The terrestrial parts of these programmes in England and Wales are known as FARM (Food and Agriculture Monitoring Programme)*

[c] *In Scotland*

Table 2.2. Scope of the nuclear site sampling in 1997*

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

* *The frequency of measurement, the types of analysis and the materials sampled vary from site to site. Not all analyses are carried out on all materials. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring when necessary, for example in relation to site incidents. The results of such monitoring are included in this report*

Table 2.3. Analytical methods

Radionuclides	Sample type	Method of measurement
^{3}H ^{3}H (organic) ^{14}C ^{32}P ^{35}S ^{45}Ca ^{147}Pm ^{241}Pu	All	Beta counting by liquid scintillation
^{90}Sr	High-level aquatic samples	Cerenkov counting by liquid scintillation
^{90}Sr	Terrestrial and low-level aquatic samples	Beta counting using gas proportional detectors
^{99}Tc ^{210}Pb beta	All	"
$^{103+106}Ru$ ^{131}I ^{144}Ce $^{134+137}Cs$	Terrestrial samples	"
^{125}I ^{129}I	Terrestrial samples[E/W]	Gamma counting by solid scintillation
^{134}Cs ^{137}Cs	Seawater	"
Gamma	Dry cloths	"
^{51}Cr ^{54}Mn ^{57}Co ^{58}Co ^{60}Co ^{59}Fe ^{65}Zn ^{95}Nb ^{95}Zr ^{103}Ru ^{106}Ru ^{110m}Ag ^{125}Sb ^{134}Cs ^{137}Cs ^{144}Ce ^{154}Eu ^{155}Eu ^{241}Am ^{233}Pa ^{234}Th	All	Gamma spectrometry using germanium detectors
^{125}I ^{129}I	Terrestrial samples[S]	"
^{129}I ^{131}I	Aquatic samples	"
U	Terrestrial samples	Activation and delayed neutron counting
^{210}Po ^{226}Ra* ^{234}U $^{235+236}U$ ^{238}U ^{237}Np ^{228}Th ^{230}Th ^{238}Pu $^{239+240}Pu$ ^{241}Am ^{242}Cm $^{243+244}Cm$	All	Alpha spectrometry
^{226}Ra	Terrestrial samples	Alpha counting using thin window proportional detectors
Alpha	Dry cloths	"

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

3. PRESENTATION AND ASSESSMENT

This section explains how data are presented and assessed in the report.

3.1 Time Averaging

The tables of monitoring results which follow contain summarised values of observations obtained during the year under review. The data are generally rounded to two significant figures but it should be noted that values near to the limits of detection will not have the precision implied by using two significant figures. Observations of a given quantity may vary throughout the year and, when levels above the limit of detection are recorded, often these variations between observations are larger than the analytical uncertainty inherent in the observations. The variations may, for example, be due to changes in rates of discharge, different conditions in the receiving environment or the random fluctuations expected in the environment. The method of presentation of the summarised results allows the data to be interpreted in terms of public radiation exposures for comparison with agreed safety standards. The appropriate period for comparison with recommended limits is one year. Standard practice is to combine annual rates of consumption or occupancy of the small group of people who are 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. The use of, for example, the single highest observed radioactivity concentration, where a food is harvested or caught over the year, with an annual consumption rate would not generally provide a realistic basis for comparison with the recommended limits.

For terrestrial foods excluding milk, such as meat and potatoes, it is recognised that the potential for storage of foods harvested at a particular time has to be taken into account. In such cases, we have presented the maximum concentration observed of each radionuclide in 1997 as well as the mean value. The maximum is labelled 'max' in the tables and forms the basis for the assessment of dose. For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean at the farm where the highest concentrations are observed. In most tables this is also labelled 'max' to distinguish it from the values which are averaged over a range of farms. However for Scottish sites bulking of milk samples across farms is carried out prior to analysis. In these cases the 'max' values are the maximum results from the analysis of bulks in a year.

The numbers of farms which are sampled to provide information on activities in milk at nuclear sites in England and Wales are indicated in the tables of results. In Scotland milk from all farms at a site is bulked and the numbers in the tables refer to the number of bulked samples analysed at the site. Otherwise, the number of sampling observations in the tables of concentrations refers to the number of samples which were prepared for analysis during the year. In the case of small animals such as molluscs, one sample may include several hundred individual animals.

The number of sampling observations does not necessarily indicate the number of individual analyses carried out for a particular radionuclide. In particular, determinations by radiochemical methods are sometimes carried out less frequently than those by gamma spectrometry. However, the results are based on bulking of samples such that the resulting determination remains representative.

3.2 Space Averaging

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

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 at the limit of detection (LoD) or minimum reporting level (MRL). There are also a few results quoted as 'not detected' (ND) by the methods used. 'Less than' values are reported at the LoD or MRL 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 1997.

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

3.4 Additional Information

The main aim of this report is to present all the results of routine surveillance from the programmes described previously. However it is necessary to carry out some averaging for clarity, and to exclude some basic data which may be of use only to those with particular research interests.

Full details of the additional data are available from MAFF and SEPA. Results of samples collected in the vicinity of nuclear sites in England and Wales are published as quarterly summaries through the Internet (www.maff.gov.uk).

The main categories of additional data are:

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

Very short-lived radionuclides such as yttrium-90, rhodium-103m, rhodium-106m, barium-137m and protactinium-234m which are formed by decay of, respectively, strontium-90, ruthenium-103, ruthenium-106, caesium-137 and thorium-234 are taken account of when performing the calculations of exposure. As a first approximation, their concentrations can be taken to be the same as those of their respective parents.

A list of research studies is given in Section 12.

3.5 Radiation protection standards

The monitoring results in this report are interpreted in terms of radiation exposures of the public i.e. 'doses'. This subsection describes the dose standards which apply.

The dose standards are embodied in national policy on radioactive waste (United Kingdom - Parliament, 1995a). The National Radiological Protection Board (NRPB) advises the UK Government on appropriate standards, including the recommendations of the International Commission on Radiological Protection (ICRP). Current UK practice relevant to the general public is based on the recommendations of the ICRP as set out in ICRP Publications 26 (ICRP, 1977) and 60 (ICRP, 1991). The Euratom Directive on basic radiation safety standards (Commission of the European Communities, 1984), with which UK legislation complies, is based on the recommendations of ICRP-26, but has been revised to take account of the changes in radiological protection criteria recommended in ICRP-60 (Commission of the European Communities, 1996); the Health and Safety Executive has consulted on draft UK legislation which will implement the requirements of the directive. The International Atomic Energy Agency (IAEA) and its related inter-governmental organisations have now published their own revised Basic Safety Standards for Radiation Protection based on ICRP-60 (IAEA, 1996).

There are two limits on individual dose which apply in this report. The limit for whole-body dose (more formally 'committed effective dose') is 1 mSv (millisievert) per year (United Kingdom - Parliament, 1995a). For skin, an alternative limit of 50 mSv per year, to the skin, applies. This is to ensure that specific effects on skin due to external exposure are prevented. It is applicable, for example, in the case of handling of fishing gear.

There are no limits on dose to populations, as opposed to individuals. Nevertheless dose to the population, 'collective dose', is a useful measure of potential harm, particularly in studies which compare waste management options. The collective dose from radioactive waste disposal has therefore been kept under review (Section 4.1.6).

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 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 can receive higher doses than adults because of their physiology, anatomy and dietary habits. Consequently we have assessed doses to different age groups and determined those most at risk.

Individual dose limits are to be used in situations where the effects of past 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, as in this report, 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, 1995a).

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 1997. 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 activity intake to a dose.

3.6.1 Radionuclide concentrations in foodstuffs

In nearly all cases, the activities in foodstuffs are determined by monitoring and are given later in this report. The Sellafield, Isle of Man and Scottish terrestrial assessments are supplemented by information from mathematical models (see Appendix 1). The concentrations chosen for the assessment are intended to be representative of the intakes of the most exposed consumers in the population. All of the

concentrations tabulated are included irrespective of the origin of the radionuclide. In some cases this means that the calculated exposures include contributions due to disposals from other sites as well as from weapons test fallout and activity deposited following the Chernobyl accident. Corrections for natural background concentrations are made in the calculations of dose.

For aquatic foodstuffs, the assessment is based on the mean concentrations from the areas where harvesting of seafood is known to take place near the site in question. For milk, the mean concentrations at a farm close to the site are taken where possible. The farm is chosen by reference to the data on concentrations such that the highest values of any farm are used in the assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers. For Scottish sites, results for individual farms are generally not available. In such cases the maximum observed concentration in the bulk samples across farms is taken to provide an adequate degree of conservatism. For other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

The tables of concentrations include 'less than' values as well as positive determinations. Where a result is presented as a 'less than' value, the dose assessment methodology treats it as if it were a positive determination in two situations: (i) when a radionuclide is specified in the relevant authorisation and (ii) when a positive determination is found in another foodstuff from the site. This accounts for the possibility that some activity is present when no positive determination is found. Although this approach will produce a slight overestimation of dose, particularly at sites where levels are low, it ensures that estimated exposures are unlikely to be understated. The assumption has little effect where there are a significant number of positive determinations. This is generally the case for the marine environment.

Formally, as a consequence of including 'less than' concentrations in the dose assessment, dose values presented in the report should be preceded by the '<' symbol. However, for reasons of clarity, we have generally presented doses without the symbol.

3.6.2 Consumption rates

In the assessment of the effects of disposals of liquid effluents, the amounts of seafood consumed are determined by site-specific habits surveys. Data are collected primarily by direct interviews with potential high-rate consumers who are often found in fishing communities. Techniques have included the use of consumption logging sheets (Leonard *et al*., 1982; Leonard, 1984) and consumption rate data have been interpreted using techniques based upon ICRP recommendations (Hunt *et al*., 1982) to select appropriate groups of high-rate consumers. Children are rarely found to eat large quantities of seafood and their resulting doses are invariably less than those of adults. The calculations presented in this report are therefore representative of adult seafood consumers.

In assessments of gaseous disposals, the amounts of food consumed are derived from national surveys of diet and are grouped for four ages, adults, 15 and 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 higher than average levels (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 by MAFF around nuclear sites. 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 3.

The assessment of exposures due to gaseous disposals is based on the assumptions: (i) that the foodstuffs eaten by the most exposed group which are most affected by site operations are those that are sampled for the purposes of monitoring; and (ii) that the consumption of such foodstuffs are sustained wholly by local sources. The two food groups resulting in the highest dose are taken to be consumed at 'critical group' consumption rates, while the remainder are consumed at average rates. The choice of two food groups at the higher consumption rates is based on statistical analysis by MAFF of national diet surveys. This shows that only a very small percentage of the population were critical rate consumers in more than two food groups (Day, personal communication). Locally grown cereals are not considered in the assessment of exposures as it is considered highly unlikely that cereals will be made into locally consumed (as opposed to nationally consumed) foodstuffs.

3.6.3 Summation of aquatic and terrestrial doses

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

The environmental data and the individuals affected that are assessed in this report naturally fall into two separate groups: those influenced by liquid waste disposal and those by gaseous waste disposal. We have therefore calculated doses separately in these two cases. This information can form the basis for a formal comparison with dose limits though the simple addition of 'liquid' and 'gaseous' doses will overestimate the dose received at a site due to radioactive waste disposal as an individual is unlikely to consume both aquatic and terrestrial foods at such high rates. In addition it should be noted that the age groups receiving the highest doses from liquid and gaseous disposals are often not the same.

As simple summation of aquatic and terrestrial doses is not appropriate and in order to give an indication of the does received via the foodchain, a calculation has been performed using a database of food consumption rates for approximately 2000 adults in Great Britain (Gregory *et al*., 1990). Doses to each individual in the data base are calculated assuming they obtain all of their food (except cereals, sugars, imported fruit and goat's milk) from the vicinity of the nuclear site under study. The distribution of the doses is evaluated using a program called INTAKE (MAFF, in preparation) and the 97.5 percentile of this distribution is then selected. This value does not necessarily correspond with any individual within the database. The value is presented in the rest of the report as the 'INTAKE' food dose.

The consumption data base used to calculate the INTAKE food dose was derived from a seven day diary study for adults between the ages of 16 and 65 living in private households. The use of national survey data is known to underestimate the consumption of seafood by those living in coastal communities. The values given by Byrom (Byrom *et al*) were derived from this database. The levels of consumption of seafoods are less than those often observed in the habit surveys reported in Appendix 3. Work is underway to develop a data set applicable to such communities. Whilst separate data sets are available within the INTAKE program for age groups other than adults, the underestimation of the consumption of seafoods by those living in coastal communities is more marked (e.g. the database for infants records no consumption of shellfish although this behaviour has been recorded in habit surveys). As the consumption of small amounts of shellfish can result in a significant proportion of the dose received as a result of consuming foodstuffs from the vicinity of the site this methodology has only been used for adults. It is hoped that the derivation of data sets for coastal communities will enable the methodology to be extended to these groups in the future. Similarly it is unlikely that a national survey of this size would have recorded the habits of the small groups who consume significant amounts of freshwater fish. For these reasons the methodology has only been applied to coastal sites.

The estimates of INTAKE food dose are for the foodchain only and do not include contributions due to external exposures, handling of fishing gear, etc. These other exposure pathways need to be taken into account in a comprehensive assessment of the exposure of the critical group.

3.6.4 Dose coefficients

Dose calculations for intakes of radionuclides are based on dose coefficients taken from ICRP Publication 72 (ICRP, 1996a). These coefficients relate the committed dose received to the activity ingested. The dose coefficients used in this report are provided in Appendix 4 for ease of reference. In past reports (e.g. The Scottish Office 1996) the dose received by infants from the consumption of milk has been calculated using the dose per unit intake values appropriate to 3-month-old infants. In this report, for uniformity with the calculations carried out for England and Wales, the values appropriate to a 1-year-old have been used. This should be considered when comparing the dose estimates reported for Scottish sites with those reported previously.

The dose assessments include consideration of children and the use of appropriate gut transfer factors. Where there is a choice of gut transfer factors for a radionuclide we have generally chosen the one which results in the highest predicted exposure. However, we have also taken into account specific research work of relevance to the foods considered in this report. This affects the assessments for polonium, plutonium and americium radionuclides.

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

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

3.6.5 External exposure

In the assessment of external exposure there are two factors to consider: (i) the dose rate from the source and (ii) the time spent near the source. In the case of external exposure to penetrating gamma radiation, uniform whole body exposure has been assumed. The measured quantity is air kerma rate. This has been converted into exposure using the factor 1 milligray = 0.85 millisievert (ICRP, 1996a). This factor applies to a rotational geometry with photon energies ranging from 50 KeV to 2 MeV. This is appropriate for the instrument used whose sensitivity is much reduced below 50 KeV, and to the geometry of deposits

of artificial radionuclides. Applying an isotropic geometry gives a value of 0.70 Sv Gy^{-1} which would be more appropriate for natural background radiation. The choice of 0.85 will therefore tend to overestimate dose rates for the situations considered in this report which include both artificial and natural radiation.

For external exposure of skin, the measured quantity is contamination in Bq cm^{-2}. In this case, dose rate factors in Sv y^{-1} per Bq cm^{-2} are used which are calculated for a depth in tissue of 7 mg cm^{-2} (Kocher and Eckerman, 1987). The exposure of gonads from beta radiation is assessed using the methods described by Hunt (Hunt, 1992). The times spent near sources of external exposure are determined by site specific habits surveys in a similar manner to consumption rates of seafood. The occupancy and times spent handling fishing gear are given in Appendix 3.

3.6.6 Subtraction of 'background' levels

When assessing the man-made effect on external exposures to gamma radiation and internal exposures due to ingestion of carbon-14 and radionuclides in the uranium and thorium decay series in seafood, estimates of dose rates and concentrations, as appropriate, due to natural background levels are subtracted. Background carbon-14 concentrations in terrestrial foods are also subtracted. The estimates of background concentrations are given in Appendix 5. 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 (Hunt, 1984) has been used. Estimates of external exposures from beta radiation include a component due to natural sources because of the difficulty in distinguishing between natural and man-made contributions. Such estimates are therefore conservative when compared with the relevant dose limit which excludes natural sources of radiation.

4. BRITISH NUCLEAR FUELS PLC (BNFL)

In 1997 BNFL was concerned mainly with the design and production of fuel for nuclear reactors and its reprocessing after irradiation. The company also operated a solid waste disposal site and two nuclear power plants supplying electricity to the national grid. Regular monitoring is carried out of the environmental consequences of disposals of radioactive waste from five BNFL sites, namely Sellafield, Drigg, Springfields, Capenhurst and Chapelcross. The company has integrated with Magnox Electric plc in January 1998 and its operations will include part of the power generation activities considered in this report in Section 6.

4.1 Sellafield and Drigg, Cumbria

Operations and facilities at Sellafield include fuel element storage, the Magnox and oxide fuel reprocessing plants, decommissioning of some facilities and the Calder Hall Magnox nuclear power station. Radioactive waste disposals (or discharges) include a very minor contribution from the adjoining UKAEA Windscale and AEA Technology facilities. The most significant disposals are made from the BNFL fuel element storage ponds and the reprocessing plants, through which pass irradiated Magnox and oxide fuel from the UK nuclear power programme, and some fuel from abroad. Small disposals are made from the Drigg site. Historically disposals from Sellafield have had the greatest impact on food and the environment of the UK. Current surveillance of the site reflects both historic and present day activities and, in view of its importance, is considered in depth in this report.

4.1.1 The aquatic monitoring programme

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

Disposals from the Sellafield pipelines during 1997 are summarised in Table 1.1. Total alpha and beta disposals were 0.185 and 138 TBq respectively (1996: 0.275 and 143 TBq respectively). The small reductions were mainly due to a shut-down of Magnox reprocessing for a period and a reduction in the activities released by the processing of stored wastes. There were also some increases in discharges of particular radionuclides (e.g. cobalt-60 and strontium-90) and reductions in others (e.g. carbon-14 and technetium-99). All disposals were within the limits set in the authorisations.

The main function of the Drigg site is to receive low level solid radioactive wastes from Sellafield and other UK sites and to dispose of them in engineered trenches or vaults on land. The authorisation for disposals allows for the discharge of leachate from the trenches through a marine pipeline. The limits for activity to be discharged through the marine pipeline and for concentrations of residual activity in the Drigg Stream are given in Table 1.1. These disposals are small compared with those discharged from the Sellafield site. Marine monitoring of the Drigg site is subsumed within the Sellafield programme which is described in the remainder of this sub-section. The contribution to exposures due to Drigg disposals is negligible compared with that due to Sellafield and any effects of Drigg disposals could not be detected in 1997 above those due to Sellafield. Regulatory monitoring of the Drigg Stream is carried out by the Environment Agency (Environment Agency, 1998).

Regular monitoring of the marine environment near Sellafield continued during 1997. Important radiation exposure pathways were consumption of fish and shellfish and external exposure to gamma rays and beta particles from occupancy over sediments, with other pathways being kept under review. In 1997, as in previous recent years, there was no harvesting of *Porphyra* seaweed in west Cumbria for manufacture of laverbread, but monitoring continued because the pathway remains potentially important. A general review of radioactivity in the Irish Sea has been compiled by Kershaw *et al.,* (1992). In addition, Hunt (1995) has provided a reconstruction of exposures due to Sellafield liquid disposals from the beginning of operations in 1952 through to 1993. A recent review of changes in disposals and effects from the site is given by Hunt *et al*.,(1998).

4.1.1.1 The fish and shellfish consumption pathway

4.1.1.1.1 Concentrations of radioactivity

Concentrations of beta/gamma activity in fish from the vicinity of the Irish Sea and from further afield are given in Table 4.1. Data are listed by location of sampling or landing point, in approximate order of increasing distance from Sellafield. Samples taken near other nuclear establishments which reflect Sellafield disposals are given later in this report. The 'Sellafield Coastal Area' extends 15 km north and south of Sellafield from St Bees Head to Selker and 11 km offshore; most of the fish and shellfish consumed by the local most exposed group is taken from this area. Specific surveys are carried out in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The results for radiocaesium generally reflect progressive dilution with increasing distance from Sellafield. However the rate of decline of radiocaesium concentrations with distance is not as marked as was the case some years ago, because significant reductions in disposals have been achieved. Radiocaesium in fish from the Baltic is not due to Sellafield disposals but is substantially from the Chernobyl accident

(Aakrog *et al.,* 1991). This is the most likely source of activity in fish sampled from a retail shop in Great Yarmouth. Concentrations of radiocaesium in fish known to have been caught in Icelandic waters remained typical of those from weapon test fallout, at a value of about 0.3 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea are similar. In the Irish Sea, the ratios of caesium-137 to caesium-134 were generally higher than those in recent disposals from Sellafield, even allowing for residence time in the water and uptake into fish; this suggests that a significant contribution from aged radiocaesium is present, due to remobilisation from the sediment of the Irish Sea (Hunt and Kershaw, 1990). Data for cod from the 'Offshore Area' typify the time trends in concentrations in fish (Figure 4.1). In particular the trend of decreasing concentrations of radiocaesium in fish in the area have continued.

A sample of rainbow trout from a small lake near Sellafield was again collected this year. The caesium-137 concentration in the sample, 39 Bq kg^{-1}, was less than in 1996 (110 Bq kg^{-1}); the variability of activities in samples of freshwater fish is known to be high (Camplin *et al.*, 1989). The absence of any detected caesium-134 in the sample suggests that fallout from Chernobyl, which is detected in other freshwater fish in Cumbria, is unlikely to be the source of activity nor would fallout from atmospheric weapon tests be the source at these concentrations. Similarly caesium activity in eels and brown trout from the River Calder is also likely to be due to discharges from the site.

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

Concentrations of artificial radionuclides in shellfish, as with fish, diminish with increasing distance from Sellafield. There are substantial variations between species: for example, lobsters tend to concentrate more technetium-99 in comparison to crabs (see also Knowles *et al.*, (1998)). In addition, molluscs tend to concentrate the less mobile nuclides to a greater extent than crustaceans, which in turn tend to concentrate them more than fish. The reverse behaviour has also been true for mobile nuclides in the past. However, since the importance of caesium-137 associated with sediment has increased relative to current disposals, concentrations of this nuclide in molluscs have tended to be higher than or similar to those for crustaceans. Long-term time trend data for 'Coastal Area' lobsters and Nethertown winkles are shown in Figures 4.2 and 4.3. When comparing 1996 and 1997 data across a wide range of sampling locations and shellfish species, it is apparent that increases

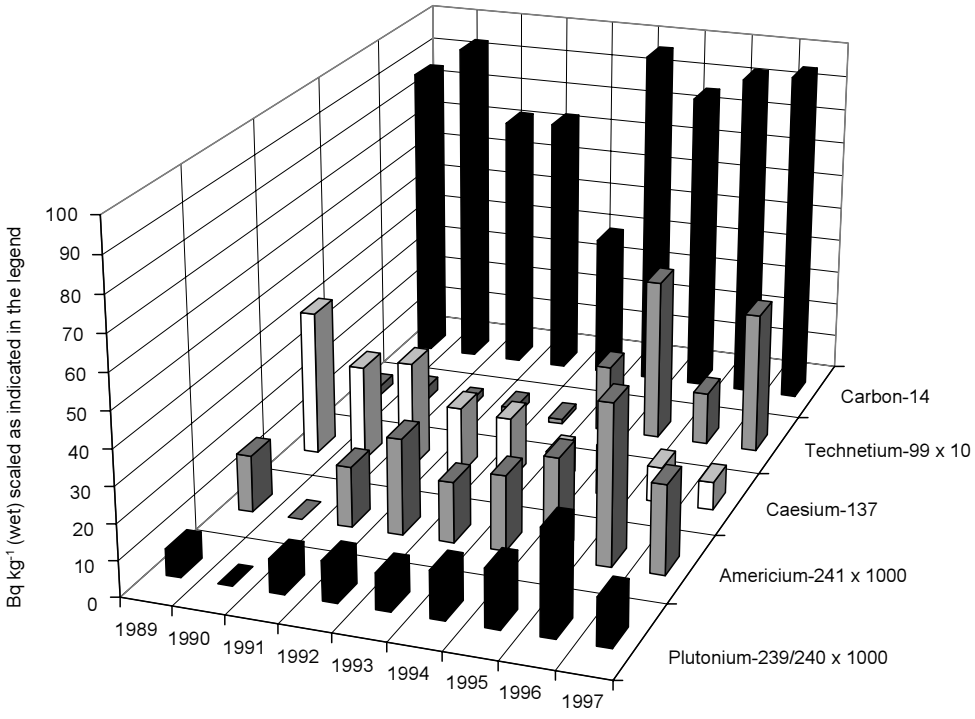

Figure 4.1. The trend in radionuclide levels in fish from Sellafield

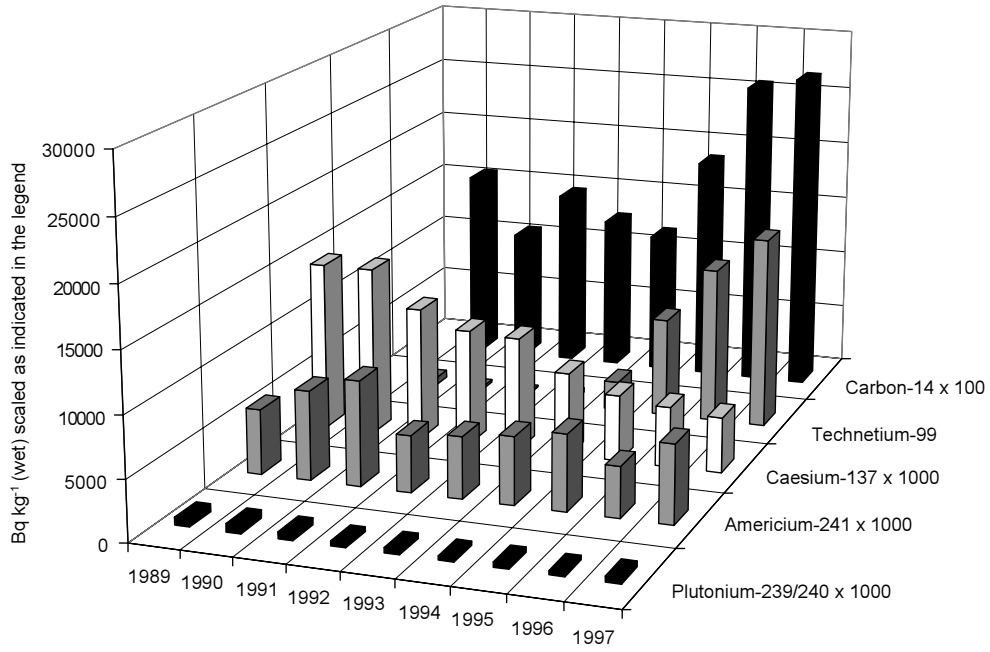

Figure 4.2. The trend in radionuclide levels in lobsters from Sellafield

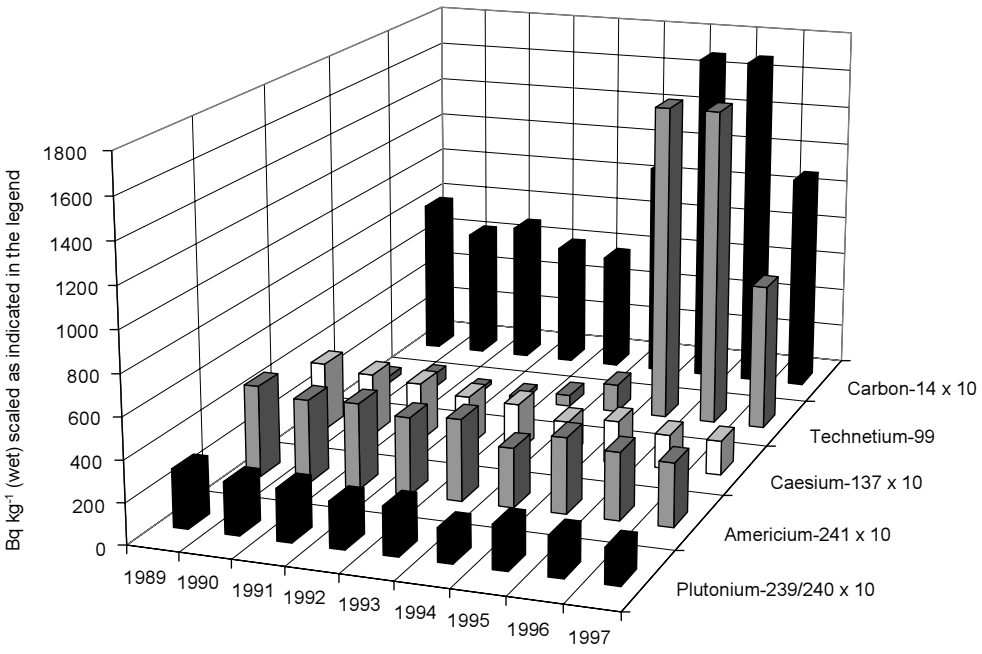

Figure 4.3. The trend in radionuclide levels in winkles from Sellafield

occurred for cobalt-60 and decreases for carbon-14. These changes appear to reflect changes in disposals of these radionuclides. Technetium-99 concentrations were more variable with some species showing decreases in line with reductions in disposals, whilst others have shown small increases. However, in general the higher levels of technetium-99 observed in recent years have been maintained. Concentrations of ruthenium-106 in molluscs reduced.

Analyses for transuranics are labour-intensive; as in previous years, a selection of samples of fish and shellfish chosen mainly on the basis of potential radiological significance was analysed for transuranic nuclides. The data for 1997 are presented in Table 4.3. Transuranics are less mobile than radiocaesium in sea water; this is reflected in higher concentrations of transuranics in shellfish as compared to fish, and a rapid reduction with distance from Sellafield in concentrations of transuranics, particularly in shellfish. Over the past decade disposals of transuranic nuclides from Sellafield have reduced significantly, resulting in overall decreases in concentrations of these nuclides in fish and shellfish. However, the non-mobile nature of these nuclides causes a delayed effect in the environment (Hunt, 1985) such that a contribution to present concentrations is provided by disposals in earlier years. In 1997, concentrations of transuranic nuclides in fish and shellfish generally declined compared to those observed in 1996.

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

4.1.1.1.2 Individual dose

Table 4.4 summarises doses in 1997 from artificial radionuclides in seafood. The dose to the local most exposed group of seafood consumers was 0.10 mSv. The decrease in dose from 0.14 mSv reported for 1996 (MAFF and SEPA, 1997) is largely due to changes in consumption rates of shellfish.

Data for natural radionuclides in fish and shellfish are discussed in Section 10; however, the effects on the Sellafield most exposed group from controlled disposals of natural radionuclides from another west Cumbrian source, Albright and Wilson Ltd, Whitehaven, are considered here to enable the total dose to be compared to the limit of 1 mSv. The dose to the local group of seafood consumers due to the enhancement of concentrations of natural radionuclides in the Sellafield area in 1997 was less than 0.28 mSv using a gut uptake factor for polonium of 0.8. Most of this was due to the polonium-210 and lead-210 content of shellfish. This gives a total dose to this group of less than 0.38 mSv. These doses may be compared with an average dose rate of approximately 2.2 mSv year^{-1} to members of the UK public from all natural sources of radiation (Hughes and O'Riordan, 1993) and are well within the limit of 1 mSv.

Exposures of groups representative of the wider fishing communities associated with fisheries in Whitehaven, Dumfries and Galloway, Fleetwood and the Morecambe Bay area have been kept under review and estimates of doses to those in Northern Ireland and the Isle of Man have been made for the first time (Table 4.4). The doses received by these groups are significantly less than that for the local Sellafield group because of the lower concentrations observed further afield. There were small decreases in the doses at Whitehaven, Dumfries and Galloway, Morecambe Bay and Fleetwood in 1997 when compared with those in 1996 (0.037, 0.047, 0.073 and 0.030 mSv as compared to 0.051, 0.065, 0.082 and 0.035 mSv respectively) (MAFF and SEPA, 1997). 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. The dose in 1997 was 0.002 mSv, the same as that for 1996 (MAFF and SEPA, 1997).

The exposure of consumers of trout from a local fish farm were also considered in 1997. Their dose, based on consumption rate data obtained by interview, was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv. This includes a contribution due to Chernobyl and weapon test fallout.

4.1.1.2 External exposure

A further important pathway leading to radiation exposure as a result of Sellafield disposals arises from uptake of gamma-emitting radionuclides by intertidal sediments in areas frequented by the public. In general, it is the fine-grained muds and silts prevalent in estuaries and harbours, rather than the coarser-grained sands to be found on open beaches, which adsorb the radioactivity more readily. Gamma dose rates currently observed in intertidal areas are mainly due to radiocaesium and natural radionuclides.

A range of coastal locations is regularly monitored, both in the Sellafield vicinity and further afield, using portable gamma-radiation dosimeters. Table 4.5 lists the locations monitored together with the dose rates in air at 1 m above ground. Dose rates on Irish Sea shorelines, near other nuclear establishments which reflect Sellafield disposals, are given later in this report. 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 1997 were generally similar to or slightly less than those data for the same locations in 1996. However increases were observed in Whitehaven inner harbour. This is likely to have been a consequence of construction activity and dredging in the harbour which would have redistributed activity in mud and sand. Undisturbed sediments preserve a depth profile of radioactivity which, at depth, reflects the higher discharges from Sellafield in the 1970s and 1980s. The occupancy by construction workers and dredgermen over sediments was low and the radiological significance of these increases was, as a consequence, also low.

Radioactivity concentrations in surface sediments are also regularly monitored, both because of relevance to dose rates and in order to keep under review distributions of adsorbed radioactivity. Concentrations of beta/gamma emitting radionuclides and transuranics, in most cases at the same locations as the dose rate measurements, are given in Table 4.6. Concentrations in sediments vary for reasons similar to those causing variation in dose rates, and comparison with results for 1996 (MAFF and SEPA, 1997) shows similar amounts of radioactivity.

In western Cumbria the maximum dose in 1997 was 0.16 mSv for a yachtsman living on a boat in Whitehaven harbour. This exposure includes a small component due to consumption of fish and shellfish. The dose to anglers who dig bait near to Sellafield and who fish in the Cumbrian coastal area was 0.057 mSv an increase from 1996. Again a small contribution due to consumption of seafood is included. In the wider area, including Cumbria, Lancashire and the north Solway coast it was confirmed that houseboat dwellers in the Ribble estuary are representative of those who receive the highest external exposures from the effects of disposals from Sellafield. Making an allowance for natural background using a dose rate of 0.07 μGy h^{-1} their external dose in 1997 was 0.13 mSv, similar to the value for 1996 (MAFF and SEPA, 1997). In terms of occupancy over tide-washed pasture, farmers are representative of those most exposed. In northern Cumbria their dose was 0.081 mSv in 1997.

Inhalation of resuspended beach sediments and inadvertent ingestion of the same material give rise to only minor radiation exposures to the public compared with the external radiation pathway considered in this sub-section (Wilkins *et al.,* 1994). In areas of salt marsh and sea-washed pastures such as the Ravenglass estuary, exposures from pathways other than those due to external radiation need consideration. Doses including external radiation in such areas were cautiously assessed for 1989 to be well within the dose limit of 1 mSv (Wilkins *et al.,* 1994). This would also have been the case in 1997 because, in general, concentrations of activity and dose rates in such areas have reduced. However, in order to investigate the effects of recent increases in technetium-99 discharges from Sellafield, additional research was undertaken. This is reported in sub-section 4.1.5.

4.1.1.3 Fishing gear

During immersion in sea water, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using portable beta dosemeters. Results for 1997 are presented in Table 4.7. Measured dose rates were generally similar to or less than those for 1996. 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 1500 h $year^{-1}$ was appropriate. The skin dose from handling of fishing gear in 1997, including a component due to natural radiation, was 0.13 mSv, which is less than 1% of the appropriate dose limit. Handling of fishing gear therefore continues to be a minor radiation exposure pathway.

4.1.2 The terrestrial monitoring programme

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

4.1.2.1 Sellafield

Disposals of gaseous wastes from Sellafield are summarised in Table 1.2. There were small decreases in the overall discharges of alpha and beta activities from the site and larger changes for particular radionuclides. Of possible environmental significance was an increase in ruthenium-106 (1997: 7.07 10^{-3} TBq; 1996: 8.80 10^{-4} TBq) and decreases in tritium (1997: 164 TBq; 1996: 529 TBq) and sulphur-35 (1997: 0.09 TBq; 1996: 0.14 TBq). The increase in ruthenium-106 was in part due to an incident in the Waste Vitrification Plant in November 1997. This triggered a special sampling programme (MAFF, 1997), the results of which are summarised in this report.

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

The results of monitoring in 1997 are presented in Table 4.8. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. However, small enhancements of some radionuclides were found close to the site.

The ratio of the mean concentration in milk collected from near and milk from far farms was close to 1 for all radionuclides though positive determinations of strontium-90 and caesium indicated a factor nearer 2. Some evidence for a site-related effect was also found by examination of the maximum concentrations at single farms. Concentrations in milk were generally similar to those in 1996 (MAFF and SEPA, 1997) though there were small reductions for some radionuclides.

Enhanced disposals of ruthenium-106 took place from the Waste Vitrification Plant in November 1997.
The initial estimate of the release made by BNFL was 3 GBq which is well within the authorised limit of 45 GBq but about 3 times the total release from the site in 1996. Additional sampling was undertaken to (i) confirm the estimate of the release and (ii) establish whether there had been a significant impact on the foodchain. To confirm the estimate of the release dry cloth detectors which are placed in an array

around the site were analysed for their ruthenium-106 content. Three cloths to the south-east of the site were found to contain enhanced activity at levels which suggested that the release was not grossly underestimated.

Samples of milk, barley, oats, grass and soil were analysed in the area towards which the plume of activity was believed to have travelled (MAFF, 1997). The results are separated from those from the routine surveillance data in Table 4.8 and are given as a footnote. The maximum result for grass was over 100 times the normal value for the area but the extent of contamination was found to be very localised, and no crops for human consumption were being grown in that area. If they had, the higher levels of contamination would have given rise to concentrations in leafy vegetables of about 20% of the relevant EU Food Intervention Level (CEC, 1989). In addition milk sampling and analysis indicated concentrations of ruthenium-106 below the limits of detection. Taken together these results confirmed that there was no significant risk to consumers of local foodstuffs.

As part of the routine surveillance programme samples of apples, blackberries and elderberries were analysed in 1997. All three fruits were good indicators of the local effects of disposals from Sellafield. Plutonium concentrations, whilst much lower than those found in seafood, gave isotopic ratios ((239+240)/238) less than 20. With a ratio of about 40 expected for background weapon test fallout, these data demonstrate a site source. The concentrations of plutonium in elderberries were the highest of those determined in any terrestrial food at Sellafield in 1997. The plutonium-241 levels were comparable to those measured in previous years (1997 2.2 Bq kg^{-1}, 1996 1.8 Bq kg^{-1}, 1995 2.2 Bq kg^{-1}). Concentrations of carbon-14 in fruit samples were also in excess of the concentrations assumed as representative of background values (Appendix 5). Concentrations of other radionuclides, for example tritium, sulphur-35, and strontium-90, also provided evidence of a local effect. Where it was possible to compare data for fruit in 1997 with those for 1996, similar concentrations of activity were found. However, in view of the limited number of samples obtained, no conclusion can be drawn as to whether there is a significant trend in levels of any particular radionuclide.

Levels of activity in bovine and ovine meat and offal continued to be analysed in 1997. Concentrations of radionuclides were low, with limited evidence for the effects of Sellafield disposals in data for tritium, carbon-14, sulphur-35, strontium-90 and the plutonium isotopic ratio.

Wheat was sampled as being representative of cereals in 1997. Sulphur-35 was detected, indeed cereals contained the highest levels of this radionuclide when compared with other food groups. In common with meat and offal samples, limited evidence for the effects of Sellafield disposals was also found in data for the plutonium isotopic ratio. The vegetables sampled in 1997 were cabbage, carrots, cauliflower, potatoes, runner beans and turnips. Concentrations of transuranic radionuclides in vegetables were very low and did not provide as distinct a Sellafield signal in the plutonium isotopic ratio as some other food groups. Evidence of the effects of Sellafield was also weak for other radionuclides in vegetables.

Finally, the most distinctive feature of the data for eggs, game, mushrooms and honey was that honey contained relatively high levels of caesium (12 Bq kg^{-1}) similar to the value for 1996 (11 Bq kg^{-1}).

The dose received by the most exposed group of terrestrial food consumers was calculated using the methods and data presented in Section 3. The results are presented in Table 4.9. Calculations were performed for four age groups (adults, 15y, 10y and 1y) and the doses received by the 1-year-old age group were found to be the highest, at 0.044 mSv (Adult: 0.034; 15y: 0.042: 10y: 0.033). 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 60% of the dose. The exposure is an upper estimate of the effects of Sellafield disposals because: (i) it is based on the assumption that a radionuclide which is not detected in a sample is present at a concentration equivalent to the limit of detection; (ii) the effects of the background of artificial nuclides in the area from Chernobyl and weapon test fallout are included; and (iii) it is assumed that most food consumed is locally produced.

The dose to the most exposed group of terrestrial foodstuff consumers (infants) decreased in 1997 to 0.044 mSv (1996: 0.055 mSv) because of small reductions in concentrations in foods.

The dose received by a typical adult consumer obtaining food from the vicinity of Sellafield, 0.017 mSv, was much less than this.

4.1.3 Total food exposures

The INTAKE food exposures, combining aquatic and terrestrial data for Sellafield, have been estimated using the method described in Section 3.6. In 1997, the dose to adults from artificial radionuclides in food, excluding contributions from intakes through inhalation and from external radiation, was 0.035 mSv or less than 5% of the dose limit of 1 mSv.

4.1.4 Drigg

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

Results for 1997 are given in Table 4.10. Low concentrations of tritium which may have leached from the site were found in rabbits and blackberries, however they were of negligible radiological significance. Other than this there was no evidence to suggest migration of activity from the site was taking place. In general concentrations of other radionuclides detected were lower than those found near Sellafield. The amount of technetium-99 found in cabbage is most likely to

have been due to sea-to-land transfer. The radiation dose to the most exposed group, including a component due to Chernobyl and weapon test fallout, was 0.018 mSv or 2% of the dose limit of 1 mSv (Table 4.9).

4.1.5 Other Surveys

4.1.5.1 Contact dose-rate monitoring of intertidal areas

Contact beta and gamma dose rates in intertidal areas are regularly monitored using purpose-built large-area detectors to locate and remove any material with unusual levels of contamination. Three items were found in 1997 with contact dose rates of between 0.004 and 0.010 mSv h^{-1}. Two were dead seagulls and the third was a seagull feather. The items were removed for further examination by BNFL. Similar finds have been detected on the beaches near Sellafield in the past and it has been postulated that their contamination arises from the open fuel storage ponds on the Sellafield site. An incident in February 1998 involving contaminated pigeons was thought to be due to birds roosting overnight at Sellafield and will be reported in the next RIFE report.

Further background information and results are given on the MAFF internet site (www.maff.gov.uk/food/incid_1/bnfp2323.htm).

A routine programme of measurements of beta dose rates on contact with shoreline sediments continued in 1997 in order to establish the contribution to effective dose made by exposures of people, such as bait diggers, who handle sediments regularly, and to estimate their exposures for comparison with the skin dose limit of 50 mSv. The results of the measurements made using portable beta dosemeters are presented in Table 4.11.

The skin dose to anglers who dig bait, based on a time handling sediment of 510 h $year^{-1}$, was 0.88 mSv in 1997 which is 2% of the appropriate dose limit. The contribution this source of exposure makes to effective dose is included in the assessment in sub-section 4.1.1.2.

4.1.5.2 Ravenglass

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

The results of measurements in 1997 are presented in Table 4.12. In general, the data are similar to those for 1996 (MAFF and SEPA, 1997) and show lower concentrations than are found in the Sellafield vicinity. Evidence for sea-to-land transfer is limited. Technetium-99 concentrations in all materials were very low. A small amount of promethium-147 (1.1 Bq kg^{-1}) was detected in cauliflowers from Ravenglass though the concentrations in grass were similar to those found at Drigg. Concentrations of plutonium isotopes in some samples indicated a local source in that the plutonium-239/240 to plutonium-238 ratio was substantially less than that expected due to weapon test fallout. Taken together these observations suggest that some sea-to-land transfer of radionuclides takes place, though the resulting effect is minor.

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

The exposure due to consumption of terrestrial foods from Ravenglass in 1997 is given in Table 4.9. The 1-year-old age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was 0.031 mSv or 3% of the dose limit of 1 mSv. From this evidence, sea-to-land transfer in this area is not having a major effect on the terrestrial food chain.

4.1.5.3 Research and other surveys

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

Seaweeds are useful indicator materials; they may concentrate certain radionuclides, so they greatly facilitate measurement and assist in the tracing of these radionuclides in the environment. Table 4.13 presents the results of measurements in 1997 on marine plants from shorelines of the Irish Sea and further afield. Although small quantities of samphire and *Rhodymenia* (a red seaweed) may be eaten, concentrations of radioactivity were of negligible radiological significance. This is also true of a sample of alginate obtained from the Hebrides. Alginates are used as emulsifiers and stabilisers in food products such as ice cream and in the manufacture of toothpaste. *Fucus* seaweeds are useful indicators, particularly of fission product radionuclides other than ruthenium-106; samples of *Fucus vesiculosus* seaweed were collected both in the Sellafield vicinity and further afield. These clearly showed the effects of increases in disposals of technetium-99 from Sellafield in recent years. Such seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a research study in 1997. The results are shown in Table 4.14.

The study comprised a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and an assessment of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added. The survey established that seaweed harvesting in the Sellafield

area was not widespread. However, three plots of land fertilised by seaweed were identified which were investigated further. Samples of soil from them were analysed by gamma spectrometry and for technetium-99, the radionuclide of main interest. The soil data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples were obtained which had been grown in the soils from these plots. The technetium-99 concentrations in vegetables ranged from about 8 to 8400 Bq kg^{-1} in the edible parts. The higher concentrations were found in spinach. Small concentrations of gamma emitting radionuclides were found in some vegetables.

Consumption rates of people who were supplied with vegetables from the plots were investigated as well as their consumption of local seafood. Based on pessimistic assumptions, the maximum dose received by the consumers was estimated to be 0.093 mSv, most of which was due to the technetium-99 content of the vegetable component of their diet. The mean dose was 0.051 mSv. Whilst the doses due to consumption of seafood and external radiation from sediments remain more important, further studies of the seaweed/vegetable pathway will be undertaken in 1998.

Table 4.14 also gives the results of sampling of tide-washed pasture at 8 locations around the Irish Sea. This was carried out to estimate the importance of sea-to-land transfer of technetium-99 in relation to consumption by animals which may graze such pastures. Samples of grass and the soil immediately underlying the root mat were analysed for their technetium-99 content. The grass samples were prepared as washed and unwashed samples to give an indication of the activity associated on soil and other materials on the surface of the grass separately from that internally incorporated.

The results show that some activity was indeed found to be removable by washing grass. However there remained a substantial fraction within the washed grass sample. Soil concentrations were higher than those found in unwashed grass by factors of between 1 and 30. The importance of these measurements in terms of potential consumption of milk, meat and offal of animals grazing the tide-washed pasture has been estimated using the transfer-factor approach outlined in Appendix 1. The maximum potential dose was for the one-year-old age group, at 0.009 mSv in 1997. This pathway is therefore of relatively low radiological significance.

In the Scottish islands seaweed may be eaten directly by sheep grazing on the foreshore. However our investigations show suggest that this does not take place to a significant extent in the Sellafield area.

No harvesting of *Porphyra* in west Cumbria, for consumption after being made into laverbread, was reported in 1997; this pathway has therefore remained essentially dormant. However, monitoring has continued in view of its potential importance, historical significance and the value of *Porphyra* as an indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 1997 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 1997 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 virtual abeyance of this exposure pathway.

4.1.6 Collective Dose

Collective doses, received during 1997 from consumption of fish and shellfish, have been estimated for the UK and other European countries. In general, the method used has been to combine data on actual fish and shellfish landings from relevant sea areas with average radioactivity concentrations in fish and shellfish caught in these areas. This method differs from that based on modelling of water movements and a (usually) fixed catch rate for different sea areas. Sea areas considered in this assessment include the Irish Sea, Scottish waters, the North Sea, the English Channel, Baltic Sea, Norwegian Sea, Spitzbergen/Bear Island area and the Barents Sea. Corrections have been made for the fraction of fish or shellfish consumed. The contribution of weapon test fallout to the radioactivity concentrations has been subtracted. Consideration has been given to the pathway due to fish offal and industrial fisheries, the product of both of which is fish meal which is fed to pigs, poultry, ruminants and farm-reared fish. Consumption of food products from these animals gives rise to a small contribution to the collective dose, and this has been included. Further research is being carried out into this pathway (Section 12).

Liquid radioactive waste disposals from Sellafield are the main source of collective dose; by comparison, the effect of liquid disposals from other establishments is very small. The small contribution due to fallout from the Chernobyl reactor accident to the Irish Sea, Scottish waters and the North Sea has been included. Most of the collective dose is due to radiocaesium in edible fish; however, approximately one quarter of the total dose is due to plutonium and americium radionuclides in shellfish. Carbon-14, strontium-90 and technetium-99 also make a small contribution to the collective dose, about 10% of the total. The results for 1997, of 4 man-Sv for the UK and 18 man-Sv for other European countries are similar to those reported for 1996. The trend of collective dose in recent years is shown in Figure 4.4.

The collective dose to the UK population due to the effects of liquid disposals may be compared to that from other sources. In Hughes and O'Riordan (1993) the collective dose to the UK population from all sources of natural background radiation is given as 127,000 man-Sv and that from all sources of artificial radiation as 23,000 man-Sv. Therefore the UK collective dose delivered in 1997 through the seafoods pathway as a result of liquid radioactive waste disposals was less than 0.01% of the total from all sources of radiation.

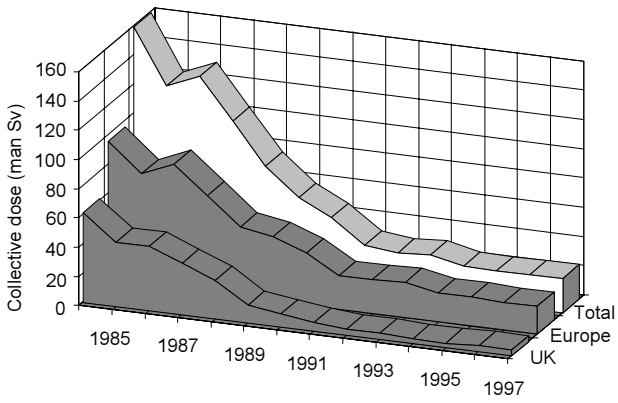

Figure 4.4. Collective dose from seafood consumption due to nuclear industry discharges

4.2 Springfields, Lancashire

This establishment is mainly concerned with the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Radioactive liquid waste arisings consist mainly of thorium and uranium and their decay products; liquid disposals are made by pipeline to the Ribble estuary. Disposals of beta emitting radionuclides, which result in the greatest contribution to the radiological impact, were similar in 1997 (142 TBq) to 1996 (153 TBq) because rates of processing of uranium ore concentrate were maintained. Disposals of gaseous effluents remained very low at a similar level to those for 1996.

Public radiation exposure in this vicinity, as a result of site disposals, is relatively low; there is, however, a contribution in the estuary due to Sellafield disposals. The most important marine pathway is external exposure, due to adsorption of radioactivity on the muddy areas of river banks and in salt marshes. The most exposed group consists of people who live on a houseboat moored in a muddy creek of the Ribble estuary. Other activities which have been found to have significant occupancies are wildfowling, farming and bird conservation which take place in intertidal areas and marshes bordering the estuary, and angling which is popular in the Preston area. Surveys have also identified consumers of seafood, particularly fish and shrimps, and they are considered as a potential critical group in this report. Gamma and beta dose rates are regularly monitored in relevant areas including muddy creeks where houseboats are moored, and some of these measurements are supported by analyses of sediments. Locally obtained fish, shellfish, wildfowl and samphire continued to be sampled. A study (Rollo *et al.*, 1994) has shown that exposures due to airborne radionuclides which may have come from disposals to the estuary and are subsequently remobilised are negligible.

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

Results for 1997 are shown in Tables 4.15(a) and (b). Radionuclides detected which were partly or wholly due to Springfields disposals were isotopes of thorium, uranium and their decay products. Natural sources also contributed to these activities. Artificial radionuclides present were mainly from Sellafield.

Contact beta and gamma dose rates in intertidal areas of the Ribble estuary are regularly monitored using purpose-built large-area detectors in order to locate any material with unusual levels of contamination. Three items were found in 1997 near the discharge point with contact dose rates of 0.004, 0.008 and 0.007 mSv h^{-1}. They were removed. The first two items were small pieces of plastic; the third was a twig. The dose rates, although elevated, were consistent with those on muds in other parts of the estuary.

Gamma dose rates over intertidal areas in 1997 were similar to those in 1996. The results of beta dose rate measurements are highly variable but overall the results for 1997 suggest small reductions. In 1997 the dose to the most exposed group of houseboat dwellers including the Sellafield component was 0.13 mSv, similar to the value for 1996 (0.14 mSv). Most of this exposure was due to the radioactivity already in the environment as a result of past disposals from Sellafield. The whole-body doses of bird conservationists, farmers, anglers and wildfowlers were assessed as being 0.058, 0.024, 0.014 and 0.035 mSv respectively in 1997. A significant proportion of the dose is due to Sellafield disposals. Consumption of wildfowl makes a very small contribution to the dose received by wildfowlers because of the very low concentrations of radionuclides in ducks and geese.

The most exposed group for skin irradiation was bird conservationists with skin doses, including a component due to natural radiation, of 3.1 mSv in 1997. This is 6% of the relevant dose limit for members of the public.

Seafood consumption was found to be dominated by fish and shrimps though small quantities of cockles and samphire were also taken into account, as indeed was external exposure over the outer parts of the estuary while fishing. The dose to seafood consumers was 0.051 mSv in 1997. Most of this was due to Sellafield disposals with only a small percentage attributable to Springfields.

The most exposed group of terrestrial food consumers were adults consuming milk and vegetables at high rates. Their dose in 1997, including a contribution due to weapon test and Chernobyl fallout and natural sources, was less than 0.005 mSv, a significant part of which was due to thorium radionuclides.

The INTAKE food dose was 0.011 mSv or 1% of the dose limit of 1 mSv.

4.3 Capenhurst, Cheshire

The main functions undertaken on the Capenhurst site are enrichment of uranium and dismantling of redundant plant. The enrichment facility is operated by URENCO Capenhurst Ltd. Radioactive waste arisings of tritium, uranium and its daughter products, and technetium-99 and neptunium-237 from recycled fuel, are minor; in 1997 BNFL had authorisations to dispose of small amounts of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. An environmental monitoring programme is carried out related to the pathways which could be of radiological significance due to all disposal routes. Plants, rain water, animal faeces, soil and dry cloths are also sampled as indicator materials.

Results for 1997 are presented in Table 4.16. Concentrations of radionuclides in materials from the land and from the Rivacre Brook were generally similar to those for 1996. There was an increase in the tritium concentration in water from the Brook but this observation is based on very few measurements. The hypothetical most exposed group for liquid disposals from the site is considered to be people who may inadvertently ingest water and sediment from the Brook. Taking pessimistic assumptions about their ingestion rates, the dose to the group was very low, at less than 0.005 mSv in 1997. The concentrations of artificial radioactivity in marine samples are consistent with values expected at this distance from Sellafield. The dose to the most exposed group of terrestrial food consumers was also low, at 0.013 mSv in 1997. Contact beta and gamma dose rates were monitored in 1997 using large-area detectors in order to locate any material with unusual levels of contamination. No such items were found.

4.4 Chapelcross, Dumfries and Galloway

At this establishment, BNFL operates a Magnox-type nuclear power station. Gaseous wastes are discharged to the local environment and liquid waste is discharged to the Solway Firth under authorisation from SEPA. Disposals in 1997 were similar to those in 1996. Terrestrial monitoring comprises sampling and analysis of milk and grass. Habits surveys have been used to investigate aquatic exposure pathways. These have established that two groups of people could receive radiation exposures of potential importance. The first of these groups are fishermen who consume local seafood and are exposed to external radiation whilst tending stake nets. The second group are wildfowlers who are exposed whilst on salt marshes. The scope of aquatic monitoring reflects these pathways. Samples of sea water and *Fucus vesiculosus*, as useful indicators, are also analysed.

The results of monitoring in 1997 are presented in Tables 4.17(a) and (b). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to Sellafield disposals, and the general levels of nuclides are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides in 1997 were generally similar to, or less than, those in 1996. Concentrations of technetium-99 due to Sellafield discharges are comparable to those in 1996 despite reductions in disposals. This is thought to be due to the transit time of this radionuclide in the Irish Sea. The whole-body dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.029 mSv in 1997 which is less than 3% of the dose limit of 1 mSv for members of the public. Measurements of the contact beta dose-rate received whilst handling nets, were below the limit of detection. Wildfowlers received a dose of 0.021 mSv. The magnitude of the Chapelcross disposals indicates that the local contribution to dose was a tiny fraction of these exposures, most of the dose being due to Sellafield disposals.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Monitoring of this area continued although work carried out by the operator in recent years has led to a decline in the incidence of these particles. However, at the end of 1997 this trend appeared to change and the incidence of detection of these particles during monitoring increased. One of the particles found was more active than normal and analysis indicated that that it was likely to have come from degraded fuel and probably discharged in the late 1970s. Following the discovery of this particle, increased monitoring did not reveal further particles of this type. SEPA has requested the operator to consider further improvements to the effluent management system to prevent further releases of these types of particles. Analysis of the more active particle indicated that the total activity was less than 10^4 Bq. Assessments carried out estimated that a potential dose of 3 mSv could arise from ingestion of such a particle, although the likelihood of encountering one is considered to be extremely low as the location is not frequented by the public. No unusual levels of contamination were found in other intertidal areas near the site.

During 1997 one of the reactors was closed for a period due to problems with a heat exchanger. This resulted in a slight decrease in gaseous discharges from the site.

Concentrations of radionuclides in milk and grass were generally similar to those in 1996. The effects of the power station were detected by observation of positive values for tritium in terrestrial samples, but the radiological significance of this radionuclide is low. The dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon test and Chernobyl fallout, was estimated to be 0.025 mSv or less than 3% of the dose limit of 1 mSv. This estimate includes a contribution due to consumption of vegetables (Appendix 1).

The INTAKE food dose, including aquatic and terrestrial components, was 0.022 mSv in 1997.

Table 4.1. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 1997

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Sellafield coastal area	Cod	8	-	<0.51	-	<0.94	<1.6	-	<2.0	<0.23	16	<1.1	200
"	Plaice	4	-	<0.36	-	<0.75	<1.2	-	<1.9	<0.21	13	<1.0	210
"	Grey mullet	1	-	<0.31	-	<1.0	<1.6	-	<2.3	<0.26	16	<1.7	-
"	Bass	1	-	<0.19	-	<0.82	<1.4	-	<1.8	<0.20	22	<0.87	-
Sellafield offshore area	Cod	2	96	<0.17	0.089	<0.90	<1.7	4.0	<1.8	<0.17	7.9	<0.90	-
"	Plaice[c]	2	140	<0.12	0.10	<0.16	<0.15	25	<0.62	<0.07	7.5	<0.35	-
"	Dab	2	-	<0.19	-	<0.53	<0.63	-	<1.5	<0.16	10	<0.73	-
"	Whiting	2	-	<0.15	-	<0.88	<1.5	-	<1.5	<0.16	12	<0.90	-
"	Spurdog	1	-	<0.16	-	<0.70	<0.84	-	<1.6	<0.14	4.8	<1.1	-
Ravenglass	Cod	8	-	<0.23	-	<1.1	<1.2	-	<2.0	<0.21	11	<1.0	-
"	Plaice	8	-	<0.18	-	<0.80	<1.4	-	<1.5	<0.16	7.4	<0.85	-
"	Salmon	1	-	<0.12	-	<0.39	<0.37	-	<1.5	<0.16	<0.18	<0.61	-
Whitehaven	Cod	4	61	<0.10	0.054	<0.29	<0.34	-	<0.97	<0.10	6.4	<0.50	-
"	Plaice	4	-	<0.12	0.053	<0.34	<0.40	-	<1.0	<0.11	7.0	<0.59	-
"	Ray	4	-	<0.15	-	<0.63	<1.1	-	<1.7	<0.17	8.2	<0.87	-
Parton	Cod	4	-	<0.18	-	<0.77	<1.3	-	<1.6	<0.18	11	<0.93	-
Morecambe Bay (Flookburgh)	Flounder	4	95	<0.14	-	<0.74	<1.4	-	<1.7	<0.16	22	<1.1	-
" (Morecambe)	Plaice	4	-	<0.12	0.037	<0.71	<1.6	8.6	<1.2	<0.12	7.9	<0.63	-
" "	Bass	2	-	<0.14	-	<0.85	<2.0	-	<1.5	<0.15	20	<0.69	-
" (Sunderland Point)	Whitebait	1	-	<0.07	0.23	<0.32	<0.62	-	<0.64	<0.07	9.0	<0.30	-
River Ehen	Sea trout	1	-	<0.23	-	<0.70	<0.83	-	<2.1	<0.22	3.1	<0.76	-
River Calder	Eel	1	-	<0.34	-	<4.6	*	-	<5.4	<0.43	93	<3.0	-
"	Brown trout	1	-	<0.34	-	<3.4	*	-	<5.0	<0.38	62	<2.6	-
Calder Farm	Rainbow trout	2	-	<0.27	-	<0.28	<0.26	-	<1.1	<0.10	39	<0.59	-
River Duddon	Sea trout	1	-	<0.07	-	<0.31	<0.45	-	<0.74	<0.07	9.9	<0.50	-
River Kent	"	1	-	<0.07	-	<0.31	<0.47	-	<0.77	<0.08	11	<0.50	-
Fleetwood	Cod	4	89	<0.07	0.097	<0.16	<0.16	4.8	<0.63	<0.07	8.2	<0.36	-
"	Plaice	4	-	<0.08	-	<0.20	<0.20	-	<0.73	<0.08	6.6	<0.40	-
"	Fish oil[d]	3	-	<0.10	-	<0.45	<0.72	-	<1.2	<0.11	<0.10	<0.69	-
Isle of Man	Cod	4	-	<0.08	-	<0.28	<0.38	-	<0.71	<0.08	2.6	<0.36	-
"	Herring	4	-	<0.08	-	<0.41	<0.76	-	<0.86	<0.09	2.6	<0.56	-
Inner Solway	Flounder	2	61	<0.12	0.11	<0.29	<0.18	2.0	<1.2	<0.13	28	<0.85	-
"	Sea trout	1	-	0.18	-	-	-	-	<1.0	<0.10	2.4	-	-
"	Salmon	1	-	<0.10	-	-	-	-	<1.0	<0.10	0.83	-	-
Kirkcudbright	Plaice	3	-	<0.10	-	-	-	-	<1.0	<0.10	3.4	-	-
Isle of Whithorn	"	2	62	<0.11	0.028	<0.31	<0.38	7.2	<0.97	<0.11	4.0	<0.43	-
North Anglesey	Ray	4	-	<0.12	-	<0.35	<0.39	-	<1.1	<0.12	1.3	<0.47	-
"	Plaice	2	39	<0.07	-	<0.22	<0.26	-	<0.65	<0.07	0.95	<0.37	-
Ribble Estuary	Flounder	1	-	<0.09	-	<1.1	*	-	<1.0	<0.09	12	<0.57	-
"	Salmon	1	-	<0.10	-	<0.83	*	-	<1.1	<0.10	0.55	<0.73	-
"	Grey mullet	1	-	<0.16	-	<1.3	<3.5	-	<1.6	<0.16	6.2	<1.2	-
Northern Ireland	Cod	8	33	<0.08	-	<0.33	<0.35	-	<0.72	<0.08	2.4	<0.39	-
"	Whiting	8	-	<0.13	-	<0.59	<0.96	-	<1.4	<0.13	4.1	<0.68	-
"	Herring	2	-	<0.12	-	<0.55	<0.96	-	<1.1	<0.12	2.1	<0.51	-
"	Spurdog	5	-	<0.12	-	<0.71	<0.61	-	<1.1	<0.12	1.7	<0.59	-
"	Saithe	4	-	<0.09	-	<0.39	<0.69	-	<0.83	<0.09	4.1	<0.47	-
West of Scotland	Mackerel	1	-	<0.07	-	<0.33	<0.61	-	<0.69	<0.07	0.19	<0.40	-
Sound of Mull	Salmon	1	-	<0.07	-	<0.27	<0.34	-	<0.68	<0.08	0.37	<0.46	-

Table 4.1. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}										
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Minch	Cod	4	-	<0.06	-	<0.23	<0.36	-	<0.58	<0.06	0.76	<0.31	-
"	Plaice	3	-	<0.06	-	<0.22	<0.32	-	<0.56	<0.06	0.69	<0.28	-
"	Mackerel	2	30	<0.07	0.0047	<0.26	<0.34	-	<0.73	<0.08	0.51	<0.35	-
"	Haddock	4	-	<0.06	-	<0.22	<0.33	-	<0.55	<0.06	0.57	<0.30	-
"	Herring	3	-	<0.06	-	<0.26	<0.37	-	<0.64	<0.07	0.29	<0.38	-
Shetland	Fish meal[d]	4	-	<0.22	0.099	<0.54	<0.56	-	<2.0	<0.22	1.0	<1.0	-
"	Fish oil[d]	4	-	<0.12	-	<0.43	<0.59	-	<1.2	<0.12	<0.11	<0.74	-
Northern North Sea	Cod	4	-	<0.07	0.0068	<0.36	<0.19	-	<0.66	<0.07	0.85	<0.34	-
"	Plaice	4	-	<0.06	-	<0.41	<0.23	-	<0.61	<0.06	0.48	<0.35	-
"	Herring	3	-	<0.06	-	<0.47	<0.33	-	<0.67	<0.07	0.51	<0.40	-
"	Haddock	4	20	<0.07	-	<0.44	<0.19	-	<0.67	<0.07	0.36	<0.38	-
Mid-North Sea	Cod	4	19	<0.06	0.0088	<0.22	<0.35	-	<0.52	<0.06	0.80	<0.26	-
"	Plaice	4	30	<0.06	0.0077	<0.24	<0.36	-	<0.57	<0.06	0.33	<0.29	-
"	Herring	3	-	<0.08	-	<0.61	<0.49	-	<0.90	<0.09	0.59	<0.53	-
Southern North Sea	Cod	2	-	<0.06	0.0064	<0.24	<0.38	-	<0.54	<0.06	0.79	<0.25	-
"	Plaice	2	-	<0.05	0.0039	<0.25	<0.39	-	<0.59	<0.06	0.39	<0.32	-
"	Herring	2	-	<0.06	-	<0.30	<0.48	-	<0.67	<0.07	0.61	<0.36	-
English Channel	Cod	4	-	<0.06	0.0076	<0.25	<0.36	-	<0.60	<0.06	0.38	<0.31	-
"	Plaice	4	-	<0.05	0.0075	<0.17	<0.22	-	<0.49	<0.05	0.12	<0.23	-
"	Mackerel	4	-	<0.08	-	<0.36	<0.58	-	<0.82	<0.09	0.29	<0.44	-
Gt Yarmouth (retail shop)	Cod	4	-	<0.06	-	<0.20	<0.26	-	<0.57	<0.10	3.6	<0.31	-
"	Plaice	4	-	<0.07	-	<0.27	<0.44	-	<0.64	<0.07	0.42	<0.30	-
Skagerrak	Cod	3	-	<0.06	-	<0.43	<0.33	-	<0.69	<0.07	0.48	<0.35	-
"	Herring	3	-	<0.08	-	<0.49	<1.1	-	<0.80	<0.08	0.82	<0.42	-
Norwegian Sea	Cod	1	-	<0.05	-	<0.41	<0.92	-	<0.58	<0.06	0.32	<0.40	-
"	Saithe	1	-	<0.06	-	<0.10	<0.07	-	<0.47	<0.05	0.34	<0.20	-
Iceland area	Cod	2	-	<0.06	-	<0.20	<0.26	-	<0.57	<0.06	0.23	<0.28	-
Icelandic processed	"	2	17	<0.06	-	<0.17	<0.17	-	<0.56	<0.06	0.31	<0.31	-
Barents Sea	"	3	-	<0.07	-	<1.2	<0.07	-	<0.73	<0.07	0.32	<0.39	-
Baltic Sea	"	2	-	<0.11	-	<0.59	<1.2	-	<1.1	0.21	12	<0.60	-
"	Herring	4	-	<0.09	-	<0.58	<1.3	-	<0.96	<0.14	8.7	<0.57	-

- not analysed
** not detected by method used*
[a] Sampling area or landing point
[b] See section 3 for definition
[c] The concentration of ^{147}Pm was 0.016 Bq kg^{-1}
[d] Concentrations refer to weight of sample as supplied

Table 4.2. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 1997

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Sellafield coastal area	Crabs	8	120	1.8	<0.30	1.5	<0.40	<0.57	70	<0.41	<1.5
"	Lobsters	8	270	2.9	<0.52	0.64	<0.77	<1.5	16000	<0.94	<2.1
"	Winkles[c]	4	130	7.5	<0.37	1.6	<0.42	<0.54	1200	<0.39	23
"	Mussels[c]	4	-	4.8	<0.29	2.1	<0.35	<0.42	-	<0.32	16
"	Limpets[c]	4	65	3.4	<0.26	8.6	<0.40	<0.76	2100	<0.56	13
"	Whelks	1	190	2.9	<0.37	0.076	<0.41	<0.63	100	<0.40	16
Sellafield offshore area	"	2	-	2.4	<0.42	-	<0.52	<0.82	-	<0.60	<12
St Bees	Winkles	4	120	16	<0.20	5.0	<0.21	<0.25	500	<0.17	25
"	Mussels	4	-	6.3	<0.26	-	<0.26	<0.27	-	<0.23	31
"	Limpets	4	-	4.2	<0.40	-	<0.42	<0.44	-	<0.35	29
Nethertown	Winkles	12	110	14	<0.44	10	<0.49	<0.67	730	<0.44	33
"	Mussels	4	170	7.1	<0.39	-	<0.83	<1.3	810	<0.42	33
Drigg	Winkles	4	180	22	<0.56	-	<0.65	<1.0	2800	<0.64	40
Ravenglass	Crabs	4	-	0.85	<0.35	0.89	<0.42	<0.58	44	<0.41	<1.6
"	Lobsters	4	-	1.2	<0.50	0.30	<0.72	<1.3	6200	<0.84	<2.1
"	Winkles	2	-	7.5	<0.39	-	<0.53	<0.93	-	<0.34	27
"	Mussels	4	-	6.7	<0.31	-	<0.36	<0.58	800	<0.29	22
"	Cockles	4	180	17	<0.36	2.5	<0.76	<1.1	64	<0.37	19
Tarn Bay	Winkles	2	-	9.3	<0.36	-	<0.52	<0.89	-	<0.63	25
Saltom Bay	"	3	-	3.1	<0.47	-	<0.55	<0.70	-	<0.55	<11
Whitehaven	*Nephrops*	4	48	<0.13	<0.34	0.078	<0.50	<0.69	540	<0.58	<1.3
Silloth	Mussels	4	-	0.43	<0.18	-	<0.22	<0.23	-	<0.23	<3.0
Parton	Crabs	4	-	0.78	<0.30	-	<0.37	<0.49	-	<0.38	<1.3
"	Lobsters	4	-	<0.30	<0.37	-	<0.55	<0.84	-	<0.59	<1.5
"	Winkles	4	-	2.9	<0.31	-	<0.40	<0.53	-	<0.42	7.3
Haverigg	Cockles	1	-	3.1	<0.92	-	<4.4	*	-	*	7.9
Millom	Mussels	2	-	1.2	<0.31	-	<0.68	<1.6	-	<1.2	5.4
Roosebeck	Pacific oysters	4	-	0.50	<0.22	-	<0.17	<0.26	-	<0.18	2.3
Morecambe Bay (Flookburgh)	Shrimps	4	79	<0.11	<0.24	-	<0.27	<0.30	13	<0.26	<0.96
" (Morecambe)	Mussels	4	84	0.69	<0.19	-	<0.31	<0.50	500	<0.40	2.5

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Sellafield coastal area	Crabs	8	2.9	<0.28	<0.12	2.8	<0.51	0.26	<0.32	<0.21	160
"	Lobsters	8	7.2	<0.44	<0.19	4.6	<0.81	1.2	<0.53	<0.34	10000
"	Winkles[c]	4	9.7	<0.99	<0.16	6.8	<0.72	0.90	<0.41	<0.31	-
"	Mussels[c]	4	<0.24	0.75	<0.12	4.2	<0.56	-	<0.40	<0.26	-
"	Limpets[c]	4	7.5	2.0	<0.11	12	<0.56	-	<0.48	<0.29	-
"	Whelks	1	8.4	0.44	<0.15	1.8	<0.56	-	<0.41	<0.27	-
Sellafield offshore area	"	2	11	<0.46	<0.15	2.1	<0.78	-	<0.47	<0.34	-
St Bees	Winkles	4	9.1	0.83	<0.85	12	<0.59	1.8	<0.25	<0.20	-
"	Mussels	4	<0.57	0.98	<0.10	5.3	<0.53	-	<0.30	<0.29	-
"	Limpets	4	5.9	1.9	<0.17	9.1	<0.75	-	<0.47	<0.33	-
Nethertown	Winkles	12	13	<1.1	<0.19	17	<0.88	2.3	<0.60	<0.38	790
"	Mussels	4	<0.33	<0.94	<0.16	5.6	<1.3	-	<0.48	<0.32	660
Drigg	Winkles	4	18	<1.1	<0.23	10	<1.3	2.5	<0.57	<0.47	2800
Ravenglass	Crabs	4	2.8	<0.33	<0.14	2.6	<0.62	-	<0.38	<0.26	150
"	Lobsters	4	6.0	<0.44	<0.19	4.2	<0.84	-	<0.51	<0.36	4100
"	Mussels	4	<0.24	0.85	<0.10	3.4	<0.56	-	<0.33	<0.25	-
"	Winkles	2	12	<1.1	<0.17	12	<1.1	-	0.66	<0.38	-
"	Cockles	4	<0.78	<0.55	<0.15	7.6	<0.98	-	<0.61	<0.31	260
Tarn Bay	Winkles	2	7.9	0.76	<0.15	11	<0.80	-	<0.37	<0.33	-
Saltom Bay	"	3	1.7	<1.2	<0.19	12	<0.85	-	<0.55	<0.37	-
Whitehaven	*Nephrops*	4	<0.24	<0.30	<0.13	3.0	<0.63	-	<0.37	<0.26	460
Silloth	Mussels	4	<0.14	<0.24	<0.08	6.4	<0.43	-	<0.21	<0.18	-
Parton	Crabs	4	1.5	<0.31	<0.12	3.1	<0.57	-	<0.34	<0.22	-
"	Lobsters	4	1.1	<0.36	<0.15	4.2	<0.74	-	<0.42	<0.31	-
"	Winkles	4	1.9	<0.64	<0.13	15	<0.75	-	<0.35	<0.35	-
Haverigg	Cockles	1	<0.61	<0.63	<0.26	7.2	<1.8	-	<0.64	<0.52	-
Millom	Mussels	2	<0.23	<0.27	<0.11	2.8	<0.60	-	<0.30	<0.22	-
Roosebeck	Pacific oysters	4	3.1	<0.14	<0.05	3.0	<0.29	-	<0.15	<0.12	-
Morecambe Bay (Flookburgh)	Shrimps	4	<0.18	<0.26	<0.09	6.9	<0.45	-	<0.26	<0.19	-
" (Morecambe)	Mussels	4	<0.14	<0.24	<0.07	3.0	<0.38	-	<0.19	<0.16	-

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru
Morecambe Bay											
" (Flookburgh)	Cockles	4	76	1.4	<0.16	0.43	<0.23	<0.30	71	<0.28	<1.1
" (Middleton Sands)	"	2	-	1.8	<0.15	-	<0.28	<0.47	-	<0.39	<1.7
Fleetwood	Lobsters	2	-	0.68	<0.41	-	<0.55	<0.74	3300	<0.55	<1.7
"	Squid	1	-	<0.10	<0.26	-	<0.23	<0.25	-	<0.20	<0.82
"	Whelks	4	84	<0.25	<0.25	0.13	<0.25	<0.26	56	<0.21	<1.6
Isle of Man	Lobsters	2	-	<0.24	<0.67	-	<0.91	<1.3	180	<0.97	<2.7
"	Scallops	4	-	<0.06	<0.15	-	<0.17	<0.19	-	<0.16	<0.51
Inner Solway	Shrimps	4	-	<0.10	<0.17	<0.10	<0.16	<0.14	<3.8	<0.15	<0.95
Southerness	Winkles	4	-	<0.38	<0.18	0.24	<0.18	<0.16	770	<0.16	<1.3
Kirkcudbright	Scallops	6	-	<0.08	<0.13	-	<0.15	<0.21	-	<0.17	<0.73
"	Queens	7	-	<0.16	<0.12	-	<0.16	<0.23	-	<0.18	<0.66
North Solway coast	Crabs	6	64	<0.35	<0.22	0.27	<0.33	<0.54	28	<0.39	<0.92
"	Lobsters	7	73	<0.27	<0.77	<0.089	<1.2	<2.1	1800	<1.4	<2.1
"	Winkles	6	-	1.3	<0.34	-	<0.46	<0.74	-	<0.54	<1.4
"	Cockles	6	38	1.6	<0.15	0.75	<0.21	<0.31	54	<0.26	<1.1
"	Mussels	7	56	<0.64	<0.17	0.91	<0.25	<0.36	300	<0.29	<1.8
Isle of Whithorn	*Nephrops*	1	44	<0.10	<0.23	-	<0.31	<0.37	580	<0.38	<0.95
Wirral	Shrimps	2	-	<0.06	<0.16	-	<0.22	<0.25	2.3	<0.23	<0.64
"	Cockles	4	-	<0.13	<0.14	-	<0.19	<0.21	92	<0.19	<0.61
Conwy	Mussels	2	-	<0.06	<0.15	-	<0.20	<0.27	-	<0.22	<0.57
Northern Ireland	*Nephrops*	8	-	<0.11	<0.31	-	<0.52	<0.89	87	<0.64	<1.2
"	Lobsters	3	-	<0.22	<0.61	-	<1.1	<1.9	190	<1.5	<2.5
"	Winkles	4	-	<0.15	<0.37	-	<0.55	<0.87	-	<0.62	<1.5
"	Mussels	1	-	<0.17	<0.41	-	<0.72	<1.2	44	<0.81	<1.7
Minch	*Nephrops*	3	-	<0.06	<0.19	-	<0.30	<0.59	43	<0.43	<0.60
Northern North Sea	"	4	-	<0.07	<0.21	-	<0.39	<0.78	24	<0.53	<0.73
Mid North Sea	Mussels[d]	2	-	<0.06	<0.14	-	<0.19	<0.20	-	<0.17	<0.61
Southern North Sea	Cockles	2	-	0.53	<0.18	-	<0.26	<0.37	-	<0.28	<0.69
"	" [e]	2	-	<0.18	<0.14	-	<0.24	<0.42	0.072	<0.30	<0.59
"	Mussels	4	-	<0.10	<0.25	-	<0.40	<0.65	2.1	<0.50	<1.1

Table 4.2. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Morecambe Bay											
" (Flookburgh)	Cockles	4	<0.12	<0.23	<0.06	4.5	<0.34	-	<0.16	<0.14	-
" (Middleton Sands)	"	2	<0.12	<0.17	<0.06	4.7	<0.42	-	<0.17	<0.18	-
Fleetwood	Lobsters	2	3.4	<0.34	<0.15	2.8	<0.63	-	<0.45	<0.25	3100
"	Squid	1	<0.17	<0.21	<0.09	1.5	<0.38	-	<0.28	<0.16	-
"	Whelks	4	<0.39	<0.25	<0.10	1.7	<0.48	-	<0.32	<0.21	-
Isle of Man	Lobsters	2	<0.46	<0.55	<0.25	<0.38	<1.1	-	<0.76	<0.42	200
"	Scallops	4	<0.10	<0.13	<0.05	0.61	<0.29	-	<0.17	<0.12	-
Inner Solway	Shrimps	4	<0.11	<0.44	<0.09	5.7	<0.54	-	<0.43	<0.43	-
Southerness	Winkles	4	<0.25	<0.49	<0.10	7.9	<0.55	-	<0.43	<0.44	-
Kirkcudbright	Scallops	6	<0.09	<0.31	<0.07	<0.25	<0.25	-	<0.32	<0.30	-
"	Queens	7	<0.12	<0.27	<0.07	0.85	<0.21	-	<0.29	<0.26	-
North Solway coast	Crabs	6	<0.54	<0.30	<0.09	2.3	<0.41	-	<0.33	<0.27	-
"	Lobsters	7	<0.42	<0.53	<0.21	3.0	<1.1	-	<0.66	<0.45	-
"	Winkles	6	<0.89	<0.43	<0.12	3.1	<0.61	-	<0.40	<0.34	-
"	Cockles	6	<0.11	<0.27	<0.07	4.7	<0.30	-	<0.25	<0.25	-
"	Mussels	7	<0.12	<0.34	<0.08	4.3	<0.40	-	<0.32	<0.31	-
Isle of Whithorn	*Nephrops*	1	<0.17	<0.26	<0.09	5.3	<0.57	-	<0.29	<0.25	-
Wirral	Shrimps	2	<0.12	<0.17	<0.07	3.6	<0.37	-	<0.19	<0.14	-
"	Cockles	4	<0.11	<0.16	<0.07	2.4	<0.32	-	<0.17	<0.14	-
Conwy	Mussels	2	<0.11	<0.14	<0.06	0.48	<0.29	-	<0.17	<0.12	-
Northern Ireland	*Nephrops*	8	<0.22	<0.25	<0.11	1.5	<0.52	-	<0.32	<0.20	-
"	Lobsters	3	<0.44	<0.54	<0.23	0.53	<1.2	-	<0.64	<0.42	-
"	Winkles	4	<0.26	<0.33	<0.14	0.46	<0.63	-	<0.38	<0.24	-
"	Mussels	1	<0.29	<0.34	<0.17	0.98	<0.61	-	<0.42	<0.23	-
Minch	*Nephrops*	3	<0.13	<0.14	<0.06	0.57	<0.30	-	<0.20	<0.11	-
Northern North Sea	"	4	<0.15	<0.16	<0.07	0.31	<0.37	-	<0.22	<0.14	-
Mid North Sea	Mussels[d]	2	<0.12	<0.15	<0.06	0.19	<0.30	-	<0.16	<0.13	14
Southern North Sea	Cockles	2	<0.14	<0.16	<0.08	0.17	<0.31	-	<0.19	<0.13	-
"	" [e]	2	<0.11	<0.13	<0.06	<0.11	<0.32	-	<0.14	<0.13	-
"	Mussels	4	<0.19	<0.25	<0.11	0.25	<0.54	-	<0.28	<0.21	-

- not analysed
** not detected by the method used*
[a] Sampling area or landing point
[b] See section 3 for definition
[c] Samples collected by Consumer 116
[d] Landed in Denmark
[e] Landed in Holland

Table 4.3. Transuranic radioactivity in fish and shellfish from the Irish Sea vicinity and further afield, 1997

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Sellafield coastal area	Cod	2	-	0.0012	0.0056	-	0.011	*	0.000028
"	Plaice	1	-	0.0018	0.0078	-	0.016	0.000043	0.000050
"	Grey mullet	1	-	-	-	-	<0.70	-	-
"	Bass	1	-	-	-	-	<0.20	-	-
"	Crabs	2	0.0057	0.069	0.34	4.5	1.3	*	0.0035
"	Lobsters	2	0.074	0.094	0.46	9.4	6.5	<0.0070	0.011
"	Winkles[c]	1	0.017	1.2	6.2	84	12	*	0.028
"	Mussels[c]	1	-	2.0	9.7	120	18	*	*
"	Limpets[c]	1	-	2.3	11	140	20	*	0.037
"	Whelks	1	-	0.49	2.3	32	3.1	*	*
Sellafield offshore area	Cod	1	-	0.0027	0.013	-	0.025	*	0.000052
"	Plaice	1	0.00044	0.0043	0.020	-	0.031	*	0.00013
"	Dab	1	-	-	-	-	<0.23	-	-
"	Whiting	2	-	-	-	-	<0.29	-	-
"	Spurdog	1	-	-	-	-	<0.45	-	-
"	Whelks	1	-	0.52	2.5	31	10	*	0.021
St Bees	Winkles	1	0.032	2.6	13	170	23	0.042	0.053
"	Mussels	2	-	2.0	9.7	130	18	<0.011	0.048
"	Limpets	1	-	1.5	7.3	-	13	*	0.030
Nethertown	Winkles	4	0.028	3.7	17	220	31	<0.021	0.061
"	Mussels	4	-	2.0	9.4	-	17	<0.013	0.044
Drigg	Winkles	4	0.030	2.7	13	190	24	*	0.099
Ravenglass	Cod	1	-	0.00089	0.0043	-	0.0073	*	0.0000090
"	Plaice	1	-	0.00061	0.0031	-	0.0068	*	0.000010
"	Salmon	1	-	-	-	-	<0.16	-	-
"	Crabs	1	-	0.053	0.27	3.4	1.1	*	0.0038
"	Lobsters	1	-	0.046	0.21	2.8	3.0	*	0.0064
"	Winkles	2	-	-	-	-	27	-	-
"	Mussels	1	-	1.8	8.2	110	17	*	0.032
"	Cockles	1	-	2.3	11	140	29	0.038	0.084
Tarn Bay	Winkles	1	-	2.2	11	150	22	0.039	0.054
Saltom Bay	"	3	-	-	-	-	17	-	-
Whitehaven	Cod	1	-	0.00029	0.0015	-	0.0029	*	0.000017
"	Plaice	1	-	0.0011	0.0052	-	0.010	*	0.000016
"	Ray	1	-	0.00054	0.0031	-	0.0050	*	*
"	*Nephrops*	1	-	0.014	0.083	-	0.19	*	*
Silloth	Mussels	1	-	0.58	3.1	-	5.0	*	0.0067
Parton	Cod	4	-	-	-	-	<0.31	-	-
"	Crabs	4	-	-	-	-	1.0	-	-
"	Lobsters	4	-	-	-	-	1.7	-	-
"	Winkles	1	-	1.9	9.5	110	16	*	0.033
Haverigg	Cockles	1	-	-	-	-	21	-	-
Millom	Mussels	2	-	-	-	-	5.5	-	-
Roosebeck	Pacific oysters	1	-	0.30	1.6	-	1.4	0.0017	0.0027
Morecambe Bay (Flookburgh)	Flounder	1	-	0.00061	0.0038	-	0.0056	*	0.000011
" (Morecambe)	Plaice	4	-	-	-	-	<0.27	-	-
" "	Bass	2	-	-	-	-	<0.15	-	-
" (Sunderland Point)	Whitebait	1	-	0.078	0.31	4.2	0.48	*	0.00067

Table 4.3. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Morecambe Bay (Flookburgh)	Shrimps	1	-	0.0056	0.029	0.37	0.047	0.00010	0.000093
" (Morecambe)	Mussels	1	-	0.32	1.8	-	3.2	*	0.0034
" (Flookburgh)	Cockles	1	-	0.32	1.8	19	4.8	*	0.013
" (Middleton Sands)	"	1	-	0.39	2.1	-	5.4	*	0.0086
River Ehen	Sea trout	1	-	-	-	-	<0.17	-	-
River Calder	Brown trout	1	-	-	-	-	<1.2	-	-
"	Eel	1	-	-	-	-	<0.85	-	-
Calder Farm	Rainbow trout	1	-	-	-	-	<0.30	-	-
River Duddon	Sea trout	1	-	-	-	-	<0.20	-	-
River Kent	"	1	-	-	-	-	<0.20	-	-
Fleetwood	Cod	1	-	0.00024	0.0012	-	0.0032	*	0.0000072
"	Plaice	1	-	0.00037	0.0017	-	0.0032	*	*
"	Fish oil[d]	3	-	-	-	-	<0.20	-	-
"	Lobsters	2	-	-	-	-	5.5	-	-
"	Whelks	1	-	0.11	0.58	6.9	0.87	*	0.0015
"	Squid	1	-	-	-	-	<0.11	-	-
Isle of Man	Cod	1	-	0.00011	0.00065	-	0.00089	*	*
"	Herring	1	-	0.00034	0.0018	-	0.0026	*	0.0000020
"	Lobsters	2	-	-	-	-	<0.42	-	-
"	Scallops	1	-	0.013	0.072	-	0.020	*	0.000073
Inner Solway	Flounder	1	-	<0.020	0.022	-	0.050	*	*
"	Sea trout	1	-	0.00027	0.00039	-	<0.00020	*	*
"	Salmon	1	-	-	-	-	<0.50	-	-
"	Shrimps	4	-	0.0033	0.016	-	0.023	*	*
Kirkcudbright	Plaice	1	-	0.0012	0.0044	-	0.0094	<0.00030	<0.00030
"	Scallops	2	-	0.014	0.070	-	0.030	0.000073	0.000072
"	Queens	2	-	0.014	0.070	-	0.089	<0.00010	<0.00027
Isle of Whithorn	Plaice	1	-	0.00042	0.0021	-	0.0040	*	0.000015
"	*Nephrops*	1	-	0.015	0.12	-	0.80	*	0.00096
Southerness	Winkles	1	-	0.31	1.6	26	2.6	*	0.0034
North Solway coast	Crabs	2	-	0.031	0.15	1.8	0.69	*	0.0013
"	Lobsters	2	-	0.030	0.16	1.9	0.92	<0.00015	0.00074
"	Winkles	2	-	0.36	1.9	21	0.39	*	0.0082
"	Cockles	5	-	0.65	3.8	39	9.5	<0.00080	<0.014
"	Mussels	2	-	0.62	3.2	38	7.3	<0.0062	<0.0049
Wirral	Shrimps	2	-	-	-	-	<0.12	-	-
"	Cockles	1	-	0.13	0.69	-	1.9	0.0039	0.0026
Conwy	Mussels	1	-	0.027	0.15	-	0.24	*	0.00055
North Anglesey	Rays	1	-	0.000044	0.00025	-	0.00039	*	*
"	Plaice	2	-	-	-	-	<0.13	-	-
Ribble Estuary	Flounder	1	-	-	-	-	<0.10	-	-
"	Mullet	1	-	-	-	-	<0.43	-	-
"	Salmon	1	-	-	-	-	<0.24	-	-
Northern Ireland	Cod	8	-	-	-	-	<0.15	-	-
"	Whiting	1	-	0.00041	0.0022	-	0.0034	*	0.0000099
"	Herring	2	-	-	-	-	<0.12	-	-
"	Spurdog	5	-	-	-	-	<0.20	-	-
"	Saithe	4	-	-	-	-	<0.19	-	-
"	Lobsters	3	-	-	-	-	<0.35	-	-
"	*Nephrops*	1	-	0.0072	0.040	-	0.14	*	0.00023
"	Winkles	1	-	0.035	0.20	-	0.15	*	0.00038
"	Mussels	1	-	-	-	-	0.19	-	-

Table 4.3. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
West of Scotland	Mackerel	1	-	-	-	-	<0.23	-	-
Sound of Mull	Salmon	1	-	-	-	-	<0.33	-	-
Minch	Cod	1	-	0.000014	0.00011	-	0.00016	*	*
"	Haddock	1	-	0.000046	0.00022	-	0.00030	*	*
"	Mackerel	1	-	0.000072	0.00044	-	0.00044	*	*
"	Plaice	3	-	-	-	-	<0.13	-	-
"	Herring	3	-	-	-	-	<0.18	-	-
"	*Nephrops*	1	-	0.00070	0.0042	-	0.0081	*	*
Shetland	Fish meal[d]	1	-	0.000094	0.00098	-	0.00040	*	*
"	Fish oil[d]	4	-	-	-	-	<0.37	-	-
Northern North Sea	Cod	1	-	0.000098	0.00047	-	0.00079	*	*
"	Plaice	4	-	-	-	-	<0.12	-	-
"	Herring	3	-	-	-	-	<0.14	-	-
"	Haddock	1	-	0.00012	0.00060	-	0.0011	*	*
"	*Nephrops*	1	-	0.00045	0.0030	-	0.0042	0.000034	0.000038
Mid North Sea	Cod	4	-	-	-	-	<0.10	-	-
"	Plaice	4	-	-	-	-	<0.09	-	-
"	Herring	3	-	-	-	-	<0.20	-	-
"	Mussels[e]	1	-	0.00023	0.0035	-	0.0012	*	*
Southern North Sea	Cod	2	-	-	-	-	<0.08	-	-
"	Plaice	2	-	-	-	-	<0.10	-	-
"	Herring	2	-	-	-	-	<0.12	-	-
"	Cockles	1	-	0.0020	0.0080	-	0.011	0.000098	0.0010
"	" [f]	1	-	0.0023	0.0095	-	0.012	0.000071	0.0011
"	Mussels	1	-	0.0034	0.021	-	0.0064	*	*
English Channel	Cod	4	-	-	-	-	<0.09	-	-
"	Plaice	4	-	-	-	-	<0.05	-	-
"	Mackerel	4	-	-	-	-	<0.18	-	-
Gt Yarmouth (retail shop)	Cod	4	-	-	-	-	<0.12	-	-
"	Plaice	4	-	-	-	-	<0.08	-	-
Skagerrak	Cod	3	-	-	-	-	<0.12	-	-
"	Herring	3	-	-	-	-	<0.11	-	-
Norwegian Sea	Cod	1	-	-	-	-	<0.15	-	-
"	Saithe	1	-	-	-	-	<0.05	-	-
Iceland Area	Cod	2	-	-	-	-	<0.15	-	-
Icelandic processed	"	1	-	0.000014	0.000075	-	0.000097	*	*
Barents Sea	"	3	-	-	-	-	<0.06	-	-
Baltic Sea	"	2	-	-	-	-	<0.24	-	-
"	Herring	4	-	-	-	-	<0.26	-	-

- not analysed
** not detected by the method used*
[a] *Sampling area or landing point*
[b] *See section 3 for definition*
[c] *Samples collected by Consumer 116*
[d] *Concentrations refer to weight as supplied*
[e] *Landed in Denmark*
[f] *Landed in Holland*

Table 4.4. Individual radiation exposures due to consumption of Irish Sea fish and shellfish, 1997

Exposed population[b]	Foodstuffs	Exposure mSv[a]										
		Total	^{14}C	^{90}Sr	^{99}Tc	^{106}Ru	^{137}Cs	^{238}Pu	$^{239+240}Pu$	^{241}Pu	^{241}Am	Others
Sellafield fishing community	Plaice and cod Crabs and lobsters Winkles and other molluscs	0.10	0.003	0.001	0.053	0.001	0.006	0.002	0.009	0.002	0.021	<0.002
Whitehaven commercial fisheries	Plaice and cod *Nephrops* Whelks	0.037	0.003		0.008	0.002	0.006	0.001	0.007	0.002	0.008	<0.001
Dumfries and Galloway	Plaice, cod and salmon Crabs, Lobster and *Nephrops* Winkles and mussels	0.047[c]	0.001		0.010		0.003		0.006	0.001	0.009	<0.002
Morecambe Bay	Flounders and plaice Shrimps Cockles and mussels	0.073[d]	0.004		0.003	0.001	0.013	0.002	0.011	0.002	0.022	<0.001
Fleetwood	Plaice and cod Shrimps Whelks	0.030	0.005		0.001		0.012		0.004		0.004	<0.001
Isle of Man	Fish and shellfish[e]	0.010			0.002	0.001	0.004				0.002	<0.001
Northern Ireland	Fish and shellfish[e]	0.012			0.002	0.001	0.004		0.001		0.001	<0.001
Typical member of the fish eating public consuming fish landed at Whitehaven and Fleetwood	Plaice and cod	0.002					0.001					<0.001

[a] *Due to artificial radionuclides: see text for exposures due to natural radionuclides. Blank data indicate a dose of less than 1 µSv. 'Others' comprises data for all radionuclides with doses below 1 µSv.*

[b] *Representative of people most exposed unless stated otherwise*

[c] *Including exposure due to 1000 h year^{-1}occupancy over intertidal sediments*

[d] *Including exposure due to 900 h year^{-1} occupancy over intertidal sediments*

[e] *Local habits surveys have not been undertaken in these areas; representative species are adopted for fish, crustaceans and molluscs*

Table 4.5. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 1997

Location	Ground type	No. of sampling observations[a]	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Cumbria			
Rockcliffe	Salt marsh	1	0.15
Rockcliffe Marsh	"	4	0.077
Eden Creek	"	1	0.10
Burgh Marsh	"	4	0.097
Port Carlisle	Mud and sand	2	0.086
"	Mud, sand & stones	2	0.090
Bowness	Mud and sand	1	0.099
"	Salt marsh	1	0.091
Greenend	"	4	0.083
"	Mud and sand	3	0.075
"	Sand	1	0.076
Cardurnock Marsh	Salt marsh	4	0.10
Newton Arlosh	"	4	0.12
Skinburness Marsh	"	1	0.10
Calvo Marsh	"	1	0.091
Silloth - silt pond	Grass	2	0.072
" - boat area	Mud and sand	2	0.098
Allonby	Sand	2	0.084
Maryport - Christchurch	Mud	4	0.11
" - outer harbour	"	4	0.10
Siddick	Sand	4	0.075
Workington Harbour	Mud	4	0.13
Harrington Harbour	Mud and sand	4	0.11
Parton	Winkle bed	3	0.099
Whitehaven - outer harbour	Mud and sand	10	0.096
" "	Coal and sand	12	0.13
" "	Sand	3	0.088
Whitehaven - inner harbour	Mud	6	0.21
" "	Mud and sand	6	0.23
" - yacht basin	Mud	12	0.21
Fishing vessel A	Cabin[b]	4	0.084
" R	"	3	0.083
" U	"	1	0.083
Saltom Bay	Winkle bed	3	0.098
St Bees	Sand	4	0.069
Nethertown	Winkle bed	4	0.10
Sellafield	Sand	4	0.073
Seascale	"	4	0.074
Drigg pipeline	"	8	0.069
Drigg Barn Scar	Mussel bed	4	0.091
Saltcoats	Salt marsh	4	0.21
Muncaster Bridge	"	4	0.23
Ravenglass - Carleton Marsh	"	4	0.25
Ravenglass - salmon garth	Mud and sand	4	0.12
" "	Sand and stones	4	0.093
" "	Mussel bed	4	0.092
" - boat area	Mud and sand	12	0.095
" "	Sand	4	0.069
" - ford	Mud and sand	4	0.10
" - River Mite	Salt marsh	4	0.21
" - Raven Villa	Mud and sand	12	0.13
" "	Salt marsh	12	0.21
" - Eskmeals Nature Reserve	"	4	0.22
Newbiggin	Mud	1	0.17
"	Mud and sand	3	0.20
"	Salt marsh	4	0.25
" - west of bridge	Mud, sand & stones	3	0.11
" "	Mud and sand	1	0.11
" "	Salt marsh	4	0.23
Tarn Bay	Sand	2	0.075
"	Winkle bed	2	0.089
Silecroft	Sand	2	0.067
Haverigg	Mud	1	0.097
"	Mud and sand	5	0.082
"	Sand and stones	1	0.070
"	Sand	1	0.068
Millom	Mud and sand	3	0.099
"	Mud, sand and stones	1	0.10
Millom Marsh	Salt marsh	1	0.16
Low Shaw	"	4	0.11
Askam	"	4	0.14
Askam Pier	Mud and sand	1	0.085
Tummer Hill Marsh	Salt marsh	4	0.16
Walney Channel	Mud and sand	4	0.084
" - Vickerstown Church	"	4	0.089
" - Sewer outfall	Mussel bed	2	0.084
Walney Island - west shore	Sand	4	0.066
Roa Island	Mud and sand	4	0.081
Sheep Island	"	1	0.087
Greenodd	Salt marsh	2	0.081
Sand Gate Marsh	"	4	0.10
Flookburgh	Mud and sand	4	0.078
High Foulshaw	Salt marsh	4	0.095
Arnside	Mud and sand	4	0.070
"	Salt marsh	4	0.11

Table 4.5. continued

Location	Ground type	No. of sampling observations[a]	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Lancashire, Merseyside and North Wales			
Bolton-le-Sands	Salt marsh	1	0.11
Hesk Bank	Mud and sand	1	0.075
Sunderland Point	"	4	0.088
Sunderland	Mud, sand & stones	4	0.079
Colloway Marsh	Salt marsh	4	0.16
Lancaster	"	3	0.097
Aldcliffe Marsh	"	3	0.12
Conder Green	Mud	1	0.11
"	Mud and sand	3	0.10
"	Salt marsh	4	0.12
Cockerham Marsh	"	4	0.11
Heads - River Wyre	"	2	0.12
Height o' th' hill - River Wyre	"	4	0.13
Hambleton	Mud	4	0.11
"	Salt marsh	4	0.12
Knott End	Mussel bed	1	0.11
Fleetwood	Sand	4	0.067
" Docks	Salt marsh	4	0.14
Skippool Creek	Mud	4	0.11
" (boat 2)	Cabin[b]	1	0.11
"	Mud	3	0.097
"	Mud and sand	1	0.094
Blackpool	Sand	4	0.057
Crossens Marsh	Mud	4	0.11
"	Salt marsh	4	0.11
Ainsdale	Sand	4	0.055
New Brighton	Mussel bed	4	0.076
West Kirby	Mud and sand	2	0.069
Rock Ferry	Mud	3	0.10
"	Mud and sand	1	0.11
Little Neston Marsh	"	2	0.082
"	Salt marsh	2	0.084
Flint	Mud	4	0.091
"	Salt marsh	4	0.12
Prestatyn	Sand	2	0.049
Rhyl	Mud	2	0.065
Llandudno	Gravel	2	0.073
Caerhun	Salt marsh	2	0.095
Llanfairfechan	"	2	0.074
South-west Scotland			
Luce Bay	Sand	3	0.060
Piltanton Burn	Salt marsh	4	0.072
Garlieston	Mud	5	0.077
"	Mud and sand	2	0.084
Innerwell	Mud	3	0.080
"	Mud and sand	4	0.082
Bladnoch	Mud	1	0.090
Creetown	Salt marsh	4	0.092
Carsluith	Mud	5	0.085
"	Mud and sand	2	0.081
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.080
Cumstoun	"	1	0.098
Kirkcudbright	"	7	0.097
Cutters Pool	Winkle bed	4	0.090
Rascarrel Bay	"	4	0.11
Palnackie Harbour	Mud	5	0.087
"	Mud and sand	2	0.092
Gardenburn	Salt marsh	4	0.096
Kippford - Slipway	Mud	5	0.094
" "	Mud and sand	2	0.087
" - Merse	Salt marsh	7	0.13
Carsethorn	Mud	3	0.063
"	Mud and sand	3	0.073
"	Mud, sand and stones	1	0.072
Glencaple Harbour	Mud and sand	4	0.085

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

Table 4.6. Radioactivity in sediment from the Cumbrian coast and further afield, 1997

Location	Material	No. of sampling observations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria												
Newton Arlosh	Turf	4	<1.3	<2.0	<4.7	<8.0	<12	<19	<2.3	<7.2	<1.6	740
Maryport - Christchurch	Mud	4	<1.9	18	<6.1	<6.7	<8.0	96	<3.5	<8.9	<2.5	680
Harrington Harbour	"	4	<0.88	12	<4.1	<7.2	<7.8	<48	<1.7	<4.4	<1.1	430
Whitehaven - yacht basin	"	4	<1.6	14	<7.7	<15	<16	<74	<2.9	<7.3	<1.8	830
St Bees	Sand	4	<0.38	2.7	<1.3	<1.9	<1.9	<4.3	<0.68	<1.3	<0.43	90
Sellafield	"	4	<0.40	3.6	<1.5	<2.1	<2.2	<4.6	<0.70	<1.4	<0.43	110
Seascale	"	4	<0.30	2.4	<1.0	<1.4	<1.4	<3.2	<0.53	<0.98	<0.36	64
Drigg - N of pipeline	"	4	<0.34	3.8	<1.0	<1.1	<1.1	<6.0	<0.57	<1.0	<0.39	56
River Mite estuary	Mud	4	<0.88	24	<6.9	<12	<4.7	150	<1.8	8.6	<1.1	410
Ravenglass - Carleton Marsh	"	4	<1.2	33	<4.5	<5.7	<6.9	190	<2.3	<9.0	<1.5	720
" - Raven Villa	"	1	<0.73	20	58	95	4.6	360	3.5	15	1.0	410
" "	Mud & sand	3	<0.98	25	<4.5	<7.0	<6.9	79	<1.8	6.5	<1.2	310
Newbiggin	Mud	4	<1.6	22	<17	<26	<14	130	<2.9	<6.2	<1.8	370
Millom	Mud & sand	4	<0.84	<4.3	<3.1	<4.1	<4.6	<37	<1.5	<3.1	<0.98	150
Low Shaw	Turf	4	<0.91	<2.3	<4.9	<9.4	<14	<13	<1.7	<4.5	<1.1	470
Flookburgh	Mud & sand	4	<0.33	<0.56	<1.2	<1.7	<1.7	<3.5	<0.58	<1.1	<0.38	98
Sand Gate marsh	Turf	4	<1.1	<1.0	<5.4	<10	<12	<11	<1.7	<3.6	<1.1	260
Lancashire, Merseyside and north Wales												
Sunderland Point	Mud & sand	4	<0.68	2.7	<2.9	<5.4	<5.1	<7.3	<1.1	<2.2	<0.81	190
Conder Green	Turf	4	<0.98	<2.2	<4.7	<8.5	<11	<14	<1.8	<4.6	<1.2	480
Hambleton	"	4	<1.3	<3.1	<7.1	<14	<20	<18	<2.4	<6.4	<1.6	730
Skippool Creek	Mud	4	<1.0	<3.4	<4.1	<5.6	<7.3	<16	<1.8	<4.6	<1.4	510
Fleetwood	Sand	4	<0.31	<0.30	<0.88	<0.95	<0.88	<3.0	<0.52	<0.85	<0.34	28
Blackpool	"	4	<0.24	<0.22	<0.79	<1.0	<0.85	<2.2	<0.41	<0.61	<0.26	7.5
New Brighton	"	2	<0.29	<0.26	<0.86	<1.1	<0.92	<2.7	<0.49	<0.74	<0.32	11
Rock Ferry	Mud	4	<0.76	<0.87	<2.3	<2.6	<3.0	<9.2	<1.3	<3.2	<1.0	240
Rhyl	"	2	<0.45	<0.48	<1.5	<1.6	<1.7	<4.6	<0.79	<1.8	<0.58	110
Caerhun	Turf	2	<0.95	<0.75	<4.5	<9.0	<8.8	<9.9	<1.5	<3.0	<1.2	220
Cemlyn Bay	Mud	2	<0.62	<0.80	<2.9	<5.0	<4.7	<6.2	<1.1	<1.8	<0.75	170
Llanfairfechan	Turf	2	<0.71	<0.56	<3.6	<7.4	<6.6	<6.8	<1.2	<2.2	<0.88	110
South-west Scotland												
Garlieston	Mud	6	<0.60	<1.8	<4.2	<5.2	<5.7	<9.3	<1.1	<2.4	<0.76	160
"	Mud & sand	1	<0.31	2.7	<0.73	<0.67	<0.80	13	<0.52	1.6	<0.41	200
Innerwell	Mud	5	<0.45	<1.4	<3.0	<2.4	<3.1	<5.4	<0.60	<1.6	<0.46	130
Bladnoch	"	1	<0.68	4.8	<2.0	<1.7	<2.2	36	<1.2	4.0	<0.86	470
Carsluith	"	6	<0.56	<2.9	<3.1	<3.9	<4.5	<11	<0.83	<2.4	<0.67	230
"	Mud & sand	1	<0.47	2.8	<1.3	<1.3	<1.6	6.1	<0.74	3.6	<0.60	150
Kippford Merse	Salt marsh	7	<0.80	6.2	<5.7	<9.9	<12	<21	<1.4	<4.0	<1.1	580
" Slipway	Mud	6	<0.49	2.9	<2.7	<3.3	<3.7	<15	<0.67	<2.0	<0.53	240
" "	Mud & sand	1	<0.29	1.7	<0.79	<0.69	<0.81	11	<0.52	1.9	<0.38	150
Palnackie Harbour	Mud	7	<0.50	3.0	<2.5	<3.3	<4.0	<16	<0.72	<2.5	<0.59	280
Carsethorn	"	4	<0.52	<1.2	<2.6	<3.5	<3.9	<6.9	<0.77	<2.3	<0.66	220
Isle of Man												
Douglas	"	1	<0.65	<0.56	<4.1	<9.6	<7.2	<6.1	<1.2	<1.7	<0.78	77
Northern Ireland												
Lough Foyle	"	2	<0.49	<0.37	<2.8	<5.6	<4.3	<4.6	<0.83	<1.1	<0.57	27
Portrush	Sand	2	<0.23	<0.17	<2.0	<1.4	<0.95	<2.0	<0.46	<0.46	<0.22	0.90
Ballymacormick	Mud	2	<0.47	<0.35	<3.6	*	<8.0	<4.1	<0.89	<1.0	<0.47	51
Strangford Lough - Nickey's Pt	"	2	<0.36	<0.28	<2.0	<4.5	<3.6	<3.3	<0.64	<0.94	<0.40	56
Dundrum Bay	"	2	<0.54	<0.42	<4.0	<1.8	<1.3	<4.6	<1.0	<1.1	<0.55	11
Carlingford Lough	"	2	<0.53	<0.43	<3.0	<6.6	<5.2	<4.9	<0.93	<1.3	<0.62	100
Oldmill Bay	"	2	<0.45	<0.36	<1.7	<2.8	<2.4	<4.2	<0.72	<1.2	<0.50	70

Table 4.6. continued

Location	Material	No. of sampling observations[a]	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Cumbria												
Newton Arlosh	Turf	4	<10	<4.9	<4.5	-	-	-	250	-	-	-
Maryport - Christchurch	Mud	4	<15	12	<5.9	110	520	-	870	0.80	1.4	-
Harrington Harbour	"	4	<7.4	7.6	<4.2	-	-	-	480	-	-	-
Whitehaven - yacht basin	"	4	<13	14	<7.7	100	500	-	820	*	1.6	2700
St Bees	Sand	4	<2.6	<1.5	<1.3	-	-	-	180	-	-	-
Sellafield	"	4	<2.6	<1.8	<1.2	-	-	-	190	-	-	-
Seascale	"	4	<2.2	<1.8	<1.8	-	-	-	160	-	-	-
Drigg - N of pipeline	"	4	<2.3	<2.6	<1.1	-	-	-	230	-	-	-
River Mite estuary	Mud	4	<19	13	<6.2	130	630	7800	1000	*	2.3	-
Ravenglass - Carleton Marsh	"	4	<15	18	8.5	-	-	-	1300	-	-	-
" - Raven Villa	Mud	1	52	11	4.8	-	-	-	720	-	-	-
" "	Mud & sand	3	<8.3	11	<4.1	-	-	-	650	-	-	-
Newbiggin	Mud	4	<17	<9.6	<5.1	100	480	6100	750	0.95	1.8	1600
Millom	Mud & sand	4	<5.9	<3.0	<2.7	-	-	-	190	-	-	-
Low Shaw	Turf	4	<8.4	<6.2	<4.0	-	-	-	410	-	-	-
Flookburgh	Mud & sand	4	<2.4	<0.93	<1.2	-	-	-	46	-	-	-
Sand Gate marsh	Turf	4	<6.5	<2.9	<2.5	-	-	-	130	-	-	-
Lancashire, Merseyside and north Wales												
Sunderland Point	Mud & sand	4	<4.1	<1.7	3.0	-	-	-	110	-	-	-
Conder Green	Turf	4	<8.5	<3.2	<3.4	-	-	-	210	-	-	-
Hambleton	"	4	<10	<4.6	<4.1	-	-	-	310	-	-	-
Skippool Creek	Mud	4	<8.3	<4.7	<3.6	-	-	-	230	-	-	-
Fleetwood	Sand	4	<1.9	<0.87	<0.86	-	-	-	15	-	-	-
Blackpool	"	4	<1.5	<0.64	<0.66	-	-	-	4.1	-	-	-
New Brighton	"	2	<1.8	<0.80	<0.81	-	-	-	3.9	-	-	-
Rock Ferry	Mud	4	<6.5	<2.1	<3.1	-	-	-	80	-	-	-
Rhyl	"	2	<2.7	<1.4	<1.2	-	-	-	37	-	-	-
Caerhun	Turf	2	<6.8	<2.2	<3.0	-	-	-	53	-	-	-
Cemlyn Bay	Mud	2	<3.3	<1.7	<1.3	4.1	23	-	32	*	0.035	-
Llanfairfechan	Turf	2	<5.3	<1.6	<2.3	-	-	-	23	-	-	-
South-west Scotland												
Garlieston	Mud	6	<7.3	<2.4	<2.0	17	87	-	140	*	0.49	-
"	Mud & sand	1	<2.8	3.6	1.6	-	-	-	180	-	-	-
Innerwell	Mud	5	<5.2	<1.8	<1.8	-	-	-	100	-	-	-
Bladnoch	"	1	<4.2	6.0	4.1	-	-	-	360	-	-	-
Carsluith	"	6	<6.6	<3.3	<2.6	22	120	-	250	*	0.27	1300
"	Mud & sand	1	<4.4	2.0	<2.0	-	-	-	130	-	-	960
Kippford Merse	Salt marsh	7	<9.2	<7.4	<4.1	57	290	-	530	*	1.0	-
" Slipway	Mud	6	<5.3	<2.9	<2.0	24	120	-	210	*	0.26	-
" "	Mud & sand	1	<2.8	2.2	1.9	-	-	-	150	-	-	-
Palnackie Harbour	Mud	7	<7.0	<3.2	<2.4	27	140	-	220	*	0.30	-
Carsethorn	"	4	<6.4	<2.3	<2.1	-	-	-	120	-	-	-
Isle of Man												
Douglas	"	1	<3.5	<1.4	1.3	-	-	-	7.2	-	-	-
Northern Ireland												
Lough Foyle	"	2	<3.0	<1.1	<1.4	1.2	6.7	-	9.5	0.0094	0.012	-
Portrush	Sand	2	<1.4	<0.53	<0.49	-	-	-	<0.59	-	-	-
Ballymacormick	Mud	2	<2.6	<1.0	<0.97	3.4	18	-	24	*	0.040	-
Strangford Lough - Nickey's Pt	"	2	<2.3	<0.85	<1.2	2.6	14	-	15	0.023	0.025	-
Dundrum Bay	"	2	<3.1	<1.3	<1.2	-	-	-	2.3	-	-	-
Carlingford Lough	"	2	<2.8	<1.3	1.8	2.4	13	-	8.9	0.018	0.010	-
Oldmill Bay	"	2	<2.9	<1.1	<1.3	3.1	16	-	23	*	0.030	-

- not analysed
** not detected by the method used*
[a] See section 3 for definition

Table 4.7. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 1997

Vessel	Type of gear	No. of sampling observations[a]	Mean beta dose rate in tissue, μSv h^{-1}
A	Nets	6	0.029
	Ropes	4	0.028
R	Nets	4	0.10
S	Gill nets	2	0.072
	Pots	2	0.15
T	Gill nets	5	0.040
	Pots	2	0.088
X	Gill nets	5	0.11
	Pots	1	0.18

[a] *See section 5 for definition*

Table 4.8. Radioactivity in terrestrial food and the environment near Sellafield, 1997

Material	Selection[d] samples[b]	Farms/	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru[l]	^{125}Sb	^{129}I	^{131}I
Milk Near farms[c]		12	<4.3	17	<0.79	<0.41	0.12	<0.0055	<2.8	<0.81	<0.012	<0.032
" "	max		6.8	21	<2.5	<0.45	0.33		<3.1	<0.85	<0.021	<0.035
" "	sub-sets	3	-	-	-	<0.30	-	-	<1.7	<0.50	-	-
" "	max								<1.8	<0.60		
" Far farms[c]		4	<3.4	15	<0.46	<0.41	0.060	<0.0055	<2.9	<0.80	<0.011	-
" "	max		<4.3	17	<0.68	<0.42	0.067		<3.1	<0.86	<0.014	
Apples[c]		2	6.5	13	0.80	<0.45	0.21	<0.029	<3.2	<0.75	<0.045	-
	max		7.0		1.1	<0.50	0.24		<3.3	<1.0	<0.056	
Blackberries[c]		2	35	30	7.5	<0.55	4.8	-	<3.6	<1.0	<0.044	-
	max		39	39	8.2	<0.60	8.7		<3.8	<1.2	<0.048	
Bovine kidney[c]		1	<4.0	27	9.1	<0.40	0.63	-	<3.3	<1.1	-	-
" liver[c]		1	<4.0	35	3.6	<0.40	0.17	<0.018	<2.9	<0.70	<0.071	-
" muscle[c]		1	<3.0	26	7.4	<0.50	<0.020	<0.019	<3.1	<0.90	<0.053	-
Cabbage[c]		2	<4.0	6.5	0.65	<0.50	3.5	-	<3.2	<0.70	<0.043	-
	max		5.0	10	0.90		6.3		<3.7		<0.047	
Carrots[c]		1	<3.0	6.0	0.80	<0.30	0.81	<0.023	<2.1	<0.50	<0.041	-
Cauliflower		1	-	-	-	-	-	-	-	-	-	-
Duck[c]		1	3.0	29	14	<0.40	0.026	<0.019	<3.5	<1.1	-	-
Eggs[c]		1	3.0	24	0.50	<0.50	<0.017	-	<2.8	<0.90	<0.036	-
Elderberries[c]		1	5.0	29	9.5	<0.60	3.3	-	<3.7	<1.3	0.063	-
Honey		1	<4.0	85	1.2	<0.20	0.046	-	<3.8	<1.2	<0.016	-
Mushrooms[e]		1	15	12	<0.30	<0.40	0.17	-	<2.3	<0.40	<0.047	-
Ovine offal[c]		2	<5.5	39	11	<0.50	0.069	<0.029	<3.4	<1.7	-	-
" "	max		7.0	51	16	<0.60			<3.5	<2.0		
" muscle[j]		2	<12	31	8.5	<0.45	<0.025	<0.028	<3.2	<1.1	<0.041	-
" "	max		20		10	<0.50	0.025	<0.035	<3.9	<1.4	<0.045	
Pheasants[c]		1	12	29	9.2	<0.60	0.039	<0.018	<4.0	<0.60	<0.068	-
Potatoes[c]		1	<3.0	18	<0.20	<0.60	0.13	-	<3.8	<0.80	<0.041	-
Runner beans[c]		2	<3.5	11	0.75	<0.35	0.70	-	<2.0	<0.80	<0.044	-
"	max		4.0	12	0.80	<0.40	0.72		<2.5		<0.046	
Turnips[j]		1	-	-	-	-	-	-	-	-	-	-
Wheat		1	12	140	27	<0.60	1.6	-	<3.6	<0.80	<0.11	-
Grass[f,g,h]		2	-	-	-	-	-	<0.045	<2.7	-	-	-
"	max							0.056	<3.5			
Soil[k]		2	-	-	-	-	-	-	-	-	-	-
"	max											
Dry cloths		340	-	-	-	-	-	-	-	-	-	-

Table 4.8. continued

Material	Selection	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}			
			^{137}Cs	Total Cs	Total U	^{238}Pu
Milk Near farms[c]		12	<0.45	0.23	-	<0.00024
" "	max		<0.53	0.34		<0.00028
" "	sub-sets	3	<0.30	-	-	-
" "	max		0.30			
" Far farms[c]		4	<0.42	0.11	-	<0.00028
" "	max		<0.43	0.17		
Apples[c]		2	-	0.28	-	<0.00035
"	max			0.39		0.00040
Blackberries[c]		2	-	3.9	-	0.0014
"	max			5.3		0.0020
Bovine kidney[c]		1	-	1.2	-	-
" liver[c]		1	-	0.72	-	0.00080
" muscle[c]		1	-	0.84	-	<0.00020
Cabbage[c]		2	-	0.26	-	<0.00025
"	max			0.36		<0.00030
Carrots[c]		1	-	0.14	-	<0.00040
Cauliflower		1	-	-	<0.025	-
Duck[c]		1	-	2.9	-	<0.00030
Eggs[c]		1	-	0.11	-	<0.00020
Elderberries[c]		1	-	8.1	-	0.040
Honey		1	-	12	-	<0.00030
Mushrooms[e]		1	-	0.39	-	0.0010
Ovine offal[c]		2	-	0.50	-	0.00050
" "	max					
" muscle[i]		2	-	1.0	-	<0.00030
" "	max			1.5		<0.00040
Pheasants[c]		1	-	4.3	-	<0.00010
Potatoes[c]		1	-	0.068	-	0.0011
Runner beans[c]		2	-	0.25	-	0.00055
"	max			0.40		0.00070
Turnips[j]		1	-	-	0.026	-
Wheat		1	-	0.60	-	0.0017
Grass[f,g,h]		2	-	-	-	-
"	max					
Soil[k]		2	-	-	51	-
"	max				66	
Dry cloths		340	-	-	-	-

Table 4.8. continued

Material	Selection[d]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta	Total gamma
Milk Near farms[c]		12	<0.00024	<0.11	<0.00038	-	-	-
" "	max		<0.00025	<0.16	<0.00050			
" "	sub-sets	3	-	-	-	-	-	-
" "	max							
" Far farms[c]		4	<0.00023	<0.087	<0.00043	-	-	-
" "	max							
Apples[c]		2	0.0016	<0.064	0.0028	-	-	-
"	max		0.0025	<0.067	0.0040			
Blackberries[c]		2	0.019	<0.093	0.0099	-	-	-
"	max		0.020	0.11	0.013			
Bovine kidney[c]		1	-	-	-	-	-	-
" liver[c]		1	0.0090	<0.13	0.0057	-	-	-
" muscle[c]		1	<0.00030	<0.12	<0.00040	-	-	-
Cabbage[c]		2	<0.00035	<0.11	<0.00075	-	-	-
"	max		<0.00040	0.12	0.0011			
Carrots[c]		1	0.0013	0.13	<0.00070	-	-	-
Cauliflower		1	-	-	-	-	-	-
Duck[c]		1	0.00070	<0.071	<0.00060	-	-	-
Eggs[c]		1	<0.00020	<0.067	0.0038	-	-	-
Elderberries[c]		1	0.19	2.2	0.075	-	-	-
Honey		1	0.00020	<0.084	0.00060	-	-	-
Mushrooms[e]		1	0.018	<0.16	0.0080	-	-	-
Ovine offal[c]		2	0.0030	<0.12	0.0011	-	-	-
" "	max							
" muscle[j]		2	<0.00045	<0.090	<0.00055	-	-	-
" "	max		0.00050	<0.11	<0.00060			
Pheasants[c]		1	0.00060	<0.094	0.00060	-	-	-
Potatoes[c]		1	0.0047	<0.089	<0.00030	-	-	-
Runner beans[c]		2	0.0017	<0.11	0.0017	-	-	-
"	max		0.0023	<0.14	0.0028			
Turnips[j]		1	-	-	-	-	-	-
Wheat		1	0.033	<0.12	0.0088	-	-	-
Grass[f,g,h]		2	-	-	-	-	-	-
"	max							
Soil[k]		2	-	-	-	-	-	-
"	max							
Dry cloths		340	-	-	-	0.32	1.7	1.0

- not analysed

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

[b] see section 3 for definition

[c] the concentration of ^{3}H (organic) was <3.8 Bq l^{-1} for milk and <3.0 Bq kg^{-1} for other samples

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

[e] the concentration of ^{3}H (organic) was 6.0 Bq kg^{-1}

[f] the mean concentration of ^{45}Ca was 3.2 Bq kg^{-1}, the maximum was 4.0 Bq kg^{-1}

[g] the mean concentration of ^{55}Fe was 4.1 Bq kg^{-1}, the maximum was 4.9 Bq kg^{-1}

[h] the mean concentration of ^{63}Ni was 0.50 Bq kg^{-1}, the maximum was 0.80 Bq kg^{-1}

[i] the concentration of ^{3}H (organic) was <6.0 Bq kg^{-1}

[j] the concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0097, <0.00060 and <0.0011 Bq kg^{-1} respectively

[k] the concentrations of ^{234}U, ^{235}U and ^{238}U were 17, 0.78 and 16 Bq kg^{-1} respectively

[l] Samples of milk, barley, oats, grass, washed grass and soil were analysed for their ^{106}Ru content to investigate enhanced levels of discharge in November 1997. The results (Bq l^{-1} or Bq kg^{-1}) were <4.8 (max <7.0), <17 (max <22), 560 (max 1200), 120 (max 900), <270 (max 1400) and <11 respectively

Table 4.9. Individual radiation exposures due to consumption of terrestrial foodstuffs near Sellafield and Drigg, 1997

Exposed population[b]	Foodstuffs	Exposure mSv[a]											
		Total	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{129}I	^{131}I	^{137}Cs	^{144}Ce	Others
Consumers near Sellafield aged 1 y	Milk Fruit	0.044	0.002	0.005	0.004	0.014	0.011	0.002	0.002	0.002	0.002		<0.001
Consumers near Drigg aged 1 y	Milk Potatoes	0.018			0.005	0.003	0.007		0.001		0.001		<0.001
Consumers near Ravenglass aged 1 y	Milk Fruit	0.031		0.001	0.005	0.004	0.010	0.002	0.002		0.001	0.005	<0.001
Typical adult member of the public eating food grown near Sellafield	Wild fruit Green vegetables	0.017				0.007	0.004		0.001		0.003		<0.002

[a] *Excluding 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*

Table 4.10. Radioactivity in terrestrial food and the environment near Drigg, 1997

Material and selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk	1	<3.0	15	<0.40	<0.48	0.080	<0.0053	<3.2	<0.83	<0.011
Blackberries	1	5.0	16	0.30	<0.40	0.23	-	<1.8	<0.80	<0.060
Cabbage	1	<3.0	7.0	1.1	<0.50	0.59	0.11	<2.2	<0.70	<0.038
Mushrooms	1	<3.0	4.0	<0.30	<0.40	0.38	-	<3.1	<0.50	<0.055
Ovine muscle	1	<3.0	30	1.3	<0.40	<0.023	<0.019	<3.3	<0.60	<0.036
Ovine offal	1	<4.0	32	2.7	<0.60	0.12	<0.022	<4.0	<1.0	-
Potatoes	1	<3.0	14	0.20	<0.40	0.080	<0.033	<3.5	<1.0	<0.044
Rabbit	1	11	32	2.0	<0.50	0.071	<0.018	<2.4	<0.80	<0.078
Grass	2	-	-	-	-	-	<0.029	-	-	-
" max							<0.030			
Soil	2	-	-	-	-	-	-	-	-	-
" max										

Material and selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
		^{137}Cs	Total Cs	^{147}Pm	^{234}U	^{235}U	^{238}U	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk	1	<0.47	0.20	<0.55	-	-	-	-	<0.00015	<0.00020	<0.096	<0.00033
Blackberries	1	-	0.20	-	-	-	-	-	<0.00030	0.0018	<0.051	0.0041
Cabbage	1	-	0.24	0.20	-	-	-	-	<0.00020	0.00030	<0.071	<0.00050
Mushrooms	1	-	0.57	-	-	-	-	-	0.0021	0.019	<0.040	0.021
Ovine muscle	1	-	2.3	-	-	-	-	-	<0.00020	0.00060	<0.079	0.00070
Ovine offal	1	-	2.0	-	-	-	-	-	-	-	-	-
Potatoes	1	-	0.40	<0.20	-	-	-	-	<0.00020	0.0012	<0.077	0.0021
Rabbit	1	-	0.69	-	-	-	-	-	<0.00030	0.00080	<0.099	0.0013
Grass	2	-	-	3.7	-	-	-	0.17	-	-	-	-
" max				6.2				0.19				
Soil	2	-	-	-	9.9	0.37	9.5	30	-	-	-	-
" max								38				

- not analysed
[a] except for milk where units are Bq l^{-1} and for soil where dry concentrations apply
[b] see section 3 for definition
[c] data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 5 for definition.

Table 4.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 1997

Location		Ground type	No. of sampling observa-tions[a]	µSv h^{-1}
Whitehaven	outer harbour	Mud and sand	4	0.48
"	inner harbour	Mud	1	1.4
"	"	Mud and sand	1	1.7
"	yacht basin	Mud	2	1.7
St Bees		Sand	2	0.23
Nethertown		Winkle bed	2	1.1
Braystones		Sand	2	0.14
Sellafield pipeline		"	2	0.26
River Ehen		Saltmarsh	2	1.4
Seascale		Sand	2	0.18
Drigg		"	2	*
Drigg Barn Scar		Mussel bed	2	0.15
Ravenglass	- Raven Villa	Saltmarsh	2	0.59
"	- salmon garth	Mussel bed	2	0.49
Tarn Bay		Sand	2	0.46

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

Table 4.12. Radioactivity in terrestrial food and the environment near Ravenglass, 1997

Material and selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}													
		^{3}H	^{14}C	^{35}S	^{55}Fe	^{60}Co	^{63}Ni	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{134}Cs
Milk	3	<3.2	15	<0.42	-	<0.43	-	0.075	<0.91	<0.89	<0.0058	<3.0	<0.83	<0.0098	<0.31
" max		<3.3	16	<0.53		<0.45		0.088	<0.95	<0.97	<0.0068	<3.2	<0.85	<0.010	<0.32
Barley	1	<4.0	87	1.6	-	<0.40	-	0.40	<0.60	<0.80	-	<3.2	<0.50	<0.13	-
Blackberries	1	<3.0	26	<0.70	-	<0.30	-	0.58	<0.70	<0.50	-	<2.7	<0.60	<0.055	-
Bovine kidney	1	<4.0	26	<0.50	-	<0.60	-	0.76	<1.1	<0.90	<0.023	<3.6	<1.2	-	-
" liver	1	<4.0	32	0.70	-	<0.40	-	0.17	<0.50	<0.80	<0.029	<3.8	<1.3	<0.061	-
" muscle	1	<3.0	26	0.40	-	<0.50	-	0.071	<1.0	<0.60	<0.025	<2.4	<0.80	<0.047	-
Broad beans	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carrots	1	4.0	8.0	<0.30	-	<0.50	-	0.22	<0.90	<0.80	<0.043	<3.6	<0.80	<0.037	-
Cauliflower	1	<3.0	5.0	1.3	-	<0.40	-	-	<0.90	<0.80	<0.023	<3.2	<0.90	<0.032	-
Honey	1	8.0	81	<0.90	-	<0.50	-	0.048	<1.0	<2.1	-	<3.7	<0.90	<0.014	-
Ovine offal	2	<4.0	30	5.4	-	<0.45	-	0.037	<1.0	<1.1	<0.023	<2.8	<1.1	-	-
" max			32	5.7		<0.50		0.040	<1.1			<3.4	<1.4		
" muscle	2	<3.5	36	3.6	-	<0.30	-	0.024	<0.85	<0.65	<0.023	<2.7	<0.80	<0.038	-
" max		4.0	46	5.3				0.027	<1.2	<0.70	<0.024	<3.2	<1.1		
Pears	1	3.0	18	<0.20	-	<0.40	-	0.39	<1.2	<1.1	-	<3.6	<0.70	<0.067	-
Potatoes	1	<3.0	12	0.40	-	<0.40	-	0.14	<0.90	<0.60	-	<2.9	<0.70	<0.066	-
Runner beans	1	<3.0	14	<0.30	-	<0.50	-	0.14	<0.90	<0.70	-	<3.7	<0.80	<0.047	-
Grass[d]	2	-	-	-	<1.4	-	0.50	-	-	-	<0.11	-	-	-	-
" max					<2.0		0.80				0.19				
Soil	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
" max															

Table 4.12. continued

Material and selection[c]	Farms/ samples[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
		^{137}Cs	Total Cs	^{144}Ce	^{155}Eu	^{147}Pm	^{234}U	^{235}U	^{238}U	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk	3	<0.45	0.20	<1.7	<0.58	<0.50	-	-	-	-	<0.00019	<0.00021	<0.087	<0.00054
" max		<0.47	0.26	<1.8							<0.00020	<0.00023	<0.095	<0.00075
Barley	1	-	0.30	<1.4	<0.50	-	-	-	-	-	<0.00050	0.0015	<0.076	0.0019
Blackberries	1	-	0.15	<1.6	<0.40	-	-	-	-	-	0.0014	0.0048	0.22	0.0072
Bovine kidney	1	-	0.93	<1.8	<0.80	-	-	-	-	-	-	-	-	-
" liver	1	-	0.75	<2.7	<0.90	-	-	-	-	-	<0.00040	0.0017	<0.049	0.0014
" muscle	1	-	1.3	<1.7	<0.60	-	-	-	-	-	<0.00040	<0.00040	<0.060	<0.00080
Broad beans	1	-	-	-	-	-	-	-	-	<0.032	-	-	-	-
Carrots	1	-	0.13	<1.4	<0.70	-	-	-	-	-	<0.00040	<0.00030	<0.093	<0.00030
Cauliflower	1	-	-	<2.2	<0.50	1.1	-	-	-	-	0.0011	0.0087	0.13	0.015
Honey	1	-	0.76	<1.0	<0.30	-	-	-	-	-	0.00030	0.0011	<0.096	0.0040
Ovine offal	2	-	0.39	<3.1	<1.6	-	-	-	-	-	-	-	-	-
" max				<4.4	<2.5									
Ovine muscle	2	-	0.70	<1.6	<0.50	-	-	-	-	-	<0.00025	<0.00050	<0.083	0.00090
" max			0.94		<0.60						0.00030	0.00070	<0.088	0.0013
Pears	1	-	0.10	<1.9	<0.90	-	-	-	-	-	0.00090	0.0055	0.066	0.011
Potatoes	1	-	0.36	<1.9	<0.30	<0.10	-	-	-	-	<0.00070	0.00030	<0.12	0.00070
Runner beans	1	-	0.14	<1.8	<0.40	-	-	-	-	-	<0.00050	0.00050	<0.072	0.0010
Grass[d]	2	-	-	-	-	5.9	-	-	-	-	-	-	-	-
" max						9.1								
Soil	2	-	-	-	-	-	18	0.60	16	65	-	-	-	-
" max										71				

- *not analysed*
[a] *except for milk where units are Bq l^{-1} and for soil where dry concentrations apply*
[b] *see section 3 for definition*
[c] *data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition*
[d] *the concentration of ^{45}Ca was 2.0 Bq kg^{-1}, the maximum was 3.1 Bq kg^{-1}*

Table 4.13. Radioactivity in aquatic plants from the Cumbrian coast and further afield, 1997

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}													
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{103}Ru	^{106}Ru	^{110m}Ag	^{125}Sb	^{129}I	^{131}I	^{134}Cs
England																
St Bees	*Fucus vesiculosus*	4	30	8.4	<0.16	6.3	<0.19	<0.25	16000	<0.17	<1.3	1.3	0.43	3.6	<0.26	<0.06
"	*Porphyra*	4	30	1.5	<0.19	0.24	<0.21	<0.27	11	<0.21	6.5	<0.14	<0.57	-	*	<0.07
"	*Rhodymenia spp.*	2	-	4.6	<0.47	-	<0.47	<0.47	-	<0.35	19	<1.3	<0.68	-	<0.34	<0.17
Braystones south	*Porphyra*	4	-	2.6	<0.28	-	<0.32	<0.42	-	<0.34	43	<0.52	<0.79	-	*	<0.10
Sellafield	*Fucus vesiculosus*	4	-	23	<0.49	29	<0.46	<0.50	60000	<0.30	<3.7	3.7	1.1	-	<1.2	<0.17
Seascale	*Porphyra*	52[c]	-	<3.4	<0.99	-	<0.74	<0.46	-	<0.41	<29	<0.86	<1.2	-	<0.59	<0.46
Rabbit Cat How, Ravenglass	Samphire	1	-	<0.05	<0.10	-	<0.10	<0.08	4.8	<0.07	<0.44	<0.07	<0.10	-	*	<0.04
Cockerham Marsh	"	1	-	0.10	<0.08	-	<0.13	<0.21	-	<0.18	<0.30	<0.06	<0.08	-	*	<0.03
Marshside Sands	"	1	-	<0.06	<0.18	-	<0.20	<0.24	-	<0.23	<0.58	<0.12	<0.15	-	*	<0.07
Wales																
Portmadoc	*Fucus vesiculosus*	1	-	<0.04	<0.14	-	<0.29	<0.56	-	<0.40	<0.48	<0.10	<0.11	-	*	<0.06
Fishguard	"	1	-	<0.14	<0.34	-	<0.31	<0.28	34	<0.21	<1.0	<0.23	<0.25	-	*	<0.14
Lavernock Point	*Fucus serratus*	2	-	<0.05	<0.15	-	<0.22	<0.35	-	<0.25	<0.45	<0.10	<0.10	-	*	<0.05
South Wales,																
Manufacturer A	Laverbread	4	-	<0.10	<0.30	-	<0.66	<1.6	-	<1.0	<1.2	<0.21	<0.22	-	*	<0.11
Manufacturer C	"	4	-	<0.11	<0.31	-	<0.64	<0.31	-	<1.1	<1.2	<0.22	<0.23	-	*	<0.11
Manufacturer D	"	4	-	<0.08	<0.23	-	<0.44	<0.92	-	<0.63	<0.83	<0.16	<0.17	-	*	<0.08
Scotland																
Port William	*Fucus vesiculosus*	7	-	<0.18	<0.22	-	<0.30	<0.46	2100	<0.34	<0.84	<0.13	<0.32	-	<0.34	<0.09
Garlieston	"	7	-	0.83	<0.35	-	<0.40	<0.50	4900	<0.40	<1.1	<0.18	<0.39	-	<0.86	<0.12
Auchencairn	"	7	-	0.64	<0.33	-	<0.37	<0.47	6400	<0.38	<1.0	<0.18	<0.40	0.25	<0.46	<0.12
Knock Bay	*Porphyra*	7	-	<0.07	<0.13	-	<0.19	<0.32	-	<0.24	<0.68	<0.09	<0.27	-	*	<0.07
Cape Wrath	*Fucus vesiculosus*	1	-	<0.07	<0.23	-	<0.45	<0.99	560	<0.68	<0.68	<0.15	<0.16	-	*	<0.07
Wick	"	1	-	<0.15	<0.43	-	<0.58	<0.82	-	<0.63	<1.6	<0.29	<0.36	-	*	<0.16
S W Uist	Alginate	1[d]	-	<0.13	<0.26	-	<0.25	<0.19	1.2	<0.18	<1.2	<0.20	<0.34	-	<1.0	<0.13
Northern Ireland																
Ardglass	*Fucus vesiculosus*	3	-	<0.10	<0.29	-	<0.40	<0.62	620	<0.46	<0.91	<0.18	<0.20	-	*	<0.11
"	*Fucus serratus*	1	-	<0.29	<0.67	-	<0.76	<0.92	-	<0.68	<2.6	<0.47	<0.54	-	*	<0.26
Portrush	"	4	-	<0.05	<0.13	-	<0.17	<0.26	-	<0.18	<0.41	<0.09	<0.10	-	<0.06	<0.05
Strangford Lough	*Rhodymenia spp.*	4	-	<0.08	<0.24	-	<0.32	<0.50	100	<0.37	<0.76	<0.16	<0.17	-	*	<0.08
Carlingford Lough	*Fucus spp.*	4	-	<0.09	<0.23	-	<0.36	<0.58	640	<0.40	<0.84	<0.15	<0.19	-	*	<0.09
Isles of Scilly	*Fucus vesiculosus*	1	-	<0.06	<0.19	-	<0.21	<0.23	0.40	<0.18	<0.61	<0.13	<0.13	-	*	<0.07

Table 4.13. continued

Location[a]	Material	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet), Bq kg^{-1}									
			^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
England												
St Bees	*Fucus vesiculosus*	4	7.4	<0.26	<0.12	1.0	5.3	-	3.1	*	0.0052	-
"	*Porphyra*	4	2.1	<0.35	<0.15	0.38	1.8	23	3.8	*	0.0059	140
"	*Rhodymenia spp.*	2	20	<0.91	<0.30	1.3	6.4	-	15	*	0.027	-
Braystones south	*Porphyra*	4	2.8	<0.60	<0.23	0.85	4.2	51	8.4	*	0.010	-
Sellafield	*Fucus vesiculosus*	4	13	<0.77	<0.42	2.8	14	-	5.3	0.0054	0.013	40000
Seascale	*Porphyra*	52[c]	<2.0	<1.8	<0.88	-	-	-	4.1	-	-	-
Rabbit Cat How, Ravenglass	Samphire	1	0.86	<0.15	<0.07	-	-	-	1.1	-	-	-
Cockerham Marsh	"	1	3.8	<0.14	<0.05	-	-	-	2.3	-	-	50
Marshside Sands	"	1	2.2	<0.27	<0.12	-	-	-	<0.13	-	-	-
Wales												
Portmadoc	*Fucus vesiculosus*	1	0.61	<0.25	<0.10	-	-	-	<0.06	-	-	-
Fishguard	"	1	0.36	<0.50	<0.23	-	-	-	<0.23	-	-	220
Lavernock Point	*Fucus serratus*	2	0.29	<0.27	<0.12	-	-	-	<0.11	-	-	200
South Wales, Manufacturer A	Laverbread	4	<0.13	<0.47	<0.18	-	-	-	<0.17	-	-	-
Manufacturer C	"	4	<0.26	<0.50	<0.18	-	-	-	<0.16	-	-	-
Manufacturer D	"	4	<0.14	<0.38	<0.14	-	-	-	<0.14	-	-	81
Scotland												
Port William	*Fucus vesiculosus*	7	2.4	<0.40	<0.32	-	-	-	0.50	-	-	-
Garlieston	"	7	6.9	<0.55	<0.37	-	-	-	3.8	-	-	-
Auchencairn	"	7	7.8	<0.56	<0.40	-	-	-	<2.4		-	-
Knock Bay	*Porphyra*	7	0.81	<0.27	<0.28	-	-	-	0.74	-	-	-
Cape Wrath	*Fucus vesiculosus*	1	0.32	<0.46	<0.19	-	-	-	<0.27	-	-	640
Wick	"	1	0.29	<0.83	<0.33	-	-	-	<0.33	-	-	250
S W Uist	Alginate	1[d]	0.16	<0.78	<0.40	0.0010	0.010	-	0.0012	*	*	-
Northern Ireland												
Ardglass	*Fucus vesiculosus*	3	0.87	<0.44	<0.18	-	-	-	<0.18	-	-	-
"	*Fucus serratus*	1	1.1	<0.89	<0.37	-	-	-	<0.23	-	-	-
Portrush	"	4	0.33	<0.23	<0.10	-	-	-	<0.15	-	-	-
Strangford Lough	*Rhodymenia spp.*	4	1.7	<0.37	<0.15	0.077	0.42	-	0.50	*	0.00095	-
Carlingford Lough	*Fucus spp.*	4	1.2	<0.37	<0.16	-	-	-	<0.13	-	-	-
Isles of Scilly	*Fucus vesiculosus*	1	<0.07	<0.26	<0.12	-	-	-	<0.13	-	-	170

- *not analysed*
* *not detected by the method used*
[a] *Sampling area*
[b] *See section 3 for definition*
[c] *counted wet*
[d] *results are Bq kg^{-1} dry*

Table 4.14. Radioactivity in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 1997

Location[b]	Material	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{60}C	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{241}Am	Total beta
Rockcliffe	Grass	1	-	-	-	0.96	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	0.63	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	0.92	-	-	-	-	-	-	-	-	-
Newton Arlosh	Grass	1	-	-	-	3.2	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	2.1	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	16	-	-	-	-	-	-	-	-	-
Sellafield 1676[d]	Beetroot	1	<0.10	<1.6	*	620	<1.2	<0.23	-	<0.11	0.26	<0.69	<0.21	<0.20	-
" "	Leek	1	<0.07	<1.1	*	21	<0.78	<0.14	*	<0.07	<0.05	<0.32	<0.09	<0.05	-
" "	Potatoes	1	<0.04	<0.66	*	72	<0.46	<0.09	<0.25	<0.04	0.33	<0.25	<0.07	<0.04	-
" "	Soil	1	1.7	<3.5	*	1100	<2.5	<0.63	3.1	<0.26	83	<1.7	1.2	33	-
" 14[d]	Beetroot	1	<0.12	<2.2	*	61	<1.5	<0.25	-	<0.13	0.19	<0.80	<0.27	<0.37	-
" "	Onions	1	<0.13	<2.7	*	7.7	<1.8	<0.32	-	<0.16	0.29	<1.0	<0.32	<0.45	-
" "	Potatoes	1	<0.03	<0.65	*	16	<0.38	<0.08	-	<0.04	0.54	<0.28	<0.08	<0.08	-
" "	Runner beans	1	<0.05	<0.88	*	20	<0.57	<0.10	*	<0.05	0.16	<0.24	<0.06	<0.03	-
" "	Soil	1	7.2	<6.0	*	4500	21	1.7	17	0.89	100	<2.1	2.3	43	-
" 1674[d]	Beetroot	1	<0.08	<1.5	*	370	<1.0	<0.17	-	<0.09	0.19	<0.46	<0.14	<0.16	-
" "	Onions	1	<0.11	<2.1	*	26	<1.5	<0.28	-	<0.12	<0.09	<0.86	<0.24	<0.21	-
" "	Potatoes	1	<0.07	<1.4	*	89	<0.76	<0.14	*	<0.07	0.27	<0.37	<0.11	<0.06	-
" "	Runner beans	1	<0.10	<1.9	*	9.5	<1.2	<0.19	-	<0.11	0.09	<0.44	<0.12	<0.07	-
" "	Spinach	1	<0.05	<0.99	*	8400	<0.62	<0.11	*	<0.05	0.44	<0.31	<0.09	<0.07	6000
" "	Soil	1	<0.28	<6.6	*	810	<3.8	<0.92	-	1.2	83	<3.2	<1.1	<1.7	-
" "	" [c]	1	<0.33	<6.6	*	1300	<3.9	<0.89	4.8	0.81	78	<2.4	2.5	2.8	-
Low Shaw	Grass	1	-	-	-	2.4	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	1.6	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	6.3	-	-	-	-	-	-	-	-	-
Sandgate Marsh	Grass	1	-	-	-	3.5	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	2.0	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	10	-	-	-	-	-	-	-	-	-
High Foulshaw	Grass	1	-	-	-	2.8	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	2.0	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	4.3	-	-	-	-	-	-	-	-	-
Aldcliffe Marsh	Grass	1	-	-	-	2.9	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	1.5	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	8.4	-	-	-	-	-	-	-	-	-
Cockerham	Grass	1	-	-	-	4.2	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	1.2	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	15	-	-	-	-	-	-	-	-	-
Hutton Marsh	Grass	1	-	-	-	1.0	-	-	-	-	-	-	-	-	-
"	Washed grass	1	-	-	-	0.63	-	-	-	-	-	-	-	-	-
"	Soil	1	-	-	-	28	-	-	-	-	-	-	-	-	-

- not analysed
** not detected by the method used*
[a] except for soil where dry concentrations apply
[b] sampling area
[c] contained hydroids
[d] Consumer numbers

Table 4.15(a). Radioactivity in food and the environment near Springfields, 1997

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs	Total Cs
Aquatic samples											
Flounder	Ribble Estuary	1	-	-	<0.09	-	-	<0.27	<0.09	12	-
Salmon	"	1	-	-	<0.10	-	-	<0.25	<0.10	0.55	-
Grey mullet	"	1	-	-	<0.16	-	-	<0.45	<0.16	6.2	-
Shrimps	"	2	-	65	<0.08	-	3.9	<0.19	<0.08	4.6	-
Cockles	"	1	-	-	0.55	-	-	<0.24	<0.10	3.5	-
Goose	"	1	-	-	<0.07	-	-	<0.14	<0.07	0.37	-
Mallard	"	1	-	-	<0.22	-	-	<0.44	<0.23	1.4	-
Samphire	Marshside Sands	1	-	-	<0.06	-	-	<0.15	<0.07	2.2	-
Turf	Hesketh Bank	4	-	-	<1.8	-	-	<4.1	<1.2	520	-
Mud	Becconsall	4	-	-	<1.2	-	-	<3.0	<1.0	280	-
"	Pipeline	3	-	-	<1.3	-	-	<4.0	<1.4	280	-
"	Savick Brook	4	-	-	<2.5	-	-	<8.3	<3.2	560	-
"	Penwortham	4	-	-	<1.4	-	-	<4.2	<1.5	310	-
Mud & sand	Pipeline	1	-	-	1.8	-	-	<4.3	<1.3	330	-
"	30m S of pipeline	4	-	-	<1.0	-	-	<4.0	<1.5	200	-
"	Deepdale Brook	4	-	-	<0.62	-	-	<1.8	<1.1	14	-
Sand	Ribble Estuary	1	-	-	1.2	-	-	<1.7	<0.66	110	-
Terrestrial samples											
Milk	Near farms	6	-	-	-	-	-	-	-	-	-
"	max										
Blackberries		1	<3.0	19	<0.50	-	-	-	<0.30	<0.40	-
Cabbage		1	3.0	4.0	<0.30	0.18	-	-	-	-	0.072
Carrots/turnips		1	<3.0	5.0	<0.60	0.20	-	-	-	-	<0.054
Duck		1	<3.0	27	<0.70	<0.018	-	-	-	-	2.1
Leeks		1	<3.0	6.0	<0.40	-	-	-	<0.20	<0.40	-
Potatoes[e]		1	<3.0	14	<0.60	0.046	-	-	-	-	-
Runner beans		1	<3.0	7.0	<0.20	-	-	-	<0.20	<0.30	-
Spinach		1	<3.0	6.0	<0.50	0.38	-	-	-	-	0.080
Bovine Faeces		6	-	-	-	-	-	-	-	-	-
"	max										
Ovine Faeces		4	-	-	-	-	-	-	-	-	-
"	max										
Grass		8	-	-	-	-	-	-	-	-	-
"	max										
Sileage		4	-	-	-	-	-	-	-	-	-
"	max										
Soil		4	-	-	-	-	-	-	-	-	-
"	max										
Dry cloths		137	-	-	-	-	-	-	-	-	-

Table 4.15(a). continued

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{155}Eu	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}Th	^{233}Pa	^{234}U	^{235}U+ ^{236}U	^{238}U	Total U
Aquatic samples													
Flounder	Ribble Estuary	1	<0.17	-	-	-	-	*	*	-	-	-	-
Salmon	"	1	<0.25	-	-	-	-	*	*	-	-	-	-
Grey mullet	"	1	<0.42	-	-	-	-	*	*	-	-	-	-
Shrimps	"	2	<0.15	<0.53	0.011	0.013	0.0047	1.8	*	-	-	-	-
Cockles	"	1	<0.18	0.030	0.38	0.41	0.18	*	*	-	-	-	-
Goose	"	1	<0.12	-	0.0046	0.013	0.0043	*	*	-	-	-	-
Mallard	"	1	<0.30	-	-	-	-	*	*	-	-	-	-
Samphire	Marshside Sands	1	<0.12	-	-	-	-	*	*	-	-	-	-
Turf	Hesketh Bank	4	<2.9	24	-	-	-	880	*	-	-	-	-
Mud	Becconsall	4	<3.5	24	33	77	20	12000	*	15	0.49	12	-
"	Pipeline	3	<4.0	22	20	62	18	19000	*	14	0.56	12	-
"	Savick Brook	4	<9.7	47	-	-	-	310000	*	-	-	-	-
"	Penwortham	4	<4.6	31	24	140	21	25000	*	28	0.91	21	-
Mud & sand	Pipeline	1	<2.7	27	23	75	19	730	*	19	0.63	16	-
"	30m S of pipeline	4	<4.9	22	19	90	15	35000	*	46	1.8	38	-
"	Deepdale Brook	4	4.3	47	23	310	19	850	11	610	28	550	-
Sand	Ribble Estuary	1	<2.2	32	27	22	24	2200	*	-	-	-	-
Terrestrial samples													
Milk	Near farms	6	-	-	-	-	-	-	-	-	-	-	0.0065
"	max												0.0066
Blackberries		1	-	-	-	-	-	-	-	-	-	-	-
Cabbage		1	-	-	-	0.0030	<0.0030	-	-	-	-	-	-
Carrots/turnips		1	-	-	-	0.033	0.034	-	-	-	-	-	-
Duck		1	-	-	-	<0.0060	<0.0090	-	-	-	-	-	-
Leeks		1	-	-	-	0.029	0.028						
Potatoes[e]		1	-	-	-	0.0030	0.0030	-	-	-	-	-	-
Runner beans		1	-	-	-	0.0080	<0.0030	-	-	-	-	-	-
Spinach		1	-	-	-	0.020	0.015	-	-	-	-	-	-
Bovine faeces		6	-	-	-	-	-	-	-	-	-	-	2.1
"	max												4.1
Ovine faeces		4	-	-	-	-	-	-	-	3.0	0.13	0.27	7.8
"	max									4.0	0.16	3.4	12
Grass		8	-	-	-	-	-	-	-	0.29	0.015	0.29	2.1
"	max												5.2
Silage		4	-	-	-	-	-	-	-	-	-	-	0.92
"	max												2.0
Soil		4	-	-	-	-	-	-	-	31	1.5	30	83
"	max												90
Dry cloths		137	-	-	-	-	-	-	-	-	-	-	-

Table 4.15(a). continued

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta	Total gamma
Aquatic samples												
Flounder	Ribble Estuary	1	-	-	-	-	<0.10	-	-	-	-	-
Salmon	"	1	-	-	-	-	<0.24	-	-	-	-	-
Grey mullet	"	1	-	-	-	-	<0.43	-	-	-	-	-
Shrimps	"	2	0.00043	0.0029	0.016	-	0.026	*	0.000071	-	-	
Cockles	"	1	-	0.23	1.2	-	3.0	*	0.006	-	-	-
Goose	"	1	-	0.0029	0.016	-	0.025	0.000014	0.00040	-	-	-
Mallard	"`	1	-	-	-	-	<0.16	-	-	-	-	-
Samphire	Marshside Sands	1	-	-	-	-	<0.13	-	-	-	-	-
Turf	Hesketh Bank	4	-	-	-	-	180	-	-	-	-	-
Mud	Becconsall	4	-	-	-	-	120	-	-	-	-	-
"	Pipeline	3	-	10	52	-	85	*	0.13	-	8300	-
"	Savick Brook	4	-	28	150	1600	230	*	0.46	-	-	-
"	Penwortham	4	0.27	-	-	-	140	-	-	-	-	-
Mud & sand	Pipeline	1	-	-	-	-	120	-	-	-	1500	-
"	30m S of pipeline	4	-	-	-	-	73	-	-	-	-	-
"	Deepdale Brook	4	1.1	-	-	-	<1.7	-	-	-	-	-
Sand	Ribble Estuary	1	-	-	-	-	55	-	-	-	-	-
Terrestrial samples												
Milk	Near farms	6	-	-	-	-	-	-	-	-	-	-
"	max											
Blackberries		1	-	<0.00020	<0.00020	<0.075	<0.00080	-	-	-	-	-
Cabbage		1	-	<0.00040	0.00040	<0.16	0.00020	-	-	-	-	-
Carrots/turnips		1	-	<0.00020	0.00030	-	<0.00070	-	-	-	-	-
Duck		1	-	-	-	-	-	-	-	-	-	-
Leeks		1	-	0.00030	0.00060	<0.099	<0.00060	-	-	-	-	-
Potatoes[e]		1	-	<0.00020	<0.00020	0.087	0.0013	-	-	-	-	-
Runner beans		1	-	<0.00020	0.00040	<0.072	<0.00090	-	-	-	-	-
Spinach		1	-	-	-	-	-	-	-	-	-	-
Bovine Faeces		6	-	-	-	-	-	-	-	-	-	-
"	max											
Ovine Faeces		4	-	-	-	-	-	-	-	-	-	-
"	max											
Grass		8	-	-	-	-	-	-	-	-	-	-
"	max											
Silage		4	-	-	-	-	-	-	-	-	-	-
"	max											
Soil		4	-	-	-	-	-	-	-	-	-	-
"	max											
Dry cloths		137	-	-	-	-	-	-	-	0.97	3.4	0.88

- not analysed
** not detected by the method used*
[a] Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment and uranium in soil where dry concentrations apply
[b] Landing point or sampling area
[c] Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition
[d] See section 3 for definition
[e] The concentration of ^{129}I was <0.039 Bq kg^{-1}

Table 4.15(b). Monitoring of radiation dose rates near Springfields, 1997

Location	Material or ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Lytham - Boatyard	Mud	4	0.12
" - Windmill Marsh	Salt marsh	1	0.11
Warton Marsh	Mud	4	0.14
"	" [c]	4	0.15
"	Salt marsh	4	0.13
The Naze	"	1	0.14
Banks marsh	Mud	4	0.16
"	" [c]	4	0.15
"	Salt marsh	4	0.17
Hesketh Bank	Mud	4	0.13
"	" [c]	4	0.14
"	Salt marsh	4	0.14
Freckleton	Mud	4	0.13
River Douglas	Grass	1	0.19
Becconsall	Mud	4	0.11
" (boat 2)	"	4	0.12
" "	Cabin[b]	8	0.091
Hutton Marsh	Mud	4	0.17
"	Salt marsh	4	0.17
Pipeline	Mud and sand	4	0.11
Pipeline (south bank)	Mud	1	0.13
"	Mud and sand	3	0.13
"	Salt marsh	4	0.16
Savick Brook - tidal limit	Mud	1	0.28
" "	Mud and sand	2	0.16
" - A583 bridge	Mud	4	0.22
" - confluence with Ribble	"	1	0.17
" "	Mud and sand	3	0.16
Penwortham	Mud	3	0.10
"	Mud and sand	1	0.10
Lower Penwortham	Mud	3	0.11
"	Grass	4	0.086
Penwortham Railway Bridge	Mud	2	0.13
"	Mud and sand	1	0.087
"	Grass	4	0.077
River Darwen	Mud and sand	1	0.080
"	Mud, sand and stones	1	0.085
"	Grass	4	0.086
Beta dose rates			µSv h^{-1}
Lytham - Windmill Marsh	Salt marsh	1	1.3
" - Boatyard	Mud	4	5.6
" - Granny's Bay	Salt marsh	1	0.42
Warton Marsh	Mud	4	4.7
"	Salt marsh	4	1.2
The Naze	"	1	0.48
Banks Marsh	Mud	4	4.2
"	Salt marsh	4	1.4
Hesketh Bank	Mud	4	5.1
"	Salt marsh	4	1.7
Freckleton	Mud	4	11
River Douglas	Grass	1	0.75
Deepdale Brook	Mud and sand	3	0.42
Becconsall	Mud	4	3.7
Hutton Marsh	Mud	3	0.76
"	Salt marsh	3	2.3
Pipeline	Mud and sand	4	4.9
Pipeline (south bank)	Mud	1	3.1
"	Mud and sand	3	7.3
"	Salt marsh	4	2.1
Savick Brook - tidal limit	Mud	2	29
" "	Mud and sand	1	28
" - A583 bridge	Mud	4	65
" - confluence with Ribble	"	1	4.1
" "	Mud and sand	2	32
Penwortham	Mud	3	5.8
"	Mud and sand	1	4.1
Lower Penwortham	Mud	3	12
"	Grass	4	1.2
Penwortham Railway Bridge	"	4	0.39
"	Mud	2	16
"	Mud and sand	1	0.59
River Darwen	Mud, sand and stones	1	4.9
"	Mud and sand	1	0.69
"	Grass	4	0.73
Ribble estuary	Gill net	2	0.56
"	Shrimp net	2	0.36

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

Table 4.16. Radioactivity in food and the environment near Capenhurst, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}															
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{233}Pa	^{234}Th	^{234}U	$^{235+236}$U	^{238}U	^{237}Np	^{238}Pu	$^{239+240}$Pu	^{241}Am	^{242}Cm	$^{243+244}$Cm	Total beta
Aquatic samples																		
Shrimps	Hoylake	2	-	<0.06	2.3	3.6	*	*	-	-	-	-	-	-	<0.12	-	-	-
Cockles	Dee estuary	4	-	<0.13	92	2.4	*	11	-	-	-	-	0.13	0.69	1.9	0.0039	0.0026	-
Elodea canadensis	Rivacre Brook	2	-	<0.14	88	0.97	18	120	24	1.4	17	2.2	-	-	<0.30	-	-	300
Mud	"	1	-	<0.53	1300	15	140	270	260	17	180	33	-	-	1.8	-	-	-
Mud & sand	"	1	-	<0.62	350	4.9	18	490	52	1.8	48	12	-	-	<2.1	-	-	-
Freshwater	"	2	160	<0.09	0.11	<0.09	*	*	0.051	<0.0013	0.023	0.00040	-	-	<0.21	-	-	-

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk	Near farms	5	-	<0.0045	-	-	-	<0.0064	-	-	-
"	Far farms	6	<3.7	-	-	-	-	-	-	-	-
	max		<8.0								
Cabbage		1	-	<0.20	0.16	0.0060	0.17	0.019	-	-	-
Mixed berries		1	-	<0.20	-	-	-	2.8	-	-	-
Potatoes		1	-	<0.019	-	-	-	<0.022	-	-	-
Bovine faeces		8	-	0.021	0.28	0.011	0.25	1.1	-	-	-
"	max			<0.026				2.0			
Grass		8	-	-	0.060	0.0030	0.062	<0.38	-	-	-
Silage		4	-	<0.018	-	-	-	<0.22	-	-	-
"	max							0.43			
Soil		4	-	-	9.5	0.40	9.5	49	-	-	-
"	max							50			
Rain water		80	<3.5	-	-	-	-	-	-	-	-
"	max		21								
Dry cloths		118	-	-	-	-	-	-	0.15	0.99	0.57

- not analysed
** not detected by the method used*
[a] Except for milk and water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for soil and sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3

Table 4.17(a). Radioactivity in food and the environment near Chapelcross nuclear power station, 1997

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																	
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{129}I	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total beta
Flounder	Inner Solway	2	-	61	<12	0.11	2.0	<1.2	<0.17	<0.51	-	28	<0.48	<0.46	<0.020	0.022	-	0.050	*	-
Sea trout	"	1	-	-	0.18	-	-	<1.0	<0.10	<0.50	-	2.4	<0.50	<0.50	0.00027	0.00039	-	<0.00020	*	-
Salmon	"	1	-	-	<0.10	-	-	<1.0	<0.10	<0.50	-	0.83	<0.50	<0.50	-	-	-	<0.50	-	-
Shrimps	"	4	-	-	<0.10	<0.10	3.8	<0.95	<0.11	<0.44	-	5.7	<0.43	<0.43	0.0033	0.016	-	0.023	*	-
Winkles	Southerness	4	-	-	<0.38	0.24	770	<1.3	<0.25	<0.49	-	7.9	<0.43	<0.44	0.31	1.6	26	2.6	0.0034	-
Whelks	Dornoch Brow	1	-	-	0.33	-	-	0.84	0.38	<0.23	-	1.1	<0.31	<0.24	-	-	-	0.75	-	-
Fucus vesiculosus	Pipeline	4	-	-	0.41	-	3600	<1.0	<0.13	<0.45	0.52	21	<0.48	<0.49	0.39	2.0	-	1.9	*	2400
Mud	Bladnoch	1	-	-	4.8	-	-	36	<1.2	4.0	-	470	6.0	4.1	-	-	-	360	-	-
Mud and sand	Pipeline	4	-	-	<0.63	-	-	<2.4	<0.28	<1.0	-	290	<1.1	<1.2	6.3	34	-	61	*	-
Sea water	"	4	29	-	-	-	-	-	-	-	-	0.16	-	-	-	-	-	-	-	-
"	Southerness	4	6.4	-	-	-	-	-	-	-	-	<0.24	-	-	<0.00049	0.0021	-	0.0060	*	-

Material	Location[b] or selection[d]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Terrestrial samples								
Milk	Near farms	4	91	14	<5.0	<0.10	<0.052	-
"	" max		170				<0.060	
"	Far farms	4	44	13	<5.7	<0.10	<0.045	-
"	" max		55		7.9		<0.056	
Grass		6	<160	27	<5.0	0.40	<0.19	<3.1
"	" max		510	46		0.54	0.35	10

- *not analysed*
- * *not detected by the method used*
- [a] *Except for sea water and milk where units are Bq l^{-1} and for sediment where dry concentrations apply*
- [b] *Landing point or sampling area*
- [c] *See section 3 for definition*
- [d] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition.*

Table 4.17(b). Monitoring of radiation dose rates near Chapelcross, 1997

Location type	Ground sampling observations[a]	No. of	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Seafield	Mud and sand	4	0.087
"	Salt marsh	4	0.090
Battle Hill	Mud and sand	4	0.081
Browhouses	Mud, sand and stones	4	0.089
Dornoch Brow	Mud and sand	4	0.082
"	Salt marsh	4	0.082
Powfoot	Sand	1	0.074
"	Salt marsh	3	0.073
" [b]	"	3	0.076
Priestside Bank	"	4	0.070
" [b]	"	1	0.077
Southerness	Winkle bed	1	0.062
Beta dose rates			µSv h^{-1}
Seafield	Stake nets	3	*
Priestside Bank	Salt marsh	1	0.36

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

5. UNITED KINGDOM ATOMIC ENERGY AUTHORITY

The United Kingdom Atomic Energy Authority (UKAEA) operates in England at Harwell, Winfrith and Windscale, adjacent to the BNFL Sellafield site, and in Scotland at Dounreay. All sites have reactors that are currently being decommissioned. Disposals of radioactive waste are related to decommissioning and decontamination operations and the nuclear related research that is undertaken at all sites. Some of this work is carried out by tenants such as AEA Technology. In addition, gaseous and liquid wastes are generated at Dounreay as a result of fuel reprocessing and small amounts of low level solid waste are disposed of by shallow land burial on the site. In previous years some solid waste was authorised for disposal in a shaft 55 metres deep at Dounreay, but no such disposals have been made since 1977. Solid and liquid waste disposals from Dounreay include a minor contribution from the adjoining reactor site (Vulcan Naval Reactor Test Establishment) which is operated by the Ministry of Defence (Procurement Executive) and the activities by AEA Technology at two of their facilities on the Dounreay site. Disposals from the Windscale site are negligible compared to Sellafield. Regular monitoring of the environment in relation to Dounreay, Harwell and Winfrith is undertaken and disposals from Windscale are monitored by the Sellafield programme. Disposals from Vulcan (NRTE) and AEA Technology (Dounreay) are monitored by the Dounreay programme.

5.1 Dounreay, Highland

Radioactive waste disposals from this UKAEA establishment are made under authorisation by SEPA. The quantities discharged from Dounreay in 1997 were generally lower than those in 1996 reflecting the suspension of reprocessing of reactor fuel following the Prototype Fast Reactor dissolver developing a leak in November 1996. The establishment is also authorised to dispose of solid low level waste on site. Monitoring in 1997 continued to include sampling of ovine liver and thyroid, grass, soil and dry cloths to detect the effects of gaseous releases. Samples of leachate from the vicinity of the landfill site were also analysed. There are no dairy herds in the Dounreay area. Routine marine monitoring involved sampling of fish and shellfish from the area of the Dounreay outfall in the Pentland Firth and other materials further afield, in combination with associated beta and gamma dose rate measurements. The results of SEPA's monitoring are presented in Tables 5.1(a) and (b).

As detailed in last years RIFE report (MAFF and SEPA 1997) a fragment of spent nuclear fuel was discovered on a public beach at Sandside Bay (2.5 km from the Dounreay site) during a routine survey by the operator in May. Although one had been found on this beach previously in 1984 it had always been assumed that this was an isolated incident and the subsequent find was therefore of great concern. SEPA immediately undertook a radiation survey of this beach augmented by an independent contractor to determine the extent of the contamination. Further, SEPA advised the operator to take all practicable steps to advise members of the public who might use the beach at Sandside Bay that a fragment of irradiated nuclear fuel had been found there. UKAEA arranged for public notices to be placed on the beach warning of this find. No further fragments were discovered during SEPA's survey, however, in November an additional fragment was discovered. These events increased the need for the operator to determine the source and pathway by which these particles were entering the environment. Further studies by the operator to isolate the mechanism for release involved a detailed sea-bed survey in the vicinity of the outfall (discharge) pipe from the site. The survey covered an area of the sea-bed some 1 km by 0.6 km around Dounreay and revealed an area of contamination. On this basis SEPA advised The Scottish Office to place a FEPA order restricting the taking of all sea foods in an area of radius 2 km, centred on the end of the outfall pipe (600 m from shore). SEPA and NRPB have conducted an extensive study into the likelihood of an encounter with, and the consequences these fragments might have on human health and the environment . A joint report is to be published soon. On the basis of present knowledge the probability of a member of the public encountering one of these particles is still assessed to be small.

During 1997 a Prohibition notice was placed on the treatment of radioactive waste sodium at an AEA Technology facility on the site until assurances were given that the resulting radioactive waste discharges could be adequately controlled and monitored.

Following notification by UKAEA in April 1998 of irregularities in the routine measurement of gaseous discharges from the main Fuel Cycle Area stack and subsequent investigation by the regulators an Enforcement notice was issued. A requirement was placed on the operator to validate critically data on these discharges in the light of this new evidence and to take steps to stop any reoccurrence by August 1998. The data has been provided by the operator and in most cases the discrepancy between the original and revised discharge data is small and the revised discharges are still well within the limits in the Authorisation for the site. Previous discharge data published in the last years report (MAFF and SEPA 1997) have also been revised, the discrepancy here between revised and original data is also small. The data are available from SEPA. The revised data do not affect the dose assessments included in last years report as these are based on observed environmental levels rather than reported discharges from the site.

In May 1997 SEPA forwarded new authorisations for Dounreay to the Secretary of State for Scotland, as required by law. On the 13 August 1997 the Secretary of State for Scotland invited SEPA to initiate a fresh consultation, based on the Certificates of Authorisation that SEPA was minded to grant. A fresh round of consultation began on 17 November 1997.

On 5th June 1998 the Government decided that Dounreay should take on no further commercial reprocessing work.

Reprocessing at Dounreay will therefore come to an end when the plant has completed reprocessing its own fuel, the Georgian Highly Enriched Uranium (HEU) and its existing commercial contracts. The UK's decision to accept a small consignment of nuclear fuel from Georgia was based on non-proliferation grounds.

During 1997, the Government accepted UKAEA's proposals for the removal of waste from the now disused wasteshaft. This will be subsequently conditioned and stored above ground at Dounreay.

Habits surveys have confirmed the existence of four potentially critical exposure pathways for marine radioactivity at Dounreay, three of which involve external irradiation. The first of these is due to radioactivity adsorbed mainly on fine particulate matter becoming entrained on fishing gear which is regularly handled. This results in skin dose, mainly from beta particles, to the hands and forearms of fishermen. The most exposed group is represented by a small number of people who operate a fishery close to Dounreay. Dose rates on their fishing gear were below the limit of detection in 1997. However, an upper limit to the skin exposure of these fishermen may be assessed. This dose, including a component due to natural radiation, was less than 0.16 mSv, or less than 0.5% of the dose limit of 50 mSv for skin doses.

The second potentially critical pathway arises also from the uptake of radioactivity by particulate material which accumulates in rocky areas of the foreshore and presents a potential source of exposure, mainly to gamma radiation, of those who visit these areas. In 1997, monitoring of sludge at Oigin's Geo showed generally decreased concentrations of radionuclides compared with 1996 reflecting the decrease in the discharge. However, there is known to be significant variability in these concentrations with differing sea and weather conditions. The more important measurements of gamma dose rates above areas of the foreshore remained unchanged. Public radiation dose via this pathway remained low, at 0.007 mSv or 0.7% of the dose limit of 1 mSv.

The third potentially critical pathway involves internal exposure of consumers of locally-collected fish and shellfish; fish, crabs, lobsters and winkles from the outfall area are sampled to enable this pathway to be kept under review. Additionally, sea water and seaweed were sampled as indicator materials. Concentrations of radionuclides in 1997 were generally similar to those for 1996, although there was an increase in technetium-99 in lobsters observed due to disposals from Sellafield. Despite these, doses from consumption of fish and shellfish continued to be low; for high-rate consumers the radiation dose was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The fourth potential critical pathway is due to consumption of molluscs and external exposure during collection. Gamma dose rates were measured over collecting areas and winkles were analysed for their radioactivity content. Gamma dose rates over the main collecting areas were similar in 1997 to those measured previously. The radiation dose due to a combination of consumption of molluscs and external exposure during collection remained low at 0.020 mSv or 2% of the dose limit of 1 mSv. This pathway was the critical marine pathway at Dounreay in 1997.

A special survey in 1996 investigated the detection by UKAEA of an area of contamination below the beach surface on the Dounreay foreshore. Sediment samples were obtained and the results of the analyses were given in Table 23(a) of last years report (MAFF and SEPA, 1997). Public access to the foreshore is very difficult and the mean levels (from a wide range of activities) of radioactivity in the sediments are similar to those found routinely within sludge in adjacent geos. On this basis, SEPA has concluded that the contamination does not represent a significant hazard, nor does it have any implication for other beaches in Caithness. This area of contamination along with historic contamination in the forecourt of Dounreay old castle has been remediated by UKAEA.

The results for terrestrial samples, Table 5.1(a), generally showed low levels of radioactivity. There was no evidence for enhanced levels of caesium-137 in ovine liver as was found in 1996. The dose to the most exposed group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be <0.040 mSv or 4% of the dose limit of 1 mSv.

The INTAKE food dose, including aquatic and terrestrial components, was 0.020 mSv in 1997.

5.2 Harwell, Oxfordshire

Disposals of radioactive wastes from Harwell continued in 1997 with liquid disposals made under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site while gaseous disposals were made to the atmosphere. The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish and indicator materials together with measurements of gamma dose rates around the liquid discharge points. Monitoring of the aquatic environment at Newbridge is undertaken to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 5.2(a) and (b). Tritium was detected in apples and blackberries collected near the site but at lower levels to those observed in local foodstuffs in previous years. Discharges of this radionuclide were about one third of those in 1996. The dose to the most exposed group of terrestrial food consumers was estimated to be less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

Concentrations of some nuclides, notably cobalt-60 and caesium-137, were enhanced close to the outfall for liquid wastes, but the levels were very small in terms of any radiological effect. Those found in Lydebank Brook were lower still.

Habits surveys have identified anglers as the most exposed group affected by direct disposals into the river. Their occupancy of the river bank has been assessed to estimate their external exposures. Consumption of freshwater fish was not found, but it is considered prudent to include a component in the assessment of the angler's exposure equivalent to a hypothetical consumption of fish at a rate of 1 kg $year^{-1}$. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 1997 was 0.014 mSv, or about 1% of the dose limit of 1 mSv.

5.3 Winfrith, Dorset

Disposals of radioactive wastes from this site continued in 1997 at the low rates typical of recent years following the shutdown of the Steam Generating Heavy Water Reactor (SGHWR) in September 1990. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. At this site the monitoring programme consisted of samples of milk, crops, fruit, seafood and indicator materials and measurements of gamma dose rates on the foreshore.

Data are presented in Tables 5.3(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous disposals. The most exposed group for gaseous disposals was the 15-year-old age group who were estimated to receive an dose of less than 0.005 mSv or 0.5% of the dose limit of 1 mSv. Concentrations of radionuclides in the marine environment continued at the low levels attained since closure of the SGHWR. No indication of the effect of disposals from the Cap de la Hague facility in France was detected. The radiation dose to the most exposed group of fish and shellfish consumers remained low in 1997 at less than 0.005 mSv or 0.5% of the dose limit.

The INTAKE food dose was less than 0.005 mSv in 1997.

Table 5.1(a). Radioactivity in food and the environment near Dounreay, 1997

Material	Location[b]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																		
			^{3}H	^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples																						
Cod	Pipeline	2	-	<0.07	<0.08	<0.10	<0.08	-	<0.73	<0.95	<0.13	<0.07	1.0	<0.32	<0.33	<0.32	<0.00010	0.00041	0.0011	<0.00020	0.00028	-
Crabs	"	4	-	<0.09	<0.09	<0.11	<0.07	8.2	<0.89	<0.17	<0.16	<0.09	<0.13	<0.37	<0.42	<0.42	0.0016	0.0077	0.0064	0.00032	0.00095	-
Lobsters	"	4	-	<0.11	<0.11	<0.70	<1.2	270	<1.2	<0.16	<0.35	<0.11	0.16	<0.63	<0.48	<0.43	0.0022	0.011	0.024	<0.00030	<0.00030	-
Winkles	Brims Ness	4	-	<0.12	<0.24	<0.77	<1.9	-	<1.3	8.9	<0.45	<0.12	<0.12	<0.80	<0.50	<0.46	0.063	0.23	0.25	*	*	-
"	Sandside Bay	4	-	<0.12	<0.48	<0.89	<2.0	-	<1.4	11	<0.48	<0.12	<0.14	<1.0	<0.50	<0.48	0.059	0.21	0.12	*	*	-
Sludge	Oigins Geo	1	-	2.4	37	<7.7	<23	-	1200	46	66	3.0	70	49	5.7	11	-	-	93	-	-	-
Sand	Sandside Bay	4	-	<0.12	<0.17	<0.70	<0.96	-	<1.2	<0.16	<0.44	<0.13	4.5	<1.1	<0.85	1.0	3.3	13	12	0.033	0.12	-
Fucus vesiculosus	"	4	-	<0.10	1.1	<0.10	<0.09	220	<0.86	<0.56	<0.10	<0.09	0.43	0.17	<0.41	<0.40	-	-	0.34	-	-	380
"	Brims Ness	4	-	<0.10	1.0	<0.10	0.14	-	<0.87	<0.41	<0.12	<0.09	0.36	<0.29	<0.41	<0.41	-	-	0.38	-	-	-
Sea water	Sandside Bay	4	<1.6	<0.10	<0.10	<0.50	<0.10	-	<1.0	<0.10	<0.50	<0.10	<0.05	-	<0.50	<0.50	-	-	<0.50	-	-	-

Material	Location or selection[d]	No. of sampling observations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{90}Sr	^{129}I	^{131}I	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am	Total alpha	Total beta	Total gamma
Terrestrial samples													
Ovine liver		2	-	-	-	-	<0.37	<0.0069	<0.0078	<0.012	-	-	-
"	max						<0.44	<0.012	<0.012	<0.020	-	-	-
Ovine thyroid		2	-	-	<0.022	<0.095	-	-	-	-			
	max				<0.030	<0.16							
Grass		6	<25	0.50	<0.13	<1.7	<0.34	<0.050	<0.050	<0.050	-	-	-
"	max			0.81	<0.20	<3.3	1.1						
Soil		6	<25	1.5	<0.48	<1.0	21	<0.060	0.30	0.14	-	-	-
"	max			2.8	<1.0	<1.8	56	0.090	0.56	0.30	-	-	-
Dry cloths		24	-	-	-	-	-	-	-	-	0.09	0.75	0.41

\- not analysed
* not detected by the method used
[a] Except for sea water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] Landing point or sampling area
[c] See section 3 for definition
[d] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3

Table 5.1(b). Monitoring of radiation dose rates near Dounreay, 1997

Location	Ground type observations[a]	No. of sampling	µGy h^{-1}
Gamma dose rates at 1 m over substrate			
Oigins Geo	Gravel and stones	3	0.14
"	Intertidal sediment	1	0.17
Sandside Bay	Sand	1	0.085
"	Winkle bed	4	0.099
"	Gill nets	1	0.070
Brims Ness	Winkle bed	1	0.14
Castletown Harbour	Mud	2	0.10
Beta dose rates			µSv h^{-1}
Pipeline	Lobster pots	1	*

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

Table 5.2(a). Radioactivity in food and the environment near Harwell, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{57}Co	^{60}Co	^{137}Cs	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Am	$^{243+244}$Cm	Total beta
Aquatic samples											
Pike	Outfall (Sutton Courtenay)	1	<0.06	<0.07	3.6	<0.16	-	-	<0.24	-	-
"	Newbridge	1	<0.04	<0.05	<0.05	<0.14	<0.000013	0.000041	0.000053	*	-
"	Staines	1	<0.03	<0.06	0.31	<0.10	-	-	<0.06	-	-
Nuphar lutea	Outfall (Sutton Courtenay)	1	<0.05	0.73	2.2	<0.16	-	-	<0.15	-	-
"	Newbridge	1	<0.03	<0.06	<0.05	<0.08	-	-	<0.04	-	-
"	Staines	1	0.12	<0.08	0.09	<0.18	-	-	<0.17	-	-
Mud	Newbridge	1	<0.39	<0.59	9.3	<1.4	-	-	<1.3	-	-
"	Lydebank/Ginge Brook	1	<0.17	0.47	28	0.96	0.15	1.4	0.60	0.0027	-
"	Position 'E'[e]	2	<0.66	11	590	<2.1	-	-	13	-	-
Mud & Sand	Staines	1	<0.17	<0.24	9.2	<0.55	-	-	<0.39	-	140
"	Outfall (Sutton Courtenay)	2	<0.60	7.7	1200	<1.9	-	-	<3.4	-	1600

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples								
Milk[d]	Near farms	4	<3.1	<0.42	<0.40	-	-	-
"	" max		<3.5	<0.45	<0.45			
Apples[d]		1	4.0	<0.40	<0.40	-	-	-
Blackberries[d]		1	18	<0.30	<0.50	-	-	-
Cabbage[d]		1	<3.0	<0.50	<0.40	-	-	-
Carrots[d]		1	<3.0	<0.40	<0.40	-	-	-
Honey		1	<4.0	<0.50	<0.60	-	-	-
Rhubarb[d]		1	<3.0	<0.60	<0.50	-	-	-
Dry cloths		95	-	-	-	0.16	1.1	0.59

- not analysed
** not detected by the method used*
[a] Except for milk and dry cloths where units are Bq l^{-1} and Bq per cloth respectively, and for sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition.
[d] The concentration of ^{3}H (organic) was <3 Bq l^{-1}
[e] Near the outfall

Table 5.2(b). Monitoring of radiation dose rates near Harwell, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over river bank			
Outfall (Sutton Courtenay)	Soil	2	0.091
Position 'E'[b]	"	2	0.079
Lydebank/Ginge Brook confluence	Mud	2	0.057
Newbridge	Grass	1	0.060

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

Table 5.3(a). Radioactivity in food and the environment near Winfrith, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{60}Co	^{65}Zn	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples											
Cod	Weymouth Bay	1	<0.07	<0.20	0.30	<0.12	-	-	<0.07	-	-
Crabs	Chapman's Pool	1	0.55	<0.62	<0.17	<0.32	0.00015	0.00068	0.0015	0.000048	-
"	Lulworth Banks	1	1.1	<0.14	<0.06	<0.17	0.00026	0.0011	0.0015	0.000042	-
Pacific Oysters	Poole	1	<0.07	<0.17	<0.06	<0.11	-	-	<0.11	-	-
Cockles	"	1	1.5	<0.13	<0.05	<0.13	-	-	<0.12	-	-
Whelks	Weymouth Bay	1	0.18	<0.21	<0.06	<0.19	-	-	<0.18	-	-
"	Poole	1	0.67	<0.22	<0.09	<0.16	0.00051	0.0024	0.0025	0.000056	-
Fucus serratus	Kimmeridge	2	1.4	<0.23	0.09	<0.13	-	-	<0.13	-	190
"	Bognor Rock	2	1.5	<0.16	0.08	<0.09	-	-	<0.06	-	-
Mud	Parkstone Bay	1	2.0	<0.79	1.3	1.2	0.067	0.35	0.29	0.0039	-
"	Hardway	2	3.8	<0.97	3.0	2.1	-	-	<0.67	-	-
Mud & sand	Kimmeridge	1	2.1	<0.92	1.6	<0.95	-	-	<0.54	-	-
"	Parkstone Bay	1	2.0	<1.2	1.6	<1.4	-	-	<1.7	-	-
Sand	Kimmeridge	1	0.68	<0.43	0.36	<0.62	-	-	<0.75	-	-

Material	Location or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples								
Milk	Near farms[e]	4	<3.1	<0.41	<0.41	-	-	-
"	" max		<3.3	<0.45	<0.45			
Apples[e]		1	<3.0	<0.40	<0.40	-	-	-
Cabbage[e]		1	<3.0	<0.40	<0.40	-	-	-
Carrots[e]		1	3.0	<0.50	<0.40	-	-	-
Honey		1	<4.0	<0.60	0.70	-	-	-
Potatoes[e]		1	3.0	<0.50	<0.40	-	-	-
Raspberries[e]		1	4.0	<0.30	<0.40	-	-	-
Grass[e]		4	<3.0	-	-	-	-	-
Dry cloths		53	-	-	-	0.12	0.68	0.30

- not analysed
[a] Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] Landing point or sampling area.
[c] See section 3 for definition
[d] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3
[e] The concentration of ^{3}H (organic) was <3.0 Bq l^{-1}

Table 5.3(b). Monitoring of radiation dose rates near Winfrith, 1997

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Kimmeridge	Mud and sand	2	0.072
Parkstone Bay	Mud	2	0.050
Hardway	"	2	0.059

[a] See section 3 for definition

6. NUCLEAR POWER STATIONS OPERATED BY ELECTRICITY GENERATING COMPANIES [b]

In 1997, the electricity companies [b] were authorised to dispose of wastes from 12 locations in the United Kingdom. All locations included operational power stations with the exception of Berkeley and Trawsfynydd where the redundant power stations were undergoing decommissioning. One of the power stations at Hunterston was also being decommissioned. The Berkeley site also provides research facilities.

6.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

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

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

Data for 1997 are presented in Tables 6.1(a) and (b). Gamma dose rates and concentrations in the aquatic environment were similar to those in recent years. Most of the artificial radioactivity detected was due to carbon-14, radiocaesium and sulphur-35. Concentrations of radiocaesium represent the combined effect of disposals from the sites, other nuclear establishments discharging into the Bristol Channel, weapon test and Chernobyl fallout, and possibly a small Sellafield-derived component. Most of the carbon-14 is due to disposals from the Nycomed Amersham site at Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the most exposed group of fish and shellfish consumers including external radiation was low, at 0.013 mSv or 1% of the dose limit of 1 mSv. This dose includes a contribution from tritium in local seafood due to discharges from Cardiff (see Section 8.2).

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

The INTAKE food dose was 0.020 mSv in 1997.

6.2 Bradwell, Essex

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

Measurements for 1997 are summarised in Tables 6.2(a) and (b). Gamma dose rates confirmed the importance of direct radiation from the reactors in the immediate vicinity of the site. Further afield, dose rates could not be distinguished from the natural background. Low concentrations of artificial radioactivity were detected in aquatic materials due to the combined effects of disposals from the station, Sellafield disposals, and weapon test and Chernobyl fallout. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were similar to those for 1996 (MAFF and SEPA, 1997). A calculation based on concentrations of radionuclides in sediments has been used to estimate the external exposure of the houseboat dwellers who were the most exposed group in 1997. Their dose including the effects of consumption pathways, was small, amounting to 0.012 mSv or 1% of the dose limit of 1 mSv. As part of a rolling programme at UK sites, contact beta and gamma dose rates in intertidal areas were monitored in 1997 in order to locate any material with unusual levels of contamination. No such items were found.

Concentrations of activity were also low in terrestrial samples. There was nevertheless an indication in local fruit that carbon-14 levels had been enhanced by the operation of the power station. Low concentrations of sulphur-35 were also detected in some samples. The most exposed group dose was estimated to be 0.006 mSv or 0.6% of the dose limit of 1 mSv, confirming that the radiological impact of authorised disposals from Bradwell was very low.

The INTAKE food dose was less than 0.005 mSv in 1997.

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[b] *With effect from 31 March 1996, these were Magnox Electric plc, Nuclear Electric Ltd and Scottish Nuclear Ltd.*

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). These are operated by Magnox Electric plc. and Nuclear Electric Ltd. respectively. Disposals are made via separate, but adjacent outfalls and stacks but for the purposes of environmental monitoring are considered together.

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

The results for 1997 are given in Tables 6.3(a) and (b). Concentrations of radiocaesium in marine materials are attributable to disposals from the stations and to weapon test fallout with a contribution due to disposals from Sellafield. Apportionment is difficult at these low levels. Trace levels of cobalt-60 in some marine materials are likely to be due to the combined effects of disposals from the site and from other sites on the English Channel coast. The small concentrations of transuranics in whelks and mud were typical of levels expected at sites remote from Sellafield. Gamma and beta dose rates were difficult to distinguish from the natural background. The most exposed group in 1997 continued to be represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.008 mSv or 0.8% of the dose limit of 1 mSv.

Activity concentrations in many terrestrial foods were close to the limits of detection. Levels of carbon-14 were generally within the range of activity concentrations observed for background sources, however some enhancements were observed in fruit and legumes. Low concentrations of sulphur-35 and caesium-137 were detected in some samples; the former is due to station disposals, but the latter is likely to be due to other sources, e.g. weapon test and Chernobyl fallout. The maximum dose due to gaseous disposals was received by the 1-year-old age group. Their dose in 1997 was estimated to be less than 0.005 mSv or 0.5% of the dose limit.

The INTAKE food dose was 0.005 mSv in 1997.

6.4 Hartlepool, Cleveland

This station is powered by twin AGRs. The critical pathway for radiation exposure due to liquid effluent disposals is internal irradiation following consumption of local fish and shellfish. Collection of small coal, which is washed ashore along this stretch of coast, is used to represent the highest beach occupancies. The sampling and measurement programmes at Hartlepool were similar to those for other power station sites. However technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield.

Results of the monitoring programme carried out in 1997 are shown in Tables 6.4(a) and (b). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though some enhancements of carbon-14 levels in terrestrial samples were apparent. The most exposed group dose in 1997 was 0.006 mSv or 0.6% of the dose limit of 1 mSv.

Disposals of tritium in liquid effluents from the power station are discontinuous and levels in the environment vary accordingly. Camplin *et al.,* (1990) has observed concentrations in excess of 100,000 Bq l^{-1} immediately after a discharge. Even at this level the radiological significance of the disposals is minor because of the very low radiotoxicity of the nuclide. No such enhancements were observed in 1997. An increase in the level of technetium-99 in *Fucus vesiculosus* was apparent this year (98 Bq kg^{-1}: 1997; 56 Bq kg^{-1}: 1996). While disposals of technetium-99 from Sellafield decreased in 1997, the increase of this radionuclide in *Fucus vesiculosus* is believed to be due to the transit time from the Irish Sea. Low levels of iodine-131 detected were likely to be from local hospitals. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. Gamma and beta dose rates were difficult to distinguish from natural background with the exception of measurements at Paddy's Hole and South Gare. In these locations, waste slag from a steel works can be found containing enhanced levels of gamma-emitting natural radionuclides. The radiation dose to the most exposed group of local fish and shellfish consumers was low, at less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The INTAKE food dose was less than 0.005 mSv in 1997.

6.5 Heysham, Lancashire

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

The results for 1997 are given in Tables 6.5(a) and (b). Similar levels to those for 1996 were observed and the effect of liquid disposals from Heysham was not detectable above the Sellafield background. The radiation dose in 1997 to the most exposed group of fishermen including a component due to external radiation was 0.073 mSv which is well within the dose limit of 1 mSv. This represents a small decrease from the estimate for 1996 of 0.082 mSv (MAFF and SEPA, 1997).

Most of this exposure was due to the effects of disposals from Sellafield. Concentrations of radioactivity in samphire were of negligible radiological significance.

The effects of gaseous disposals were difficult to detect in 1997. Small enhancements of concentrations of carbon-14 were apparent in blackberries. The most exposed group dose was estimated to be 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The INTAKE food dose was 0.013 mSv in 1997.

6.6 Hinkley Point, Somerset

At this establishment there are two separate 'A' and 'B' nuclear power stations; the 'A' station is powered by Magnox reactors and the 'B' station by AGRs. These are operated by Magnox Electric plc. and Nuclear Electric Ltd. respectively. Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were also carried out.

The results for 1997, presented in Tables 6.6 (a) and (b) indicate a small enhancement of radioactivity levels due to disposals of gaseous wastes. Activity concentrations of tritium and gamma emitters in terrestrial materials were all below or close to the limits of detection. Concentrations of sulphur-35 showed the effects of the power stations and some of the concentrations of carbon-14 in fruit and crops were higher than the default values used to represent background levels (Appendix 5). The estimated most exposed group dose to radioactivity in the terrestrial environment was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The concentrations observed in the Bristol Channel were generally similar to those in 1996. The concentration of tritium in seawater increased in 1997 but, as discussed for Hartlepool, the results of such measurements are highly variable in view of the discontinuous discharge of this radionuclide. Concentrations of other radionuclides in the aquatic environment represent the combined effects of releases from the stations, from other establishments which discharge into the Bristol Channel, from Sellafield, and from weapon test and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However the carbon-14 content in seafood was likely to have been due to disposals from Nycomed Amersham, Cardiff as the disposals from this site are significantly higher than those from the Hinkley Point power stations. The concentrations of transuranic nuclides were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were difficult to distinguish from the natural background with the exception of the measurements close to the station which were affected by direct radiation from the reactors. The most exposed group from liquid disposals from the site in 1997 were represented by local fishermen who were estimated to receive an dose of 0.013 mSv or 1% of the dose limit of 1 mSv. This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff but excludes the effects of direct radiation from the site.

The INTAKE food dose was less than 0.005 mSv in 1997.

6.7 Hunterston, North Ayrshire

At this establishment there are two separate 'A' and 'B' nuclear power stations; the 'A' station was powered by Magnox reactors and the 'B' station is powered by AGRs. . The 'A' station ceased power production at the end of March 1990. Liquid radioactive waste disposals are made to the Firth of Clyde under authorisation granted by SEPA. Gaseous disposals are made separately from 'A' and 'B' stations. Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling fish and shellfish and measurement of gamma dose rate on the foreshore. Samples of sand are also analysed in support of the gamma dose rate measurements and sea water and *Fucus* seaweed are analysed as indicator materials. Quarterly samples of milk and grass are taken for the terrestrial programme.

In February 1997 an incident occurred at the Hunterston B site involving the backflow of gas from the reactor coolant circuit to the clean operational carbon dioxide storage tanks. This led to the possibility that radioactivity had been carried off site by delivery tankers and of subsequent contamination of other carbon dioxide users including food and drinks manufacturers. Monitoring by SEPA and The Scottish Office confirmed initial assessments that the incident was of negligible radiological significance, although the fact that the incident was avoidable led to it being regarded as important by the regulators. A joint report by the regulators (HSE and SEPA) will be published giving further details of the monitoring which took place in the aftermath of the incident and arrangements which have been put in place to prevent a reoccurrence of the incident.

In November 1997 there was a spillage of contaminated water on site at Hunterston A due to a blockage caused by a dead animal in the liquid effluent handling system. Further investigations by SEPA confirmed that the incident had not caused any contamination outside the site.
The results of monitoring in 1997 are shown in Tables 6.7(a) and (b). The concentrations of artificial radioactivity in the marine environment are predominantly due to Sellafield disposals, the general values being consistent with those to be expected at this distance from Sellafield. Small concentrations of activation products such as manganese-54 were probably due to disposals from the site; however, these were of negligible radiological significance. In 1997, the dose, including external radiation, to members of the most exposed group of fish and shellfish consumers near Hunterston was low, at 0.027 mSv or less than 3% of the dose limit of 1 mSv.

The concentrations of radionuclides in milk and grass were generally low and similar to previous years' results. The radiation dose to the most exposed group of terrestrial food consumers, including a contribution due to weapon test and Chernobyl fallout, was 0.025 mSv or less than 3% of the dose limit of 1 mSv.

The INTAKE food dose was 0.017 mSv in 1997.

6.8 Sizewell, Suffolk

At this establishment there are two stations. The 'A' station is powered by Magnox reactors whilst the 'B' station is powered by a Pressurised Water Reactor (PWR). Station 'B' began operation in 1995. These are operated by Magnox Electric plc and Nuclear Electric Ltd respectively. Authorised disposals of radioactive liquid effluent from both power stations are discharged via adjacent outfalls to the North Sea. In 1997, the Environment Agency granted an increase in the authorisation for discharge of tritium from the PWR from 20 to 40 TBq y^{-1}. This was to accommodate the operational needs of the power station. 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 1997 are shown in Tables 6.8 (a) and (b).

In the aquatic programme, analysis of seafood and indicator materials and measurements of gamma and beta dose rates in intertidal areas were undertaken. Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield disposals and to weapon test and Chernobyl fallout. Trace levels of activation products were likely to have been due to disposals from the power stations though there was no conclusive evidence of the effects of the new 'B' station. In 1997, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv or 0.5% of the dose limit of 1 mSv. Measured gamma and beta dose rates were indistinguishable from the natural background except in the immediate vicinity of the power station where direct radiation is known to have an effect. The above assessment includes a contribution for external exposure based on a calculation using radionuclide concentrations in sediment.

Gamma spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit showed very low levels of artificial radioactivity near the power stations in 1997. 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 or 0.5% of the dose limit of 1 mSv. There has been no detectable increase in levels of radioactivity in foodstuffs due to the operation of the PWR.

The INTAKE food dose was less than 0.005 mSv in 1997.

6.9 Torness, East Lothian

This station, which is powered by two AGRs, came into operation at the end of 1987. The monitoring programme at this site included sampling of milk and seafood, and samples of seawater, seaweed and grass are monitored as indicator materials. Measurements are also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

Results of this monitoring in 1997 are shown in Tables 6.9(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield disposals and to weapon test and Chernobyl fallout, though trace levels of activation products were likely to have been due to disposals from the station. The group of fish and shellfish consumers received a low dose, 0.008 mSv, or less than 1% of the dose limit of 1 mSv. The beta radiation from fishermen's nets and pots was typical of that due to natural radiation and the most exposed group of terrestrial food consumers would have received a dose, including a contribution due to weapon test and Chernobyl fallout, of 0.023 mSv, or 2% of the dose limit of 1 mSv. The INTAKE food dose was less than 0.014 mSv in 1997.

6.10 Trawsfynydd, Gwynedd

This station is being decommissioned. Low level disposals continued during 1997 under authorisations granted by the Environment Agency. Disposals of liquid radioactive waste were made to a freshwater lake making the power station unique in UK terms. Monitoring is carried out on behalf of the Welsh Office. The aquatic monitoring programme is directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are those of caesium and to a lesser extent, strontium-90. Habits surveys have established that species of fish regularly consumed are brown trout, rainbow trout and a small amount of perch. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period which they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than those of indigenous fish.

The results of the terrestrial programme, including those for local milk, crops and indicator materials are shown in Tables 6.10 (a) and (b). Concentrations of activity in all terrestrial foods were low, the most significant being those of 6.6 Bq kg^{-1} and 1.9 Bq kg^{-1} of radiocaesium in ovine muscle and offal respectively. The most likely source of radiocaesium in these and other samples is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. In all cases, detected activities were low, and similar to observations in other areas

of England and Wales, where activity was attributable to weapon test fallout. No evidence was therefore found that resuspension of activity in sediment from the lake shore contributed to exposure from transuranic radionuclides in 1997.

The most exposed group for terrestrial foods at Trawsfynydd in 1997 received doses of 0.006 mSv or 0.6% of the dose limit of 1 mSv. This assessed dose includes a contribution from the caesium activity detailed above.

In the lake itself, there remains clear evidence for the effects of disposals from the power station. Concentrations of caesium exceed 1000 Bq kg^{-1} in the mud from the bed of the lake and in peat from below the hydroelectric power station at Maentwrog. Gamma dose rates found on the shoreline where occupancy by anglers is relevant were only slightly enhanced above background and were similar to or less than those in 1996.

The concentrations of caesium-137 in lake water remained above those for water coming into the lake via the Afon Prysor and were similar to those in 1996. However, there were small decreases in concentrations of radiocaesium in fish in 1997. Taking this and the results of measurements of gamma dose rates into account, the dose to the most exposed group of anglers was 0.023 mSv in 1997, or about 2% of the dose limit of 1 mSv. In 1996, their estimated dose was 0.043 mSv (MAFF and SEPA, 1997), the decrease being due to both the concentrations in fish and the dose rates.

Contact monitoring of the lake shore revealed no items with unusual levels of contamination.

6.11 Wylfa, Isle of Anglesey

Gaseous and liquid wastes from this station were discharged in 1997 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of disposals on the Irish Sea and the local environment is carried out on behalf of the Welsh Office. Such disposals and effects are very low.

The results of the programme in 1997 are given in Tables 6.11 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield disposals though trace levels of activation products were likely to have been due to disposals from the station. The concentrations were generally similar to or less than those for 1996, and continued to show the recent 'signal' of increased disposals of technetium-99 from Sellafield. The dose to the most exposed group of high-rate fish and shellfish consumers was low, at 0.006 mSv or 0.6% of the dose limit of 1 mSv. Gamma dose rates, measured using portable instruments, continued to be difficult to distinguish from the natural background, but a small contribution due to external exposure of the most exposed group has been included in the total above.

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

The INTAKE food dose was less than 0.005 mSv in 1997.

Table 6.1(a). Radioactivity in food and the environment near Berkeley and Oldbury nuclear power stations, 1997

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples											
Dover sole	Lydney	2	240	<0.11	0.26	<0.17	-	-	<0.15	-	-
Elvers	Littleton Warth	1	-	<0.05	0.07	<0.08	-	-	<0.05	-	-
Shrimps	Lydney	2	130	<0.06	0.29	<0.09	0.00040	0.0024	0.0020	0.000048	-
Fucus vesiculosus	Pipeline[d]	2	-	<0.06	0.50	<0.15	-	-	<0.12	-	120
Mud	"	2	-	<0.60	33	<1.4	-	-	1.0	-	-
"	Lydney	2	-	<0.53	29	<1.6	-	-	<1.3	-	-
"	Hills Flats	2	-	<0.58	29	<1.6	-	-	<1.0	-	-
"	1km south of Oldbury	2	-	0.79	34	1.7	-	-	<1.2	-	-

Material	Location or selection[c]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Near farms	8	<3.3	16	<0.49	<0.33	<0.43	-	-	-
"	" max		<4.0	19	<0.60	<0.38	<0.45			
Apples		1	<3.0	13	<0.20	<0.30	<0.30	-	-	-
Blackberries		1	4.0	27	<0.70	<0.30	<0.40	-	-	-
Cabbage		1	<3.0	8.0	0.50	<0.20	<0.40	-	-	-
Carrots		1	<3.0	3.0	<0.30	<0.30	<0.40	-	-	-
Goats milk		1	<3.0	14	0.20	<0.30	<0.40	-	-	-
Potatoes		1	6.0	20	0.60	<0.30	<0.40	-	-	-
Runner Beans		1	<3.0	10	0.30	<0.30	<0.30	-	-	-
Wheat		1	9.0	110	2.1	<0.20	<0.30	-	-	-
Dry cloths		159	-	-	-	-	-	0.12	0.98	0.43

- *not analysed*
[a] *Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *See section 5 for definition*
[c] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 5*
[d] *Berkeley*

Table 6.1(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 1997

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
1 km south of Oldbury	Mud	2	0.075
2 km south west of Berkeley	"	2	0.074
Guscar Rocks	"	2	0.075
Lydney Locks	"	2	0.070
Berkeley pipeline (new)	"	2	0.081
Sharpness	"	2	0.077
Hills Flats	"	2	0.070

[a] *See section 3 for definition*

Table 6.2(a). Radioactivity in food and the environment near Bradwell nuclear power station, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic Samples															
Sole	Bradwell	1	-	<0.11	<0.33	-	<0.13	0.69	<0.17	-	-	<0.11	-	-	-
Herring	"	1	-	<0.08	<0.23	-	<0.09	0.51	<0.16	-	-	<0.10	-	-	-
Bass	Pipeline	1	-	<0.05	<0.18	-	0.34	2.6	<0.16	-	-	<0.15	-	-	-
Mullet	"	1	-	<0.06	<0.22	-	0.20	0.85	<0.17	-	-	<0.17	-	-	-
Native oysters	Tollesbury N Channel	2	15	<0.06	0.48	-	0.14	0.49	<0.09	0.00058	0.0027	0.0055	0.000046	0.00021	-
Pacific oysters	Goldhanger Creek	1	-	<0.04	0.57	-	0.16	0.33	<0.07	-	-	<0.07	-	-	-
Winkles	Pipeline	2	-	0.46	<0.51	-	<0.21	0.66	<0.30	-	-	<0.28	-	-	-
Fucus vesiculosus	Waterside	2	-	0.38	<0.17	16	0.71	3.1	<0.13	-	-	<0.11	-	-	210
Mud	Pipeline	2	-	2.7	<0.89	-	5.4	28	2.3	-	-	<1.0	-	-	-
"	West Mersea	2	-	1.1	<0.86	-	3.7	23	1.3	-	-	<0.56	-	-	-
"	Maldon	2	-	2.2	<1.0	-	9.4	67	1.9	-	-	<1.5	-	-	-

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples											
Milk	Near farms	3	<3.0	15	<0.67	<0.38	<0.29	<0.37	-	-	-
"	" max				<0.85	<0.40	<0.33	<0.38			
"	Far farms	3	<3.0	20	<0.57	<0.40	<0.29	<0.37	-	-	-
"	" max			26	<0.60	<0.45	<0.30	<0.40			
Apples		1	<3.0	15	1.5	<0.40	<0.30	<0.40	-	-	-
Blackberries		1	<3.0	16	0.30	<0.30	<0.30	<0.40	-	-	-
Cabbage		1	<3.0	9.0	1.0	<0.40	<0.30	<0.50	-	-	-
Carrots		1	<3.0	7.0	0.50	<0.40	<0.20	<0.50	-	-	-
Potatoes		1	<3.0	14	0.40	<0.50	<0.30	<0.50	-	-	-
Rabbit		1	<3.0	21	<1.2	<1.0	<0.40	<0.70	-	-	-
Wheat		1	<4.0	77	4.3	<0.40	<0.30	<0.40	-	-	-
Lucerne		1	<3.0	13	7.5	<0.40	<0.30	<0.50	-	-	-
Dry cloths		118	-	-	-	-	-	-	0.17	1.1	0.76

- not analysed
[a] Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3

Table 6.2(b). Monitoring of radiation dose rates near Bradwell, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Pipeline	Mud	2	0.24
1.5 km east of pipeline	Sand	1	0.044
"	Shell and sand	1	0.044
Waterside	Mud	2	0.059
West Mersea	"	2	0.062
Maldon	"	2	0.056

[a] See section 3 for definition

Table 6.3(a). Radioactivity in food and the environment near Dungeness nuclear power stations, 1997

Material	Location	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{90}Sr	^{60}Co	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples															
Plaice	Pipeline	2	-	-	-	<0.04	<0.05	0.21	<0.10	-	-	<0.09	-	-	-
Cod	"	2	-	-	-	<0.05	<0.06	0.39	<0.14	-	-	<0.17	-	-	-
Bass	"	1	-	-	-	<0.14	<0.13	0.61	<0.19	-	-	<0.10	-	-	-
Spiny spider crabs	Hastings	1	-	-	-	0.54	<0.11	<0.09	<0.18	-	-	<0.10	-	-	-
Shrimps	Pipeline	2	-	25	-	<0.08	<0.09	0.37	<0.13	-	-	<0.10	-	-	-
Whelks	"	2	-	-	0.017	0.14	<0.09	<0.12	<0.16	0.00087	0.0031	0.0025	0.000023	0.00023	-
Fucus vesiculosus	Copt Point	2	-	-	-	0.48	<0.06	0.15	<0.11	-	-	<0.10	-	-	200
Mud & sand	Rye Harbour	2	-	-	-	2.4	<0.35	1.9	<1.7	0.076	0.35	0.30	*	0.018	-
Sand	Camber Sands	2	-	-	-	<0.47	<0.27	0.41	<1.1	-	-	<2.7	-	-	-
"	Pilot Inn	2	-	-	-	0.68	<0.25	0.58	<0.51	-	-	<0.49	-	-	-
Sea water	Pipeline	2	2.3	-	-	-	-	-	-	-	-	-	-	-	-

Material	Location or selection[c]	No. of sampling observ-ations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{60}Co	^{134}Cs	^{137}Cs	Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta	Total gamma
Terrestrial samples																
Milk[d]	Far farms	2	<3.1	16	<0.46	-	<0.45	<0.31	<0.43	-	-	-	-	-	-	-
"	" " max		<3.3	17	<0.55		<0.48	<0.33	<0.45							
Beans		1	<3.0	84	2.4	-	<0.60	<0.20	<0.50	-	-	-	-	-	-	-
Blackberries		1	<3.0	22	0.50	-	<0.50	<0.40	0.40	-	-	-	-	-	-	-
Chicken		1	<3.0	22	<0.70	0.023	<0.40	-	-	0.18	<0.00020	<0.00020	0.00060	-	-	-
Chicken (Free range)		1	<3.0	34	<0.40	<0.014	<0.20	-	-	0.21	<0.00020	<0.00010	<0.00040	-	-	-
Honey		1	<4.0	79	<0.50	-	<0.40	<0.40	<0.40	-	-	-	-	-	-	-
Ovine muscle		1	<3.0	30	<1.2	<0.019	<0.40	-	-	<0.049	0.00010	0.00010	0.00030	-	-	-
Ovine offal		1	<4.0	25	6.5	0.016	<0.40	-	-	<0.044	<0.00010	0.00020	<0.00040	-	-	-
Peas		1	<3.0	91	2.9	-	<0.30	<0.30	<0.40	-	-	-	-	-	-	-
Porcine Muscle		1	<3.0	32	<0.70	<0.010	<0.40	-	-	0.25	<0.00020	<0.00030	0.00060	-	-	-
Porcine Offal		1	<4.0	32	<0.70	0.027	<0.40	-	-	0.55	<0.00010	0.00020	0.00040	-	-	-
Potatoes		1	<3.0	15	<0.40	-	<0.60	<0.30	<0.50	-	-	-	-	-	-	-
Sea kale		1	14	5.0	<0.60	-	<0.40	<0.40	0.50	-	-	-	-	-	-	-
Dry cloths		96	-	-	-	-	-	-	-	-	-	-	-	0.25	1.4	0.69

- not analysed
** not detected by the method used*
[a] Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3
[d] There are no farms producing milk near this site

Table 6.3(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 1997

Location	Ground type	No. of sampling observations[a]	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Camber Sands	Sand	2	0.049
Old Lifeboat Station	Stones	1	0.041
"	Gravel	1	0.039
Pilot Inn	Sand	2	0.048
Rye Harbour	Mud	1	0.071
"	Mud and sand	1	0.064
Beta dose rates			μSv h^{-1}
Rye Harbour	Mud and sand	1	0.19

[a] *See section 3 for definition*

Table 6.4(a). Radioactivity in food and the environment near Hartlepool nuclear power station, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total beta
Aquatic samples															
Plaice	Pipeline	2	-	36	<0.05	-	*	0.41	<0.09	-	-	<0.06	-	-	-
Cod	"	2	-	-	<0.04	-	*	0.90	<0.13	-	-	<0.13	-	-	-
Crabs	"	2	-	47	<0.06	-	*	0.18	<0.12	0.0011	0.0062	0.0063	*	0.000022	-
Winkles	South Gare	2	-	-	<0.11	-	*	0.44	<0.20	0.0093	0.052	0.040	0.00029	0.00012	-
Fucus vesiculosus	Pilot Station	2	-	-	<0.05	98	<2.6	0.32	<0.10	-	-	<0.11	-	-	290
Mud	Greatham Creek	2	-	-	<0.28	-	*	7.9	2.3	-	-	<0.79	-	-	-
"	Paddy's Hole	2	-	-	<0.26	-	*	15	2.5	-	-	<0.77	-	-	-
Coal & sand	Little Scar	2	-	-	<0.19	-	*	1.3	<0.54	-	-	<0.54	-	-	-
Sea water	Pipeline	2	<1.6	-	-	-	-	-	-	-	-	-	-	-	-

Material	Location[b] or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Far farms	4	<3.0	24	<0.36	<0.41	<0.41	-	-	-
"	" max			28	0.40	<0.48	<0.45			
Apples		1	<3.0	11	<0.40	<0.50	<0.30	-	-	-
Cabbage		2	<3.0	8.0	<0.50	<0.40	<0.45	-	-	-
"	max			10	<0.70		<0.50			
Carrots		1	<3.0	10	<0.40	<0.40	<0.40	-	-	-
Elderberries		1	<3.0	28	<0.40	<0.40	<0.40	-	-	-
Honey		1	<4.0	79	<0.80	<0.50	<0.60	-	-	-
Potatoes		1	<3.0	19	<0.80	<0.30	<0.40	-	-	-
Wheat		1	<4.0	78	1.8	<0.50	<0.40	-	-	-
Dry cloths		118	-	-	-	-	-	0.27	1.6	1.0

\- *not analysed*
* *not detected by the method used*
[a] *Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *Landing point or sampling area*
[c] *See section 3 for definition*
[d] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3*

Table 6.4(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 1997

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Greatham Creek	Mud	1	0.076
"	Mud and sand	1	0.079
Little Scar	Coal and sand	1	0.057
"	Sand	1	0.059
North Gare	"	2	0.059
Paddy's Hole	Mud	2	0.10
South Gare	Winkle bed	1	0.13
Beta dose rates			µSv h^{-1}
Little Scar	Coal and sand	1	*

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

Table 6.5(a). Radioactivity in food and the environment near Heysham nuclear power stations, 1997

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu
Aquatic samples																
Flounder	Flookburgh	4	-	95	-	<0.14	-	-	<1.7	<0.30	<0.49	*	<0.16	22	<0.42	<0.43
Plaice	Morecambe	4	-	-	-	<0.12	0.037	8.6	<1.2	<0.25	<0.29	*	<0.12	7.9	<0.35	<0.24
Bass	"	2	-	-	-	<0.14	-	-	<1.5	<0.29	<0.37	*	<0.15	20	<0.42	<0.25
Whitebait	Sunderland Point	1	-	-	-	<0.07	0.23	-	<0.64	<0.13	<0.17	*	<0.07	9.0	<0.18	<0.12
Shrimps	Flookburgh	4	-	79	-	<0.11	-	13	<0.96	<0.18	<0.26	<0.38	<0.09	6.9	<0.26	<0.20
Cockles	Middleton Sands	2	-	-	-	1.8	-	-	<1.7	<0.12	<0.17	*	<0.06	4.7	<0.17	<0.18
"	Flookburgh	4	-	76	-	1.4	0.43	71	<1.1	<0.12	<0.23	*	<0.06	4.5	<0.16	<0.14
Winkles	Red Nab Point	4	-	-	-	1.1	-	-	<3.4	1.0	<0.45	*	<0.22	9.5	<0.23	<0.17
Mussels	Morecambe	4	-	84	-	0.69	-	500	2.5	<0.14	<0.24	*	<0.07	3.0	<0.19	<0.16
Fucus vesiculosus	Half Moon Bay	4	-	-	-	0.50	-	6100	<0.81	<0.16	<0.27	*	<0.10	6.4	<0.27	<0.23
Samphire	Cockerham Marsh	1	-	-	-	0.10	-	-	<0.30	<0.06	<0.08	*	<0.03	3.8	<0.09	<0.05
Mud & sand	Flookburgh	4	-	-	-	<0.56	-	-	<3.5	<0.58	<1.1	*	<0.38	98	<0.93	<1.2
"	Half Moon Bay	4	-	-	-	3.6	-	-	<14	<1.1	<2.6	<1.7	<0.78	220	<2.0	<1.9
"	Sunderland Point	4	-	-	-	2.7	-	-	<7.3	<1.1	<2.2	<4.3	<0.81	190	<1.7	3.0
"	Morecambe Central Pier	4	-	-	-	1.5	-	-	<8.3	<0.74	<1.8	<2.2	<0.53	140	<1.2	<1.6
Turf	Conder Green	4	-	-	-	<2.2	-	-	<14	<1.8	<4.6	*	<1.2	480	<3.2	<3.4
"	Sand Gate Marsh	4	-	-	-	<1.0	-	-	<11	<1.7	<3.6	*	<1.1	260	<2.9	<2.5
Sea water	Pipeline	2	35	-	-	-	-	-	-	-	-	-	-	-	-	-
"	Half Moon Bay	1	-	-	-	-	-	-	-	-	-	-	0.0016	0.27	-	-
Terrestrial samples																
Milk	Near farms	9	<3.2	15	<0.39	<0.35	-	-	<3.1	<0.51	-	-	<0.30	<0.41	-	-
"	" max		<4.0	18	<0.65	<0.43			<3.4	<0.60			<0.35	<0.45		
Apples		1	<3.0	13	<0.70	<0.40	-	-	<2.8	<0.50	-	-	<0.20	<0.40	-	-
Barley		1	6.0	87	1.1	<0.40	-	-	<3.6	<0.60	-	-	<0.30	<0.50	-	-
Blackberries		1	5.0	37	<0.70	<0.20	-	-	<2.3	<0.30	-	-	<0.20	<0.30	-	-
Cabbage		1	3.0	7.0	1.8	<0.40	-	-	<2.2	<0.50	-	-	<0.20	<0.40	-	-
Mushrooms		1	<3.0	5.0	<0.20	<0.30	-	-	<2.3	<0.40	-	-	<0.20	<0.40	-	-
Potatoes		1	<3.0	16	0.30	<0.30	-	-	<3.0	<0.50	-	-	<0.20	<0.40	-	-
Sprouts		1	<3.0	9.0	0.60	<0.60	-	-	<3.9	<0.70	-	-	<0.40	<0.60	-	-
Fodder beet		1	<3.0	5.0	<0.80	<0.60	-	-	<2.8	<0.60	-	-	<0.30	<0.40	-	-
Silage		1	-	-	-	<0.30	-	-	<3.2	<0.60	-	-	<0.40	<0.50	-	-
Dry cloths		78	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.5(a). continued

Material	Location[b] or selection[c]	No. of sampling observa-tions[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta	Total gamma
Aquatic samples											
Flounder	Flookburgh	4	0.00061	0.0038	-	0.0056	*	0.000011	-	-	-
Plaice	Morecambe	4	-	-	-	<0.27	-	-	-	-	-
Bass	"	2	-	-	-	<0.15	-	-	-	-	-
Whitebait	Sunderland Point	1	0.078	0.31	4.2	0.48	*	0.00067	-	-	-
Shrimps	Flookburgh	4	0.0056	0.029	0.37	0.047	0.00010	0.000093	-	-	-
Cockles	Middleton Sands	2	0.39	2.1	-	5.4	*	0.0086	-	-	-
"	Flookburgh	4	0.32	1.8	19	4.8	*	0.013	-	-	-
Winkles	Red Nab Point	4	0.52	2.8	-	4.8	*	0.0082	-	-	-
Mussels	Morecambe	4	0.32	1.8	-	3.2	*	0.0034	-	-	-
Fucus vesiculosus	Half Moon Bay	4	-	-	-	0.79	-	-	-	4500	-
Samphire	Cockerham Marsh	1	-	-	-	2.3	-	-	-	50	-
Mud & sand	Flookburgh	4	-	-	-	46	-	-	-	-	-
"	Half Moon Bay	4	9.6	51	-	85	*	0.16	-	-	-
"	Sunderland Point	4	-	-	-	110	-	-	-	-	-
"	Morecambe Central Pier	4	-	-	-	81	-	-	-	-	-
Turf	Conder Green	4	-	-	-	210	-	-	-	-	-
"	Sand Gate Marsh	4	-	-	-	130	-	-	-	-	-
Sea water	Pipeline	2	-	-	-	-	-	-	-	-	-
"	Half Moon Bay	1	-	-	-	-	-	-	-	-	-
Terrestrial samples											
Milk	Near farms	9	-	-	-	-	-	-	-	-	-
"	" max										
Apples		1	-	-	-	-	-	-	-	-	-
Barley		1	-	-	-	-	-	-	-	-	-
Blackberries		1	-	-	-	-	-	-	-	-	-
Cabbage		1	-	-	-	-	-	-	-	-	-
Mushroom		1	-	-	-	-	-	-	-	-	-
Potatoes		1	-	-	-	-	-	-	-	-	-
Sprouts		1	-	-	-	-	-	-	-	-	-
Fodder beet		1	-	-	-	-	-	-	-	-	-
Silage		1	0.00080	0.0055	<0.11	0.0084	-	-	-	-	-
Dry cloths		78	-	-	-	-			0.09	0.66	0.35

- not analysed
** not detected by the method used*
[a] Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] Landing point or sampling area
[c] Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3
[d] See section 3 for definition

Table 6.5(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Greenodd	Salt marsh	2	0.081
Sand Gate marsh	"	4	0.10
Flookburgh	Mud and sand	4	0.078
High Foulshaw	Salt marsh	4	0.095
Arnside	Mud and sand	4	0.070
"	Salt marsh	4	0.11
Morecambe Central Pier	Mussel bed	4	0.078
"	Mud	2	0.081
"	Mud and sand	2	0.078
Half Moon Bay	"	4	0.084
Pipeline	"	4	0.077
Red Nab Point	"	4	0.080
Sunderland Point	Mud and sand	4	0.088
Sunderland	Mud, sand and stones	4	0.079
Colloway Marsh	Salt marsh	4	0.16
Lancaster	"	3	0.097
Aldcliffe Marsh	"	3	0.12
Conder Green	Mud	1	0.11
"	Mud and sand	3	0.10
"	Salt marsh	4	0.12
"	Cabin[b]	1	0.090
Cockerham Marsh	Salt marsh	4	0.11

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

Table 6.6(a). Radioactivity in food and the environment near Hinkley Point nuclear power stations, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}														
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{131}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples																	
Flounder	Stolford	2	-	99	<0.06	<0.06	<0.16	*	<0.12	0.78	<0.34	<0.14	-	-	<0.13	-	-
Shrimps	"	2	-	89	<0.05	<0.05	<0.12	*	<0.07	0.44	<0.28	<0.12	0.00021	0.0010	0.0011	0.000025	-
Fucus vesiculosus	Pipeline	2	-	-	0.66	1.8	<0.54	<0.51	4.5	22	<0.90	<0.21	-	-	<0.31	-	290
Mud	1.6km east of pipeline	2	-	-	<0.67	<1.3	<1.5	*	3.5	32	<3.1	<1.9	-	-	<1.5	-	-
Mud & sand	Pipeline	2	-	-	0.55	2.3	<0.87	*	11	53	<5.2	<1.1	-	-	<1.2	-	-
"	River Parrett	2	-	-	<0.79	<0.79	<1.7	<11	1.7	37	<4.1	<2.6	-	-	<2.4	-	-
Sea water	Pipeline	2	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Material	Location[b] or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs	^{144}Ce	Total alpha	Total beta	Total gamma
Terrestrial samples												
Milk	Near farms	7	<3.0	16	<0.51	<0.39	<0.29	<0.40	<1.9	-	-	-
"	" max		<3.3	19	<0.75	<0.45	<0.33	<0.43	<2.2	-	-	-
"	Far farms	1	<3.0	19	<0.50	<0.45	<0.35	<0.40	<2.0	-	-	-
Apples		1	<3.0	10	<0.20	<0.30	<0.20	<0.40	<1.1	-	-	-
Blackberries		1	5.0	22	1.4	<0.40	<0.30	<0.30	<1.3	-	-	-
Honey		1	5.0	62	<0.60	<0.40	<0.40	1.4	<2.4	-	-	-
Kale		1	3.0	9.0	2.6	<0.50	<0.30	<0.50	<1.6	-	-	-
Maize		1	<4.0	28	1.2	<0.40	<0.30	<0.40	<1.9	-	-	-
Potatoes		1	<3.0	37	1.0	<0.50	<0.30	<0.50	<2.1	-	-	-
Wheat		1	<3.0	51	5.1	<0.40	<0.40	<0.40	<1.1	-	-	-
Fodder Beet		1	<3.0	10	0.30	<0.50	<0.30	<0.40	<1.9	-	-	-
Dry cloths		97	-	-	-	-	-	-	-	0.23	1.5	1.1

- not analysed
** not detected by the method used*
[a] Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] Landing point or sampling area.
[c] See section 3 for definition
[d] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3

Table 6.6(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 1997

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
0.8 km east of pipeline	Mud	1	0.072
"	Mud and sand	1	0.060
0.8 km west of pipeline	Mud	1	0.18
"	Mud and sand	1	0.19
1.6 km east of pipeline	Mud	1	0.098
"	Mud and sand	1	0.064
Pipeline	"	2	0.10
River Parrett	Mud	1	0.070
"	Mud and sand	1	0.073

[a] See section 3 for definition

Table 6.7(a). Radioactivity in food and the environment near Hunterston nuclear power station, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																
			^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Am	^{242}Cm	$^{243+244}$Cm	Total Beta
Aquatic samples																			
Cod	Millport	2	-	<0.19	-	<0.10	-	-	<0.10	-	<0.10	3.4	<0.50	-	-	<0.50	-	-	-
Hake	"	2	-	<0.10	-	<0.10	-	-	<0.10	-	<0.10	4.0	<0.50	-	-	<0.50	-	-	-
Crabs	"	1	-	<0.10	-	<0.10	-	-	<0.10	-	<0.10	0.75	<0.50	0.0058	0.029	0.029	*	*	-
Nephrops	"	2	-	<0.10	-	<0.10	-	-	<0.10	-	<0.10	1.3	<0.50	-	-	<0.37	-	-	-
Lobsters	Largs	1	-	<0.10	-	<0.10	-	-	<0.10	-	<0.10	0.86	<0.50	-	-	<0.50	-	-	-
Squat lobsters	"	3	-	<0.10	-	<0.10	-	1.4	<0.10	-	<0.10	<1.0	<0.50	0.0046	0.019	0.0074	*	*	-
Oysters	Fairlie	2	-	<0.10	<0.08	<0.08	<0.12	-	0.40	*	<0.07	0.23	<0.29	-	-	<0.29	-	-	-
Winkles	Pipeline	3	-	1.6	<0.06	1.1	0.22	-	1.7	<0.28	<0.08	1.5	<0.37	0.034	0.14	0.082	0.0016	0.0034	-
Scallops	"	3	-	<0.10	-	<0.10	-	-	<0.10	-	<0.10	<0.38	<0.50	0.0019	0.011	0.0017	<0.00020	<0.00020	-
Fucus vesiculosus	"	3	-	7.8	0.15	1.7	<0.29	-	<1.6	0.58	<0.9	2.7	<0.43	-	-	<0.48	-	-	1400
Sand	"	3	-	0.73	<0.22	0.59	<0.41	-	<0.17	*	<0.11	18	<0.60	-	-	<0.50	-	-	-
Sea water	"	10	<13	-	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-
"	Rearing tank	1	7.0	-	-	-	-	-	-	-	-	<0.05							

Material	Location[b] or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Terrestrial samples								
Milk		4	<25	17	<5.1	<0.10	0.31	-
"	max			20	5.3		0.51	
Grass		4	<25	26	<5.0	<0.85	0.55	<1.7
"	max			37		1.4	0.77	2.9

- not analysed
** not detected by the method used*
[a] Except for milk and sea water where units are Bq l^{-1} and for sediment where dry concentrations apply
[b] Landing point or sampling area
[c] See section 3 for definition
[d] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition

Table 6.7(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 1997

Location type	Ground sampling observa-tions[a]	No. of	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
0.5 km north of pipeline	Sand	3	0.057
0.5 km south of pipeline	Sand and stones	3	0.066

[a] See section 3 for definition

Table 6.8(a). Radioactivity in food and the environment near Sizewell nuclear power stations, 1997

Material	Location[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H	^{14}C	^{58}Co	^{60}Co	^{65}Zn	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Aquatic samples															
Cod	Sizewell	1	-	-	<0.09	<0.04	<0.12	0.89	<0.06	-	-	<0.04	-	-	-
Flounder	"	1	-	-	<0.12	<0.06	<0.16	0.46	<0.09	-	-	<0.05	-	-	-
Crabs	"	2	-	37	<0.22	<0.11	<0.27	0.23	<0.19	0.00023	0.0012	0.0023	0.000024	0.000041	-
Pacific oysters	Blyth estuary	1	-	-	<0.03	<0.02	0.07	0.07	<0.06	-	-	<0.06	-	-	-
Whelks	Dunwich	1	-	-	<0.20	0.19	<0.21	0.16	<0.13	-	-	<0.08	-	-	-
Mud	Southwold	2	-	-	<1.0	1.9	<0.82	14	<1.4	-	-	<0.87	-	-	810
Sand	Rifle Range	2	-	-	<0.39	<0.13	<0.35	0.39	<0.50	-	-	<0.70	-	-	-
"	Aldeburgh	2	-	-	<0.30	<0.11	<0.26	0.25	<0.37	-	-	<0.39	-	-	-
Sea water	"	2	<1.6	-	-	-	-	-	-	-	-	-	-	-	-

Material	Location[b] or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Near farms	3	<3.0	16	<0.31	<0.39	<0.38	-	-	-
"	" max			18	<0.38	<0.40	<0.40	-	-	-
"	Far farms	4	<3.0	20	<0.32	<0.46	<0.40	-	-	-
"	" max			23	<0.38	<0.53	<0.43	-	-	-
Apples		1	<3.0	13	<0.20	<0.30	<0.40	-	-	-
Blackberries		1	<3.0	26	0.60	<0.40	<0.40	-	-	-
Cabbage		1	<3.0	11	1.7	<0.50	<0.50	-	-	-
Carrots		1	<3.0	5.0	0.60	<0.40	<0.40	-	-	-
Honey		1	<3.0	71	<0.50	<0.30	<0.40	-	-	-
Potatoes		1	<3.0	19	<0.40	<0.60	<0.50	-	-	-
Runner Beans		1	<3.0	5.0	0.30	<0.50	<0.40	-	-	-
Wheat		1	<4.0	87	1.4	<0.30	<0.40	-	-	-
Dry cloths		111	-	-	-	-	-	0.19	1.2	0.77

- not analysed
[a] Except for milk and seawater where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] Landing point or sampling area.
[c] Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 5 for definition.
[d] See section 3 for definition

Table 6.8(b). Monitoring of radiation dose rates near Sizewell nuclear power station, 1997

Location	Ground type	No. of sampling observa-tions[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Pipeline	Sand	2	0.11
Dunwich	"	2	0.044
Rifle range	"	2	0.047
Sizewell Hall	"	2	0.044
Aldeburgh	Sand and stones	1	0.042
"	Sand and gravel	1	0.044
Southwold Harbour	Mud	2	0.066
Beta dose rates			µSv h^{-1}
Southwold Harbour	Mud	1	0.22

[a] See section 3 for definition

Table 6.9(a). Radioactivity in food and the environment near Torness nuclear power station, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Total beta
Aquatic samples											
Cod	Pipeline	1	-	<0.10	<0.10	-	<0.10	0.79	<0.50	<0.50	-
Crabs	Cove	2	-	<0.10	<0.10	-	<0.10	<0.20	<0.50	<0.50	-
Lobsters	"	1	-	<0.10	<0.10	20	<0.10	0.21	<0.50	<0.50	-
Nephrops	Dunbar	3	-	<0.08	<0.08	-	<0.10	<0.31	<0.38	0.012	-
Winkles	Pipeline	2	-	<0.12	<0.12	-	<0.38	<0.15	<0.50	<0.50	<18
Fucus vesiculosus	"	3	-	0.36	<0.18	-	<0.11	0.32	<0.38	<0.39	530
Mud	Eyemouth Harbour	2	-	<0.30	<0.29	-	<0.51	17	1.6	<1.5	-
Dredge spoil mud	"	1	-	<0.41	<0.36	-	<0.67	42	1.6	<1.9	
Mud and sand	Dunbar inner harbour	3	-	<0.16	<0.14	-	<0.20	6.5	<0.68	<0.70	-
"	Barns Ness	1	-	<0.10	<0.10	-	<0.10	4.0	<0.50	<0.50	-
Mud, sand and stones	"	1	-	<0.30	<0.25	-	<0.45	4.9	<1.0	<1.8	
Sand	Thornton Loch Beach	3	-	<0.09	<0.11	-	<0.14	2.9	<0.51	<0.58	-
Seawater	Pipeline	12	<22	-	-	-	-	<0.062	-	-	-

Material	Location or selection[d]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Terrestrial samples								
Milk		3	<25	15	<6.2	<0.10	<0.047	-
"	max			16	8.5		<0.050	-
Grass		6	<26	30	<5.0	0.39	<0.14	<1.2
"	max		30	56		0.61	<0.20	2.0

- not analysed
** not detected by the method used*
[a] Except for milk and sea water where units are Bq l^{-1} and for sediment where dry concentrations apply
[b] Landing point or sampling area
[c] See section 3 for definition
[d] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition

Table 6.9(b). Monitoring of radiation dose rates near Torness, 1997

Location type	Ground sampling observa-tions[a]	No. of	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Barns Ness	Mud and sand	2	0.061
"	Sand and stones	1	0.064
Skateraw Harbour	Sand	3	0.059
Thornton Loch Beach	"	3	0.049
Eyemouth Harbour	Mud	1	0.063
"	Sand	1	0.071
Dunbar Inner Harbour	Mud and sand	3	0.076
St Abbs	Sand	3	0.086
Beta dose rates on fishing gear			µSv h^{-1}
Cove	Pots	1	*
Dunbar Harbour	Nets	1	0.18
"	Pots	1	0.24

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

Table 6.10(a). Radioactivity in food and the environment near Trawsfynydd nuclear power station, 1997

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Pu	^{241}Am
Freshwater samples																			
Brown trout	Lake	6	-	37	-	<0.38	4.3	<5.4	<1.8	5.0	150	-	<2.7	<1.0	<0.96	0.000097	0.00024	-	0.00041
Rainbow trout	"	6	-	-	-	<0.10	-	<0.98	<0.24	<0.20	5.5	-	<0.52	<0.30	<0.19	-	-	-	<0.13
"	Hatchery	1	-	-	-	<0.13	-	<1.4	<0.32	<0.15	1.6	-	<0.97	<0.36	<0.37	-	-	-	<0.53
Perch	Lake	3	-	-	-	<0.16	2.5	<4.6	<1.7	7.7	250	-	<2.9	<0.70	<1.1	0.00013	0.00046	-	0.00081
Rudd	"	1	-	-	-	<0.20	-	<3.7	<1.5	6.1	210	-	<2.3	<0.62	<0.80	-	-	-	<0.43
Fontinalis	Afon Prysor	2	-	-	-	<0.25	-	<3.6	<0.83	<0.55	38	-	<2.0	<0.72	<0.73	-	-	-	<0.67
"	Gwylan Stream	2	-	-	-	6.6	-	<6.0	7.4	2.0	100	-	<2.5	<1.5	2.8	-	-	-	2.6
Mud	Pipeline (bankside)	1	-	-	-	58	-	<89	160	22	5400	-	<46	44	<20	-	-	-	330
"	Hot lagoon	2	-	-	-	81	-	<82	200	71	5700	-	<38	35	<18	30	90	2100	150
"	Barrier wall	2	-	-	-	85	-	<45	230	52	5000	-	<21	30	12	-	-	-	170
Mud, sand and stones	Gwylan Stream	2	-	-	-	6.6	-	<8.7	16	18	1200	-	<6.6	<1.5	<3.1	-	-	-	<3.8
Peat	Below Maentwrog power station	1	-	-	-	630	-	190	490	76	3100	-	53	74	72	-	-	-	200
Water	Bailey bridge	2	<3.1	-	-	-	-	-	-	0.0016	0.070	-	-	-	-	-	-	-	-
"	Cold lagoon	2	-	-	-	-	-	-	-	0.0016	0.071	-	-	-	-	-	-	-	-
"	Afon Prysor	2	-	-	-	-	-	-	-	*	0.0060	-	-	-	-	-	-	-	-
Terrestrial samples																			
Milk	Near farms	1	<3.0	15	-	<0.35	0.076	<2.9	<0.63	<0.35	<0.45	0.15	<1.9	<0.43	<0.53	-	-	-	-
"	Far farms	1	<3.0	16	-	<0.43	0.057	<3.1	<0.68	<0.35	<0.45	0.17	<2.0	<0.43	<0.58	-	-	-	-
Blackberries		1	<3.0	22	0.20	<0.30	-	<3.2	<0.90	<0.30	<0.60	-	<2.1	<0.50	<0.70	0.00010	0.00020	-	0.00030
Cabbage		1	<3.0	6.0	<0.30	<0.50	-	<3.6	<1.0	<0.20	<0.50	-	<2.2	<0.50	<0.80	<0.00010	0.00090	-	<0.00050
Chicken		1	<3.0	28	<0.50	<0.50	-	<3.1	<0.50	<0.20	<0.40	-	<0.90	<0.50	<0.60	<0.00010	<0.00020	-	0.0010
Hazelnuts		1	<4.0	61	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Onions		1	<3.0	12	<0.30	<0.50	-	<3.7	<0.70	<0.20	<0.60	-	<3.2	<0.90	<2.4	0.00010	<0.00010	-	<0.00080
Ovine muscle		2	<3.0	25	-	<0.40	<0.036	<3.8	<1.0	-	-	6.6	<3.3	<0.90	<2.2	<0.00010	0.00010	-	<0.00055
"	Max			30			0.050					12	<3.4	<1.0		0.00010			<0.00060
Ovine offal		2	<4.0	27	-	<0.40	0.32	<3.8	<1.0	-	-	1.9	<3.9	<0.90	<2.2	<0.00025	0.00025	-	<0.00075
"	Max			31				<3.9	<1.4				<4.4	<1.0	<2.3	<0.00040	0.00030		<0.0011
Potatoes		1	<3.0	18	<0.30	<0.40	-	<1.7	<0.80	<0.30	<0.40	-	<1.6	<0.50	<0.60	<0.00010	0.00040	-	0.00040
Dry cloths		129	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6.10(a). continued

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{242}Cm	$^{243+244}$Cm	Total alpha	Total beta	Total gamma
Freshwater samples							
Brown trout	Lake	6	*	0.000023	-	-	-
Rainbow trout	"	6	-	-	-	-	-
"	Hatchery	1	-	-	-	-	-
Perch	Lake	3	*	0.000027	-	-	-
Rudd	"	1	-	-	-	-	-
Fontinalis	Afon Prysor	2	-	-	-	-	-
"	Gwylan Stream	2	-	-	-	-	-
Mud	Pipeline (bankside)	1	-	-	-	-	-
"	Hot lagoon	2	0.89	4.4	-	6400	-
"	Barrier wall	2	-	-	-	-	-
Mud, sand and stones	Gwylan Stream	2	-	-	-	-	-
Peat	Below Maentwrog power station	1	-	-	-	-	-
Water	Bailey bridge	2	-	-	-	-	-
"	Cold lagoon	2	-	-	-	-	-
"	Afon Prysor	2	-	-	-	-	-
Terrestrial samples							
Milk	Near farms	1	-	-	-	-	-
"	Far farms	1	-	-	-	-	-
Blackberries		1	-	-	-	-	-
Cabbage		1	-	-	-	-	-
Chicken		1	-	-	-	-	-
Hazelnuts		1	-	-	-	-	-
Onions		1	-	-	-	-	-
Ovine muscle		2	-	-	-	-	-
"	max						
Ovine offal		2	-	-	-	-	-
"	max						
Potatoes		1	-	-	-	-	-
Dry cloths		129	-	-	0.12	0.82	0.44

- not analysed
** not detected by the method used*
[a] Except for milk and water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition

Table 6.10(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over areas near lake shoreline			
Bailey Bridge	Peat	2	0.074
South end of lake	"	2	0.062
Cae Adda boat mooring	"	2	0.073
Footbridge	Rock	2	0.082
Nant Islyn Bay	Mud and stones	2	0.082
West of footbridge	Stones	2	0.079

[a] See section 3 for definition

Table 6.11(a). Radioactivity in food and the environment near Wylfa nuclear power station, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Pu	^{241}Am	^{242}Cm	$^{243+244}$Cm	Total beta
Aquatic samples													
Plaice	Pipeline	2	39	<0.07	-	0.95	-	-	-	<0.13	-	-	-
Crabs	"	2	-	<0.12	4.8	0.51	0.0033	0.018	-	0.045	*	0.000062	-
Lobster	"	2	-	<0.06	280	0.62	-	-	-	<0.25	-	-	310
Winkles	Cemaes Bay	2	-	0.20	-	1.0	0.040	0.22	2.5	0.25	0.00088	0.00056	-
Fucus vesiculosus	"	2	-	<0.04	-	0.97	-	-	-	<0.13	-	-	950
Mud	Cemlyn Bay	2	-	<0.80	-	170	4.1	23	-	32	*	0.035	-
Seawater	Cemaes Bay	1	-	-	-	0.04	-	-	-	-	-	-	-

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples										
Milk	Near farms	5	<3.1	16	0.69	<0.41	<0.42	-	-	-
"	" max		<3.5	17	0.78	<0.45	<0.45			
Apples		1	<3.0	11	0.60	<0.50	<0.40	-	-	-
Barley		1	<4.0	110	23	<0.50	<0.40	-	-	-
Blackberries		1	<3.0	22	4.0	<0.50	<0.40	-	-	-
Broccoli		1	<3.0	8.0	0.80	<0.40	0.40	-	-	-
Cabbage		1	<3.0	5.0	0.60	<0.50	<0.50	-	-	-
Goats milk		2	<3.0	13	0.35	<0.45	<0.50	-	-	-
"	max			17	0.40	<0.50	<0.60			
Honey		1	<4.0	79	<0.60	<0.40	<0.50	-	-	-
Potatoes		1	<3.0	23	0.40	<0.50	<0.40	-	-	-
Swede		1	<3.0	8.0	0.70	<0.30	<0.40	-	-	-
Dry cloths		95	-	-	-	-	-	0.13	1.1	0.49

\- *not analysed*
* *not detected by the method used*
[a] *Except for milk and sea water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply*
[b] *See section 3 for definition*
[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3*

Table 6.11(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
Cemaes Bay	Sand	4	0.053
Cemlyn Bay	Mud	4	0.078

[a] *See section 3 for definition*

7. DEFENCE ESTABLISHMENTS

Surveillance by MAFF and SEPA is undertaken near 8 defence related establishments in the UK. As reported in Section 1, low-level discharges also occur from Burghfield in Berkshire. Environmental monitoring at this site and at nuclear submarine berths is carried out by the Ministry of Defence.

7.1 Aldermaston, Berkshire

The Atomic Weapons Establishment at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. Liquid disposals are made to the River Thames at Pangbourne and to the sewage works at Silchester. Samples of milk, other terrestrial foodstuffs, freshwater fish and indicator materials were taken together with measurements of gamma dose rates near the main outfall on the River Thames. 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 7.1(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low. The gamma dose rate on the river bank at Pangbourne was difficult to distinguish from natural background. Habits surveys have established that the most exposed group affected by disposals into the river are anglers whose occupancy of the river bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established, however the assessment has conservatively included consumption of fish at a low rate of 1 kg year^{-1}. The overall radiological significance of liquid disposals was very low: the radiation dose to anglers was much less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The concentrations of radioactivity in milk, vegetables, fruit and terrestrial indicator materials were also very low. Results for tritium, uranium and transuranic radionuclides were similar to those for 1996. The most likely source of the radionuclides detected was natural background or weapon test fallout. The maximum dose was assessed to be for adults. The dose in 1997, including contributions from the natural and fallout sources, was less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

7.2 Barrow, Cumbria

Whilst the site operated by Vickers Shipbuilding and Engineering Ltd at Barrow is not strictly a defence establishment, the small amounts of liquid radioactive wastes which are authorised for disposal to the Irish Sea are related to submarine activities and are therefore included in this section for completeness. No discharges were made in 1997 however the monitoring programme continued to provide baseline levels. Measurements of gamma dose rates and analyses of sediments collected near the outfall were made. The results, given in Tables 7.2(a) and (b), show no enhancement due to site activities above the background to be expected in the Irish Sea at this distance from Sellafield. The external dose to the most exposed group at the site was estimated to be 0.023 mSv, representing less than 3% of the dose limit of 1 mSv. Most of this exposure was due to historic disposals from Sellafield.

7.3. Devonport, Devon

Disposals of liquid radioactive waste are made by Devonport Royal Dockyard plc and the Ministry of Defence under authorisation into the Tamar Estuary. The monitoring programme in 1997 consisted of measurements of gamma dose rates, contact contamination monitoring in intertidal areas and analysis of seafood and indicator materials. The results given in Tables 7.2(a) and (b) were similar to those in 1996. No activity was detected in grass and no contaminated items were found. Trace quantities of fission and activation products and actinides were detected in the marine environment. The detection of iodine-131 is most likely to be related to its medical uses. The dose to the most exposed group taking account of consumption of marine foods and occupancy times was estimated to be less than 0.005 mSv or 0.5% of the dose limit of 1 mSv. The radiological significance of this, in common with other defence establishments, continued to be low.

7.4 Faslane, Argyll and Bute

Disposals of liquid radioactive waste into Gare Loch are made under letter of agreement by the Ministry of Defence. The monitoring programme in 1997 was undertaken primarily to investigate external radiation pathways. Levels of cobalt-60 in sediments shown in table 7.2(a) could be attributed to local disposals but the concentrations were very low. Caesium-137 concentrations were consistent with the distant effects of disposals from Sellafield and weapon test and Chernobyl fallout. Gamma dose rates were difficult to distinguish from natural background (Table 7.2(b)). The dose to the most exposed group was 0.015 mSv in 1997 or less than 2% of the dose limit of 1 mSv.

7.5 Greenwich, London

In order to monitor the potential effects of the small disposals of gaseous activity from the Royal Naval College at Greenwich, grass is sampled and analysed by gamma spectrometry. In 1997 a small amount of caesium-137 above the limit of detection (0.9 ± 0.1 Bq kg^{-1}) was detected. This activity is typical of that expected due to the residual but radiologically insignificant effects of weapon tests and Chernobyl fallout in the area. Therefore there was no detected impact in the environment due to the operation of the site in 1997.

The reactor at this site is due to be decommissioned.

7.6 Holy Loch, Argyll and Bute

A small programme of monitoring Holy Loch continued in surveillance of the effects of past disposals from the US submarine support facilities which closed in March 1992. Low levels of cobalt-60 detected in sediments from the Loch were due to these earlier operations. However, measurements of gamma dose rates in intertidal areas were difficult to distinguish from natural background (Tables 7.2(a) and (b)). The external dose to the most exposed group was 0.005 mSv in 1997 or 0.5% of the dose limit of 1 mSv.

7.7 Rosyth, Fife

Activities at the Rosyth Royal Dockyard continued to give rise to disposals of low levels of liquid radioactive waste into the Firth of Forth. An application for an increase in the annual tritium limit for the liquid discharge was submitted by the Company in anticipation of an increase in submarine refitting and decommissioning work at the dockyard in coming years. In December 1997 a variation to the liquid radioactive waste authorisation was granted by SEPA, allowing up to 40 GBq per year of tritium (10 GBq previous limit). At the same time the annual limit for cobalt-60 was halved to 5 GBq.

The monitoring programme comprised sampling and analysis of crabs and indicator materials and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 7.2(a) and 7.2(b). As was the case at other defence establishments, the radioactivity levels detected were low, and in most part due to other sources. Very low levels of manganese-54 were detected in some estuarine samples connected with Rosyth, but these are believed to be associated with discharges from Torness Power Station (see section 6.9). . Gamma dose rates were difficult to distinguish from natural background. Dose to the most exposed group in 1997 was estimated to be 0.010 mSv or 1% of the dose limit of 1 mSv.

7.8 Vulcan NRTE, Highland

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

Table 7.1(a). Radioactivity in food and the environment near Aldermaston, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{57}Co	^{60}Co	^{137}Cs	^{155}Eu	^{238}Pu	$^{239+240}$Pu	^{241}Am	Total beta
Aquatic samples										
Pike	Newbridge	1	<0.04	<0.05	<0.05	<0.14	<0.000013	0.000041	0.000053	-
"	Outfall (Pangbourne)	1	<0.05	<0.07	0.84	<0.12	0.000019	0.00011	0.00032	-
"	Staines	1	<0.03	<0.06	0.31	<0.10	-	-	<0.06	-
Nuphar lutea	Newbridge	1	<0.03	<0.06	<0.05	<0.08	-	-	<0.04	-
"	Outfall (Pangbourne)	1	<0.04	<0.06	0.30	<0.12	-	-	<0.12	-
"	Staines	1	0.12	<0.08	0.09	<0.18	-	-	<0.17	-
Clay	Outfall (Pangbourne)	1	<0.24	<0.30	0.53	1.6	-	-	<0.81	400
Mud	Foudry Brook	1	<0.18	<0.22	3.3	<0.59	-	-	<0.38	-
"	Newbridge	1	<0.39	<0.59	9.3	<1.4	-	-	<1.3	-
Mud & sand	Staines	1	<0.17	<0.24	9.2	<0.55	-	-	<0.39	140

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{137}Cs	Total U	^{238}Pu	$^{239+240}$Pu	^{241}Am	Total alpha	Total beta	Total gamma
Terrestrial samples												
Milk	Near farms	4	<3.3	<0.38	<0.40	<0.0065	<0.00013	<0.00013	<0.00032	-	-	-
"	max		<3.5	<0.40	<0.43	<0.0067	<0.00015	<0.00018	<0.00040			
Blackberries		1	<3.0	<0.30	<0.20	0.093	0.00010	<0.00010	<0.00030	-	-	-
Carrots[d]		1	<3.0	<0.50	<0.50	0.040	<0.00020	<0.00020	<0.0010	-	-	-
Honey		1	<4.0	<0.40	<0.60	0.0058	0.00010	<0.00020	<0.00070	-	-	-
Lettuce		1	<3.0	<0.50	<0.50	0.98	0.00020	0.0030	0.0070	-	-	-
Marrow		1	<3.0	<1.0	<0.70	<0.022	<0.00020	<0.00010	<0.00040	-	-	-
Potatoes		1	<3.0	<0.50	<0.40	<0.020	<0.00030	<0.00020	<0.00040	-	-	-
Runner beans		1	5.0	<0.40	<0.50	0.0079	0.00040	0.00010	<0.00040	-	-	-
Wheat[e]		1	<3.0	<0.50	<0.40	0.20	<0.00010	0.0013	0.00040			
Soil[f]		4	-	-	-	61	-	-	-	-	-	-
"	max					72						
Dry cloths		84	-	-	-	-	-	-	-	0.10	0.60	0.35

- not analysed
** not detected by the method used*
[a] Except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment and soil where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column.'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition.
[d] The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.017, <0.0011 and 0.013 Bq kg^{-1} respectively
[e] The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.041, 0.003 and 0.043 Bq kg^{-1} respectively
[f] The concentrations of ^{234}U, ^{235}U and ^{238}U were 11, 0.42 and 11 Bq kg^{-1} respectively

Table 7.1(b). Monitoring of radiation dose rates near Aldermaston, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over river bank			
Pangbourne	Grass	1	0.057
Newbridge	"	1	0.060

[a] see section 3 for definition

Table 7.2(a). Radioactivity in food and the environment near naval establishments, 1997

Material	Location[b] or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																		
			^{3}H	^{14}C	^{54}Mn	^{58}Co	^{60}Co	^{95}Nb	^{95}Zr	^{106}Ru	^{124}Sb	^{125}Sb	^{131}I	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm
Barrow																					
Mud	Walney channel (sewer outfall)	2	-	-	<0.65	<1.1	<2.6	<2.7	<2.5	<16	<2.6	<2.5	*	100	<4.8	<2.3	<2.1	-	-	140	-
Mud and sand	" (Vickerstown church)	4	-	-	<0.74	<1.4	8.7	<5.8	<3.4	38	<2.5	<3.1	<3.6	200	<6.6	4.1	<2.4	-	-	270	-
Grass		2	<3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devonport																					
Dogfish	Plymouth Sound	1	-	-	<0.10	<0.28	<0.09	<1.0	<0.50	<1.0	<0.68	<0.21	*	0.30	<0.45	<0.32	<0.17	-	-	<0.10	-
Crabs	"	1	-	30	<0.06	<0.12	<0.06	<0.35	<0.24	<0.56	<0.33	<0.13	*	<0.05	<0.27	<0.16	<0.10	-	-	<0.06	-
Fucus vesiculosus	Kinterbury	2	-	-	<0.08	<0.18	<0.08	<0.66	<0.35	<0.68	<0.33	<0.16	*	<0.10	<0.36	<0.25	<0.14	-	-	<0.09	-
Mud	"	2	-	-	<0.34	<0.46	<0.30	<1.2	<0.97	<2.9	<0.88	<0.83	<1.9	5.1	<2.4	<0.86	1.9	0.031	0.56	0.22	0.0016
"	Torpoint Ferry East	2	-	-	<0.43	<0.94	<0.77	<3.6	<1.9	<3.9	<2.1	<0.94	*	7.1	<2.4	<1.1	<1.0	-	-	<1.1	-
"	Torpoint South	2	-	-	<0.39	<0.60	<0.35	<1.4	<1.2	<3.3	<1.1	<0.88	*	2.2	<2.5	<1.0	<1.6	-	-	<1.5	-
"	Calstock	2	-	-	<0.56	<0.89	<0.52	<2.0	<1.8	<4.8	<1.9	<1.2	*	9.3	<2.5	<1.5	<1.9	-	-	<0.96	-
"	Lopwell	2	-	-	<0.58	<1.0	<0.57	<2.9	<2.1	<5.0	<2.4	<1.2	*	12	<2.7	<1.6	<2.4	-	-	<1.5	-
"	Wilcove	2	-	-	<0.34	<0.49	<0.31	<1.2	<0.98	<3.0	<0.90	<0.83	<1.6	3.9	<2.4	<0.89	<1.1	0.024	0.48	0.17	*
Grass	Devonport	3	<3.0	-	-	-	<0.47	<0.87	<1.1	<3.6	-	-	-	<0.50	<2.1	-	-	-	-	-	-
"	max						<0.50	<0.90	<1.2	<3.9				<0.60	<2.6						
Faslane																					
Mud and sand	Carnban boatyard	2	-	-	<0.17	-	<0.12	-	-	-	-	-	-	10	-	-	0.85	-	-	-	-
Sea water	"	1	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Holyloch																					
Sand	Mid-Loch	1	-	-	0.25	-	14	-	-	-	-	-	-	50	-	-	1.1	-	-	2.0	-
Rosyth																					
Crabs	East of dockyard	3	-	-	<0.09	<0.12	<0.09	<0.22	<0.20	<0.70	<0.24	<0.19	*	<0.17	<0.48	<0.20	<0.40	-	-	<0.40	-
Fucus vesiculosus	"	3	-	-	<0.09	<0.06	<0.09	<0.07	<0.11	<0.50	<0.08	<0.13	1.2	<0.30	<0.28	<0.22	<0.38	-	-	<0.41	-
Mud	East of dockyard	1	-	-	<0.30	<0.38	<0.30	<0.74	<0.79	<2.6	<0.76	<0.71	*	27	<1.7	<0.84	2.1	-	-	<1.3	-
"	Port Edgar	3	-	-	<0.31	<0.52	<0.20	<0.96	<1.0	<3.8	<0.93	<1.1	*	22	<2.9	<1.1	<1.6	-	-	<1.1	-
"	Blackness Castle	1	-	-	<0.68	<0.76	<0.66	<1.3	<1.6	<6.0	<1.5	<1.5	*	21	<3.1	<1.9	2.1	-	-	1.4	-
Mud and sand	West of dockyard	3	-	-	<0.16	<0.28	<0.15	<0.78	<0.56	<2.3	<0.54	<0.66	<6.3	5.0	<1.9	<0.66	<0.62	-	-	<0.69	-
"	Blackness Castle	1	-	-	<0.17	-	<0.10	-	-	-	-	-	-	15	-	-	0.95	-	-	<0.73	-
Sand	Burntisland Bay	1	-	-	<0.29	<0.41	<0.27	<0.71	<0.81	<2.8	<0.79	<0.65	*	1.3	<1.5	<0.80	<0.69	-	-	<0.49	-
"	East of Dockyard	1	-	-	<0.10	-	<0.10	-	-	-	-	-	-	4.8	-	-	<0.56	-	-	<0.50	-

- *not analysed*
* *not detected by the method used*
[a] *Except for sediment where dry concentrations apply, and for seawater where units are Bq l^{-1}*
[b] *Landing point or sampling area*
[c] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition*
[d] *See section 3 for definition*

Table 7.2(b). Monitoring of radiation dose rates near naval establishments, 1997

Establishment	Location		Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas					
Barrow	Walney Channel	(1 km south of outfall)	Mud and sand	4	0.084
"	"	(Vickerstown church)	"	4	0.089
"	"	(Sewer outfall)	Mussel bed	2	0.084
Devonport	Kinterbury		Mud	2	0.070
"	Brunel Bridge East		"	2	0.074
"	Torpoint Ferry East		"	2	0.068
"	Stonehouse		"	2	0.071
"	Torpoint South		"	2	0.072
"	Calstock		"	2	0.099
"	Lopwell		"	2	0.081
"	Wilcove		"	2	0.080
Faslane	Gareloch Head		Mud, sand and stones	2	0.051
"	Gulley Bridge Pier		Sand and stones	2	0.059
"	Rhu		Gravel	2	0.051
"	Rosneath		Sand and gravel	2	0.054
"	Carnban boatyard		Mud and sand	2	0.075
Holy Loch	North Sandbank		"	1	0.070
"	Kilmun Pier		Sand and stones	1	0.060
"	Mid-Loch		Sand	1	0.048
Rosyth	Blackness Castle		Mud and sand	3	0.060
"	Burntisland Bay		Sand	2	0.058
"	Pettycur		"	1	0.057
"	East of Dockyard		"	2	0.057
"	"		Sand and stones	1	0.066
"	Port Edgar		Mud	3	0.062
"	West of Dockyard		Mud and sand	3	0.067

[a] *See section 3 for definition*

8. NYCOMED AMERSHAM PLC

This company manufactures radioactive materials for use in medicine, research and industry. The company's principal establishment is located in Amersham, Buckinghamshire and it also operates from Cardiff and on the Harwell site. The Harwell facility is being shut down and any environmental effects from it are covered by surveillance of the UKAEA operations on the same site.

8.1 Amersham, Buckinghamshire

Disposals of liquid radioactive wastes are made under authorisation to the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Disposals of gaseous wastes are also authorised. The monitoring programme consists of measurements of gamma dose rates on the river bank of the Grand Union Canal and analysis of fish, milk, crops and indicator materials. Monitoring at Newbridge on the Thames acts as an indication of background levels in the catchment. Additional monitoring of non-food pathways is carried out by the Environment Agency.

The results are presented in Tables 8.1(a) and (b). The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Concentrations of a few radionuclides, e.g. cobalt isotopes, were slightly enhanced close to the outfall. However, the gamma dose rates on the river bank were indistinguishable from natural background.

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

Habits surveys have identified anglers as the most exposed group affected by disposals into the canal/river system. Their occupancy of the river bank has been assessed to estimate their external exposures. Consumption of freshwater fish was also considered but none was found. Nevertheless, it is considered prudent to include a component in the assessment of the anglers' exposure and a hypothetical consumption of fish at a rate of 1 kg year^{-1} was assumed. The anglers' dose in 1997 was much less than 0.005 mSv or 0.5% of the dose limit of 1 mSv.

The dose to the most exposed group of terrestrial food consumers was assessed as being 0.006 mSv or 0.6% of the dose limit.

8.2 Cardiff

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

Monitoring, carried out on behalf of the Welsh Office, includes consideration of consumption of food and external exposure over muddy, intertidal areas. Measurements of external exposure are supported by analyses of intertidal sediment. Indicator materials including seawater, *Fucus* seaweed, rape, silage and dry cloths provide additional information.

The results of monitoring in 1997 are presented in Tables 8.2(a) and (b). The main effect of liquid disposals is seen in increases of tritium and carbon-14 activities above those expected due to background. Concentrations of carbon-14 were slightly less than those found in 1996.

Measurements of the concentration of tritium in fish have been undertaken and reported by the operators of the site as a condition of their authorisation for some time. The results of these measurements are included in the public register held by Environment Agency Wales. These measurements have been added to the MAFF programme this year in order to ensure that all contributions to exposure due to discharges from the site are considered. Previously the programme has relied on measurements of levels of tritium in seawater. The tritium activity detected in fish, 19000 Bq kg^{-1} (wet), is high compared to other radionuclides. This activity is predominately in the form of Organically Bound Tritium. The radiotoxicity of this radionuclide is low. Further measurements of tritium in seafood at this and other sites in the UK are being undertaken in 1998.

Concentrations of other radionuclides in aquatic samples were low and can be explained by other sources such as Chernobyl and weapon test fallout and disposals from other establishments. Gamma dose rates over sediment, as measured using portable instruments, were difficult to distinguish from those expected from the natural background. The dose to the most exposed group of fish and shellfish consumers including external radiation was 0.032 mSv or 3% of the dose limit of 1 mSv. The increase over the value for 1996, 0.012 mSv (MAFF and SEPA, 1997), is largely due to the inclusion of tritium into the assessment.

The main effects of gaseous disposals were seen in results for tritium and carbon-14. Concentrations of tritium, organically bound tritium and carbon-14 were found to be higher in milk sampled from farms close to the site than from farms far from the site. When compared with data for other sites, relatively high concentrations of these nuclides were also detected in other terrestrial samples including grass (Section 9). The concentrations of other radionuclides were low and generally close to the limits of detection.

The maximum estimated dose from food consumption was to the 1-year-old age group. The most exposed group dose received 0.023 mSv or 2% of the dose limit of 1 mSv. The largest contribution was from carbon-14 in milk.

The INTAKE food dose was 0.052 mSv or 5% of the dose limit of 1 mSv.

Table 8.1(a). Radioactivity in food and the environment near Amersham, 1997

Material	Location	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{14}C	^{57}Co	^{58}Co	^{60}Co	^{65}Zn	^{75}Se	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	$^{239+240}$Pu	^{241}Am	Total beta
Aquatic samples															
Pike	Newbridge	1	-	<0.04	<0.15	<0.05	<0.16	<0.11	*	<0.05	<0.05	<0.14	0.000041	0.000053	-
"	Outfall (Grand Union Canal)	1	20	0.06	<0.06	<0.05	0.22	<0.05	<0.94	0.09	0.25	<0.09	-	<0.05	-
"	Staines	1	-	<0.03	<0.17	<0.06	<0.18	<0.10	*	<0.05	0.31	<0.10	-	<0.06	-
Nuphar lutea	Newbridge	1	-	<0.03	<0.12	<0.06	<0.15	<0.09	*	<0.06	<0.05	<0.08	-	<0.04	-
"	Outfall (Grand Union Canal)	1	-	0.85	0.27	<0.03	0.67	<0.05	*	<0.03	<0.03	<0.05	-	<0.03	-
"	Staines	1	-	0.12	<0.19	<0.08	<0.22	<0.18	*	<0.09	0.09	<0.18	-	<0.17	-
Mud	Outfall (Grand Union Canal)	1	-	2.9	<1.0	<0.38	4.9	<0.80	*	<0.57	21	2.1	-	<0.54	430
"	Newbridge	1	-	<0.39	<1.3	<0.59	<1.6	<1.1	*	<0.82	9.3	<1.4	-	<1.3	-
Mud & sand	Staines	1	-	<0.17	<0.37	<0.24	<0.53	<0.38	*	<0.25	9.2	<0.55	-	<0.39	140

Material	Location or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{35}S	^{60}Co	^{75}Se	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples													
Milk	Near farms	2	<3.4	0.54	<0.38	<0.51	<0.025	<0.036	<0.31	<0.40	-	-	-
"	" max		<3.8	0.58	<0.40	<0.53	<0.026	<0.039	<0.35	<0.43			
Apples		1	<3.0	<0.20	<0.50	<0.40	<0.10	-	<0.30	<0.40	-	-	-
Beetroot		1	5.0	<0.70	<0.40	<0.40	<0.089	-	<0.20	<0.40	-	-	-
Chicken		1	<3.0	0.40	<0.30	<0.50	<0.069	-	<0.20	<0.30	-	-	-
Leeks		1	4.0	0.70	<0.60	<0.40	<0.11	-	<0.40	<0.50	-	-	-
Rhubarb		1	<3.0	<0.40	<0.40	<0.40	<0.056	-	<0.40	<0.50	-	-	-
Runner beans		1	<3.0	1.1	<0.40	<0.40	<0.12	-	<0.30	<0.50	-	-	-
Wild berries		1	<3.0	<0.20	<0.50	<0.50	<0.11	-	<0.30	<0.40	-	-	-
Wheat		1	<4.0	0.80	<0.50	<0.50	<0.15	-	<0.40	<0.50	-	-	-
Dry cloths		69	-	-	-	-	-	-	-	-	0.16	1.0	0.37

- not analysed
** not detected by the method used*
[a] except for milk where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition

Table 8.1(b). Monitoring of radiation dose rates near Amersham, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over river bank			
Grand Union Canal	Grass and concrete	1	0.046
Newbridge	Grass	1	0.060

[a] See section 3 for definition

Table 8.2(a). Radioactivity in food and the environment near Cardiff, 1997

Material	Location[b]	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	Total beta
Aquatic samples									
Flounder	East of new pipeline	4	19000[d]	490	*	<0.08	0.40	<0.16	-
Mussels	Orchard Ledges	2	-	570	*	<0.16	0.30	<0.29	-
Fucus vesiculosus	"	2	-	37	<0.73	<0.07	0.52	<0.17	-
Fucus spiralis	East of new pipeline	2	-	18	*	<0.05	0.32	<0.14	150
Mud	"	2	-	17	*	<0.76	<14	<1.2	-
"	West of new pipeline	2	-	34	*	<0.73	25	<1.4	-
Sea water	Orchard Ledges East	2	53	-	-	-	-	-	-

Material	Location[b] or selection[c]	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}												
			^{3}H (organic)	^{3}H	^{14}C	^{32}P	^{35}S	^{45}Ca	^{57}Co	^{125}I	^{134}Cs	^{137}Cs	Total alpha	Total beta	Total gamma
Terrestrial samples															
Milk	Near farms	4	<36	<63	28	<0.39	<0.58	<0.30	<0.30	<0.027	<0.31	<0.41	-	-	-
"	" max		74	130	41	<0.43	0.93		<0.35	<0.030	<0.35	<0.43	-	-	-
"	Far farms	2	<4.3	<7.4	17	-	<0.51	<0.30	<0.30	<0.029	<0.31	<0.40	-	-	-
"	" max		<4.8	<8.4			<0.58		<0.33	<0.032	<0.33				
Barley		1	-	17	110	-	1.4	4.2	<0.30	<0.31	<0.30	<0.40	-	-	-
Blackberries		1	5.0	35	25	-	0.60	0.60	<0.10	<0.043	<0.20	<0.20	-	-	-
Cabbage		1	<3.0	<3.0	13	-	2.1	1.0	<0.30	<0.16	<0.20	<0.40	-	-	-
Honey		1	-	55	120	-	<0.60	<0.20	<0.20	<0.093	<0.40	<0.40	-	-	-
Potatoes		1	<3.0	9.0	18	-	<0.30	<0.30	<0.40	<0.14	<0.30	<0.50	-	-	-
Strawberries		1	<3.0	<3.0	8.0	-	0.80	0.30	<0.30	<0.028	<0.30	<0.40	-	-	-
Swede		1	<3.0	9.0	11	-	0.60	3.3	<0.30	<0.11	<0.20	<0.50	-	-	-
Rape		1	-	11	94	-	3.0	7.9	<0.30	<0.17	<0.30	<0.50	-	-	-
Grass		2	13	26	18	-	-	-	-	-	-	-	-	-	-
"	max			28	22										
Silage		2	68	98	58	-	-	-	-	-	-	-	-	-	-
"	max		96	140	62										
Dry cloths		95	-	-	-	-	-	-	-	-	-	-	0.12	0.65	0.30

- not analysed
** not detected by the method used*
[a] except for milk and sea water where units are Bq l^{-1}, for dry cloths where units are Bq per cloth and for sediment where dry concentrations apply
[b] landing point or sampling area.
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum. See section 3 for definition.
[d] sample collected by Nycomed Amersham and analysed by CEFAS

Table 8.2(b). Monitoring of radiation dose rates near Cardiff, 1997

Location	Ground type	No. of sampling observations[a]	µGy h^{-1}
Gamma dose rates at 1 m over intertidal areas			
East of pipeline	Mud	2	0.070
West of pipeline	"	1	0.061
"	Mud and sand	1	0.063
Beta dose rates			µSv h^{-1}
West of pipeline	Mud	1	0.28

[a] See section 3 for definition

9. MINOR SITES AND EURATOM SAMPLING

Three minor sites with very low levels of discharge are monitored using a small programme of sampling indicator materials. The results, given in the following sub-sections, show that there was no detected impact on the environment in 1997 due to operation of these sites. This section also presents the results of indicator sampling around the major nuclear sites carried out in relation to the Euratom Treaty.

9.1 Imperial College Reactor Centre, Ascot, Berkshire

Two grass samples were analysed by gamma spectrometry. All results in 1997 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 1997 were less than the limits of detection.

9.3 Rolls Royce plc, Derby, Derbyshire

Results of monitoring at Derby are presented in Table 9.1. Uranium activity detected in grass and soil samples was similar to levels in 1996. Isotopic analysis of the soil samples confirmed that the activity was not enriched in uranium-235. The activities detected are therefore due to natural sources.

9.4 Scottish Universities Research Reactor Centre, South Lanarkshire

Decommissioning has commenced on this site and although disposals of small amounts of radioactive wastes take place, the only monitoring carried out is that performed by the operator. The reactor has been defuelled and the fuel removed for storage.

9.5 Euratom sampling

In 1993, MAFF established a programme of grass and soil sampling near nuclear sites in England and Wales to fulfil requirements of Articles 35 and 36 of the Euratom Treaty (MAFF, 1995). The information from this programme has been analysed in this and previous reports but the programme in England and Wales has ceased in 1998 and the results in this report are the final ones of the series. The monitoring in Scotland forms part of SEPA's monitoring programme and this continues unchanged. Further details are given in section 11.

Supplementary information on grass and soil analyses is provided for some sites in the foregoing site-specific sub-sections.

The programme in England and Wales undertakes sampling of paired grass and soil samples from three permanent plots at each site, generally situated 500 m from the site perimeter along the three dominant landward wind directions. The soil samples include the root mat and are taken to a depth of 7 cm. In 1997 samples continued to be analysed for tritium, carbon-14, sulphur-35, strontium-90, caesium-137, plutonium-238 and plutonium-239 and 240. Occasional analyses for americium-241 were also performed. The results are given in Table 9.2.

The mean concentrations of tritium were variable and ranged from <24 to 570 Bq kg^{-1} in grass. The highest concentration observed was at the Nycomed Amersham site at Amersham and is unexpected in view of the low level of reported discharges from this site. In contrast the levels in grass at Sellafield were low in relation to the larger discharges from this site. It appears that such measurements are not a good indicator of relative disposals from each site, as tritium levels in vegetation are dependant on the atmospheric concentrations at the time of sampling.

Carbon-14 activity concentrations depend on the carbon content of the samples and are also highly variable. Interpretation of the data without a knowledge of the carbon content is therefore difficult. Nevertheless, taken with other site-specific data some general conclusions may be drawn. Typical ranges of mean concentrations in grass and soil were approximately 100-300 and 10-30 Bq kg^{-1} respectively. Sites where concentrations were found outside these ranges were:

- Cardiff — 370 Bq kg^{-1} in grass; 65 Bq kg^{-1} in soil
- Hartlepool — 64 Bq kg^{-1} in soil
- Hinkley Point — 37 Bq kg^{-1} in soil
- Trawsfynydd — 40 Bq kg^{-1} in soil

Of these sites, the carbon-14 signal is clearest at Cardiff and is supported by data on other materials (see Section 8.2). The observation of a significant enhancement of carbon-14 levels near Sellafield in 1994 (MAFF, 1995) was not repeated in 1997. This is probably due to the large reduction in disposals of this nuclide in gaseous wastes from this site (1993: 7.4 TBq; 1994: 1.0 TBq; 1995: 0.71 TBq; 1996: 0.63 TBq; 1997: 0.53 TBq). Gaseous wastes have been diverted to liquid disposals.

Mean concentrations of sulphur-35 in grass and soil were typically in the ranges 5-30 and 1-5 Bq kg^{-1} respectively. Significant variations outside these ranges were found at:

- Hinkley Point — 73 Bq kg^{-1} in grass
- Oldbury — 70 Bq kg^{-1} in grass
- Sellafield — 81 Bq kg^{-1} in grass

The relatively high levels detected in grass at these sites were not reflected in the results of other monitoring carried out in their vicinity.

Mean concentrations of strontium-90 were less than 10 Bq kg^{-1} in grass and soil and similar to values for 1996 (MAFF and SEPA, 1997). Concentrates at Sellafield were at the higher end of this range and support the evidence for enhancement found in other samples from the site (Section 4.1.2).

Mean caesium-137 concentrations in grass and soil were generally similar to those in 1996, with levels in grass being less than 10 Bq kg^{-1} and in soil being less than 100 Bq kg^{-1}. As previously found, higher levels were observed at Sellafield and Trawsfynydd. The long term effects of fallout from weapon tests and Chernobyl would have played a significant part in determining these differences.

As was found in 1996, mean plutonium-239 and 240 concentrations detected in grass from Sellafield, approximately 1 Bq kg^{-1}, were significantly higher than those at other sites which were generally in the range less than 0.1 Bq kg^{-1}. In soil, higher concentrations than the norm were found at Sellafield (15 Bq kg^{-1}) and Trawsfynydd (3.1 Bq kg^{-1}). A typical level at other sites was less than 1 Bq kg^{-1}. Fallout from weapon testing will have had a major influence on these levels. However, taken with the observations for plutonium-238, there is evidence for a site-related effect at Sellafield. The expected ratio of plutonium-239 and 240/plutonium-238 in fallout is about 40. That in recent disposals from Sellafield is less than 10. The observed ratios in grass and soil near Sellafield in 1997 were 11 and 20 respectively.

An indication of the potential radiological significance of these measurements can be given by comparing the levels with the appropriate Generalised Derived Limits (GDLs) for these radionuclides. GDLs for grass and soil are activity concentrations which correspond to a dose of 1 mSv. They are based on simple, conservative models and as such do not provide a realistic assessment of exposures (Attwood *et al*., 1996). Their main use is in screening monitoring results to establish whether specific studies should be undertaken. Table 9.3 compares the highest observed concentrations in grass and soil with the relevant GDLs. This comparison is not strictly valid as GDLs are derived for well mixed soil to a depth of 300 mm whereas the soil samples taken as part of this programme are to a depth of 70 mm. Generally, the highest mean concentrations observed were lower than, often very much lower than, the 10% trigger level for site-specific investigations. However, at Trawsfynydd a value for soil in excess of the 10% trigger level was observed. The site-specific assessments for this site were considered in earlier sub-sections of this report. These assessments evaluate the dose received using the activities found in locally produced foods and show that the doses were significantly less than 0.1 mSv.

Table 9.1. Radioactivity in the environment near Derby, 1997

Material	No. of samples	Mean radioactivity concentration, Bq kg^{-1}			
		Total U	^{234}U	^{235}U	^{238}U
Grass[a]	4	0.13	0.048	0.0020	0.045
" max		0.15			
Soil[b]	4	87	27	0.97	24
" max		110			

[a] *fresh weight*
[b] *dry weight*
\- *not analysed*

Table 9.2. Radioactivity in grass and soil near nuclear sites - EURATOM[c] sampling, 1997

Site/material	No. of samples	Selection[b]	Mean radioactivity concentration (dry)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am
Grass										
Aldermaston	3		<27	140	30	1.7	<3.0	<0.0010	<0.0033	-
		max	<34	235	46	4.0			0.0060	
Amersham	3		570	190	<11	1.1	<3.0	0.0033	0.0057	-
		max	600	260	21	1.8		0.0040	0.0080	
Cardiff	3		150	370	<0.90	<1.1	<5.4	<0.076	0.060	-
		max	200	460		1.6	9.4	0.22	0.14	
Berkeley	3		<24	220	29	0.78	<3.0	<0.0030	0.0087	-
		max	<27	250	35	0.97		0.0060	0.015	
Bradwell	3		<30	82	<8.4	0.70	<3.9	<0.0027	0.0090	-
		max	<32	94	23	1.4	5.8	0.0060	0.016	
Capenhurst	3		<31	230	<1.4	<0.79	<2.7	0.0037	0.0093	-
		max	<32	330	2.2	1.5	<3.0	0.0070	0.012	
Dungeness	2		<28	140	19	<1.0	<3.2	0.019	0.070	-
		max		160	34	1.1	3.3	0.036	0.13	
Hartlepool	3		<40	160	10	<0.40	<3.0	<0.0033	0.011	-
		max	<45	230	21	0.45		0.0060	0.012	
Harwell	3		54	99	<0.90	<0.50	<3.0	0.0090	0.013	0.050
		max	57	120				0.011	0.017	0.075
Heysham	3		<35	100	<11	0.96	<3.0	<0.0023	0.0067	-
		max	49	120	23	1.6		0.0050	0.0080	
Hinkley Point	3		<26	140	72	<0.75	<2.9	<0.0040	0.032	-
		max			170	1.4	<3.0	0.0070	0.049	
Oldbury	3		120	260	70	<0.67	<2.6	<0.0013	0.012	-
		max		290	90	1.3	<3.0	0.0020	0.015	
Sellafield	3		72	150	81	7.7	38	0.14	1.5	0.69
		max	95	200	90	13	77	0.23	1.9	0.91
Sizewell	3		<25	99	<0.90	1.7	<3.0	<0.0017	0.0053	0.040
		max	<26	150		2.4		0.0030	0.0060	0.059
Springfields	3		<28	150	<7.8	1.0	<3.0	<0.0020	0.0057	-
		max		180	22	1.9		0.0030	0.0060	
Trawsfynydd	3		<39	130	<0.90	4.4	43	<0.0083	0.0073	-
		max	52	240		7.0	56	0.022	0.010	
Winfrith	3		<38	89	<4.5	2.3	<5.3	<0.0050	0.089	-
		max		110	12	3.5	7.0	0.012	0.25	
Wylfa	3		120	280	42	<3.0	5.6	<0.0037	0.014	-
		max	190	540	59	8.2	8.0	0.0070	0.023	

Table 9.2. continued

Site/material	No. of samples	Selection[b]	Mean radioactivity concentration (dry)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	^{238}Pu	$^{239+240}$Pu	^{241}Am
Soil										
Aldermaston	3		-	<15	<1.0	1.1	7.6	0.014	0.16	-
		max				1.8	12	0.022	0.24	
Amersham	3		-	24	<0.9	0.71	8.7	0.0087	0.15	-
		max		26		0.84	11	0.012	0.19	
Cardiff	3		-	65	<1.0	1.0	15	0.045	0.34	-
		max		78		1.9	18	0.12	0.37	
Berkeley	3		-	<23	<2.4	1.5	10	0.013	0.31	-
		max		38	4.2	1.8	12	0.020	0.35	
Bradwell	3		-	<15	<1.0	<0.82	15	0.029	0.15	-
		max				1.5	23	0.050	0.21	
Capenhurst	3		-	<19	<1.6	1.3	11	<0.0077	0.28	-
		max		28	2.9	1.6	20	0.013	0.51	
Dungeness	2		-	<22	<1.0	<1.8	37	0.029	0.47	-
		max		28		3.1	48	0.034	0.67	
Hartlepool	3		-	64	<1.0	<0.99	10	<0.0077	0.30	-
		max		130		2.6	18	0.021	0.49	
Harwell	3		-	<24	<0.90	<0.80	27	0.077	0.82	0.87
		max		42			30	0.13	1.3	1.1
Heysham	3		-	<16	<1.7	<1.8	42	0.041	0.54	-
		max		17	3.0	<2.0	61	0.054	0.91	
Hinkley Point	3		-	37	<1.0	5.3	15	<0.024	0.52	-
		max		47		12	20	0.054	0.62	
Oldbury	3		-	<26	<9.9	1.8	14	0.098	0.33	-
		max		44	22	1.9	15	0.12	0.44	
Sellafield	3		-	<16	<1.0	5.1	78	0.75	15	2.1
		max		18		5.9	100	0.98	16	2.8
Sizewell	3		-	<15	<0.93	<0.62	5.4	<0.015	0.40	0.043
		max			<1.0	1.2	7.2	0.024	1.0	0.050
Springfields	3		-	<19	<1.0	2.0	19	0.028	0.39	-
		max		25		2.5	22	0.039	0.46	
Trawsfynydd	3		-	<40	<2.6	4.2	180	0.10	3.1	-
		max		76	6.1	8.3	300	0.21	6.4	
Winfrith	3		-	23	<1.7	2.1	34	0.052	0.69	-
		max		29	3.1	4.6	61	0.090	1.2	
Wylfa	3		-	<15	<1.0	1.5	19	<0.0097	0.22	-
		max				2.0	21	0.017	0.24	

- not analysed
[a] Except for ^{3}H where wet 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. See section 3
[c] Other data for grass and soil samples near nuclear sites can be found in the site-specific tables

Table 9.3. Comparison of highest observed grass and soil concentrations with Generalised Derived Limits[b], 1997

	Mean activity concentration Bq kg^{-1} (dry)[c]							
	Grass				Soil			
	Observed	GDL	%	Site	Observed	GDL[a]	%	Site
^{3}H	570	30000	2	Amersham	-			
^{14}C	370	4000	9	Cardiff	-			
^{35}S	81	20000	<1	Sellafield	9.9	30000	<1	Oldbury
^{90}Sr	7.7	2000	<1	Sellafield	5.3	400	1	Hinkley Point
^{137}Cs	43	3000	1	Trawsfynydd	180	1000	18	Trawsfynydd
^{238}Pu		-			0.75	5000	<1	Sellafield
$^{239+240}$Pu		-			15	5000	<1	Sellafield
^{241}Am		-			2.1	5000	<1	Sellafield

- not available
[a] Assumed to be well mixed soil, 0-30 cm
[b] Based on Attwood et al, 1996 and MAFF assessments
[c] except for ^{3}H where wet concentrations apply

10. INDUSTRIAL AND LANDFILL SITES

10.1 Albright and Wilson Ltd, Whitehaven, Cumbria

In view of the radiological importance of natural radionuclides to fish and shellfish consumers (Pentreath *et al.,* 1989; Rollo *et al*., 1992; Camplin *et al*., 1996), a small programme of monitoring for these radionuclides in the UK marine environment has continued. Previous surveys (Rollo *et al.,* 1992) have established that an important man-made source was the Albright and Wilson chemical plant at Whitehaven in Cumbria which has manufactured phosphoric acid from imported phosphate ore. Phosphogypsum, a waste product of this process, has been discharged as a liquid slurry by pipeline to Saltom Bay. The radioactive waste disposals are authorised by the Environment Agency and contain low levels of natural radioactivity consisting mainly of thorium, uranium and their daughter products. Discharge rates during 1997 continued at the low rates attained since the introduction of changes in waste treatment techniques and the cessation of use of phosphate ore in 1992.

The results of monitoring for natural radioactivity near the site in 1997 are shown in Table 10.1.

Analytical effort has focused on lead-210 and polonium-210 which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other natural radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figure 10.1 shows how concentrations of polonium-210 in winkles have decreased substantially since 1989. It also demonstrates the seasonal variations in concentrations which have been previously observed (Rollo *et al*., 1992). Concentrations of polonium-210 slightly increased in 1997. This increase may be due to the dredging operations in Whitehaven harbour causing the remobilisation of activity. However the level of enhancement of polonium-210 concentrations in winkles is now less than 20 Bq kg^{-1} compared with more than 100 Bq kg^{-1} in the early 1990s. Concentrations of other natural radionuclides are difficult to distinguish from natural levels.

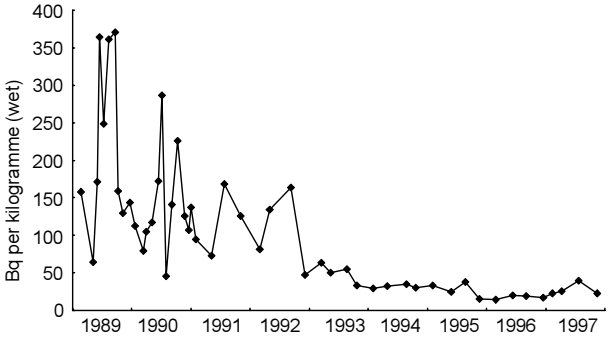

Figure 10.1. Polonium-210 in Parton winkles

The critical radiation exposure pathway is internal irradiation, due to the ingestion of natural radioactivity in local fish and shellfish. In this assessment, the contribution due to background levels of natural radionuclides has been subtracted. The most exposed group consists of people who consume seafood collected from Saltom Bay and Parton. This group is distinct from the group associated with commercial fisheries at Whitehaven discussed in section 4. 1.1.1.2. Consumption rates were reviewed in 1997 and slight increases to fish and shellfish data were made. The dose to the most exposed group in 1997 was 0.25 mSv on the basis of the current generic ICRP advice for a gut transfer factor of 0.5 for polonium. This value is to be applied in the absence of specific information.

As discussed in Section 3.6.4, a specific research study involving the consumption of crab meat containing natural levels of polonium-210 provides evidence for a gut transfer factor of 0.8 for polonium. Estimates of exposures due to polonium intakes due to consumption of seafood have therefore also been calculated using the conservative assumption that the value of 0.8 applies to the total intake of polonium. These data indicate that the most exposed group dose has increased from 0.17 mSv in 1996 (MAFF and SEPA, 1997) to 0.40 mSv in 1997, the increase being due to a combination of increased concentrations and consumption rates. It is worth noting that this level is an upper estimate for two reasons. Firstly it is based on the application of a relatively high gut transfer factor of 0.8 to all species, whereas the experimental evidence is limited to crabs. Secondly, there is limited information on the normal background levels of polonium-210 in seafood. In view of the uncertainty we have chosen low values in order to ensure that the assessment of local enhancements of these nuclides is not underestimated.

The fish and shellfish consumed by the most exposed group also contains artificial radionuclides due to Sellafield disposals. The additional exposure due to artificial radionuclides has been calculated using data from Section 4. In 1997 these exposures added a further 0.091 mSv to the doses above resulting in a total dose to this group of up to 0.49 mSv. The estimated doses in 1997 are therefore well within the dose limit for members of the public of 1 mSv.

Use of the INTAKE methodology gives a dose to adults of 0.014 mSv.

10.2 Other industrial sites

Levels of natural radionuclides in gaseous wastes from some large-scale industrial activities also have the potential to raise the radionuclide concentrations in foodstuffs. Examples of such activities are combustion of fossil fuels and metal or phosphate ore processing. Since 1991, a small rolling programme to examine the effects of these activities has been carried out. In 1997 four sites were chosen for study:

- Buxton, Derbyshire (lime kiln)
- Llanwern, Newport (steel works)
- Southampton, Hampshire (industrial waste incinerator)
- Redditch, Hereford and Worcester (hospital waste incinerator)

The results of the sampling of grass, soil and animals in 1997 is given in Table 10.2. The analyses performed included ones for man-made radionuclides to rule out the possibility that these nuclides were enhanced by some mechanism.

There is considerable variability in the concentrations of natural radionuclides in the terrestrial environment. It is therefore difficult to draw firm conclusions about the effects of man-made sources of natural radionuclides. With this proviso, we conclude that in 1997 the concentrations of natural radionuclides in grass and soil were within the ranges expected for natural sources. However, the existence of unsupported polonium-210 has been observed before when monitoring industrial sites (MAFF, 1995) and has been attributed to gaseous disposals of this radionuclide. Monitoring of such sites will therefore continue in 1998.

The concentrations of man-made radionuclides in all samples were all low and of negligible radiological significance.

10.3 Landfill sites

Some organisations are authorised by the Environment Agency or SEPA to dispose solid wastes containing very low levels of radioactivity to landfill waste disposal sites. In addition items with a small radioactive content can be disposed of in general refuse in accordance with RSA 93. Specific exemption orders apply in certain cases. There is potential for the radioactivity in wastes disposed of in this way to migrate in groundwater and in leachates to surrounding farmland. Monitoring of leachates in England and Wales is carried out by the Environment Agency (Environment Agency, 1998). In Scotland, this function is undertaken by SEPA whose results are presented in Table 10.3. These show very low levels of carbon-14 and caesium-137 but, in common with data for sites in England and Wales, there is evidence for migration of tritium from the disposal sites. Inadvertent ingestion of such leachate (2.5 l y^{-1}), even at the highest concentration of tritium observed, would only result in a dose of 0.0001 mSv.

Once covered over, landfill sites may also be converted back to agricultural use. In recognition of this, the programme in England and Wales includes monitoring of indicator materials (grass) collected near such sites. In 1997 the sites chosen were:

- Avonmouth, Bristol
- Beddingham, East Sussex
- Kibblesworth, Tyne and Wear
- Lamby Way, Cardiff

Grass samples were collected at each site. Mean concentrations of tritium were less than the values detected in 1996 (up to 100 Bq kg^{-1}) at other sites, being an order of magnitude lower than those which can be detected in grass in the vicinity of some nuclear sites. They are of negligible radiological significance. The evidence for migration of tritium at these landfill sites was therefore limited. The results for other nuclides were typical of those expected due to natural background, weapon tests or Chernobyl fallout. These results are summarised in Table 10.4.

Table 10.1. Natural radioactivity in fish and shellfish, 1997

Material	Location[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{210}Po	^{210}Pb	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Winkles	Saltom Bay	3	19	1.9	-	-	-	-	-	-	-
"	Parton	4	28	3.8	9.6	0.99	2.9	0.70	2.0	0.070	1.8
"	North Harrington	1	25	-	-	-	-	-	-	-	-
"	Fleswick Bay	4	17	-	-	-	-	-	-	-	-
"	Nethertown	4	16	3.0	-	-	-	-	-	-	-
"	Drigg	4	-	-	-	0.36	0.67	0.27	-	-	-
"	Tarn Bay	1	18	-	-	-	-	-	-	-	-
Mussels	Parton	2	51	3.1	-	-	-	-	-	-	-
"	Nethertown	4	47	2.3	-	-	-	-	-	-	-
Cockles	Southern North Sea	2	-	-	-	0.40	0.26	0.34	-	-	-
Limpets	Sellafield coastal area	1	-	-	0.48	-	-	-	-	-	-
Crabs	Parton	4	23	<0.06	-	0.078	0.027	0.012	0.079	0.0028	0.068
"	St Bees	4	18	0.16	-	-	-	-	-	-	-
"	Sellafield coastal area	4	10	0.099	-	-	-	-	-	-	-
Lobsters	Parton	4	13	<0.060	-	0.029	0.019	0.0076	0.029	0.00090	0.027
"	St Bees	4	15	0.12	-	-	-	-	-	-	-
Shrimps	Ribble Estuary	2	-	-	<0.53	0.011	0.013	0.0047	-	-	-
Cod	Parton	2	0.91	0.017	-	0.014	0.0076	0.0017	0.0052	0.00030	0.0046
Flounder	Whitehaven	1	1.1	-	-	-	-	-	-	-	-

- not analysed
[a] landing point or sampling area

Table 10.2 Radioactivity in food and the environment near industrial sites, 1997

Site	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	^{238}Pu	$^{239+240}$Pu
Buxton, Derbyshire	Grass	2	<0.07	0.10	3.2	1.6	0.59	0.031	<0.000074	0.00044
	Soil	2	<1.0	21	91	75	110	19	0.014	0.15
	Rabbit	1	<0.15	<0.16	-	0.051	0.020	<0.0040	<0.00019	<0.00025
Llanwern, Newport	Grass	4	<0.15	<0.20	5.3	2.5	0.19	0.21	<0.000085	<0.00063
	Soil	4	<0.69	14	32	29	26	20	0.024	0.13
	Rabbit	1	<0.20	<0.18	0.021	0.073	0.019	0.0036	<0.00039	<0.00032
Southampton, Hampshire	Grass	4	0.13	0.13	6.8	2.4	0.33	0.078	0.00013	0.0011
	Soil	4	0.30	11	22	21	14	12	0.029	0.12
	Rabbit	2	<0.20	<2.0	0.045	0.046	0.026	<0.0035	<0.00022	<0.00019
Redditch, Hereford & Worcester	Grass[b]	4	<0.10	<0.18	4.3	1.9	0.23	0.16	<0.000056	<0.00049
	Soil	4	<0.68	9.1	23	20	16	16	<0.0098	0.070

- not analysed
[a] except for soil samples where dry concentrations apply
[b] concentrations of 5.2, 22, <1.6, <0.068 and <0.46 Bq kg^{-1} (wet) of tritium, carbon-14, iodine-123, iodine-125 and iodine-131 were also detected in this sample

Table 10.3. Radioactivity in surface water leachate from landfill sites in Scotland, 1997

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{40}K	^{137}Cs
Aberdeen City	Ness Tip	1	<25	<15	3.5	<0.050
City of Edinburgh	Braehead	1	<25	<15	0.68	<0.050
City of Glasgow	Summerston Tip	1	640	<15	9.4	0.051
Clackmannanshire	Black Devon	1	<25	<15	2.1	0.10
Dundee City	Riverside	1	58	<15	0.89	<0.050
East Dunbartonshire	Birdston Tip	1	<25	<15	<0.050	<0.050
Fife	Balbarton	1	36	<15	1.7	<0.050
"	Melville Wood	1	55	<15	5.9	<0.050
Highland	Longman Tip	1	<25	<15	0.41	<0.050
North Lanarkshire	Dalmacoulter	1	170	<15	5.9	<0.050
"	Kilgarth	1	<25	<15	0.23	<0.050
Stirling	Lower Polmaise	1	200	<15	8.1	0.053

Table 10.4. Radioactivity in plants near landfill sites, 1997

Sampling location	Material	No. of samples	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{90}Sr	^{125}I	^{134}Cs	^{137}Cs	^{238}Pu	$^{239+240}Pu$
Avonmouth, Avon	Grass	4	10	40	0.44	<0.063	<0.21	<0.22	<0.00010	0.00016
Beddingham Lewes, East Sussex	"	4	<9.3	56	0.33	<0.075	<0.28	<0.29	<0.00013	<0.00028
Kibblesworth, Tyne and Wear	"	4	<5.5	39	0.27	<0.15	<0.18	<0.18	<0.000065	0.00028
Lamby Way, Cardiff	"	4	16	37	0.16	<0.14	<0.13	<0.13	<0.00014	0.00081

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

11. CHERNOBYL AND REGIONAL MONITORING

11.1 Chernobyl

The programme of monitoring in relation to the effects of fallout from this accident has continued in 1997 with surveillance of sheep and indigenous freshwater fish. Caesium is detected in sheep grazing certain upland areas in the UK which were subjected to heavy rainfall after the Chernobyl accident in 1986. Restrictions are in place on the movement and slaughter of sheep from these areas in order to prevent animals from entering the foodchain above the action level of 1000 Bq kg^{-1} of caesium; a level which was recommended by an EC expert committee in 1986.

In the summer of 1997 intensive monitoring surveys of 55,000 sheep in parts of the post-Chernobyl restricted areas of Cumbria, north Wales and Scotland were carried out. The results of the surveys enabled restrictions to be lifted on 18 holdings and parts of 5 others. In addition 2 holdings were issued with consents exempting them from restrictions. This leaves 392 holdings or parts of holdings within the restricted areas of England, Scotland and Wales. These areas are identified in Figures 11.1 to 11.3. This represents a reduction of 96% since 1986 when approximately 8900 holdings were under restriction.

In addition, the radiocaesium monitoring of sheep carcasses at slaughter-houses has continued in England and north Wales to ensure that continuing restrictions are adequate. The mean result of samples analysed in 1997 was 49 Bq kg^{-1} and the highest result was 479 Bq kg^{-1}. Further information and results have been published by MAFF (MAFF, 1998b) and the Scottish and Welsh Offices (Scottish Office, 1998; Welsh Office, 1998).

Sampling locations for freshwater fish were mostly in areas of relatively high deposition of fallout from Chernobyl, namely Cumbria, north Wales and parts of Scotland. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 11.1 presents concentrations of caesium-134 and -137 in fish and water. Artificial radionuclides, other than those of radiocaesium were, in 1997, no longer detectable from the Chernobyl accident. Concentrations of radiocaesium in freshwater fish varied between locations, reflecting the areas of deposition of radioactivity from Chernobyl and the small sampling programme. Perch had the highest concentrations of any of the freshwater species but, as they are not eaten in large quantities, the radiological significance or these concentrations is low. Concentrations in all species were less than 1000 Bq kg^{-1}. Where there are data for the same species and locations to compare with results for 1996 there are likely to be large statistical fluctuations because of the small sampling programme, but concentrations of radiocaesium were generally similar in

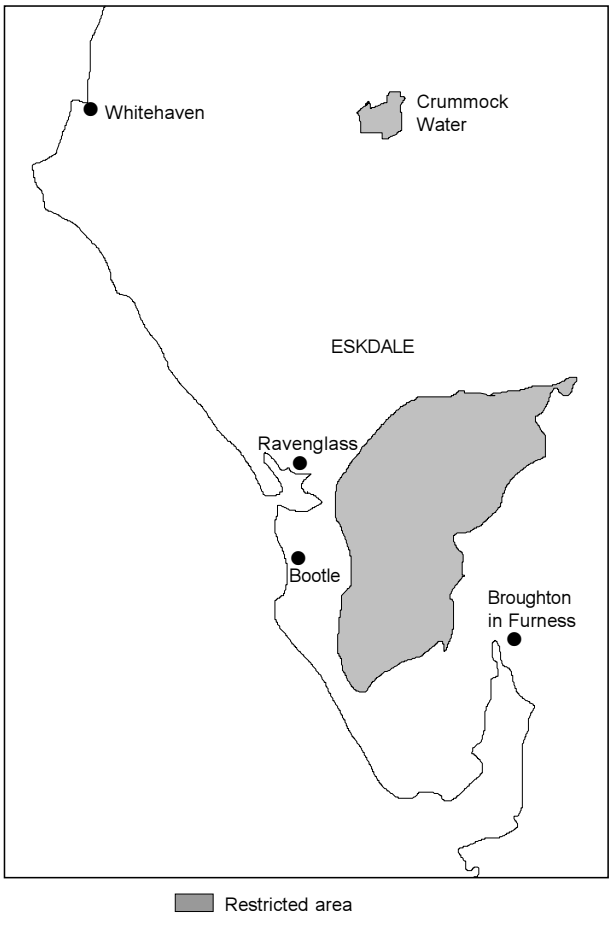

Figure 11.1. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - England

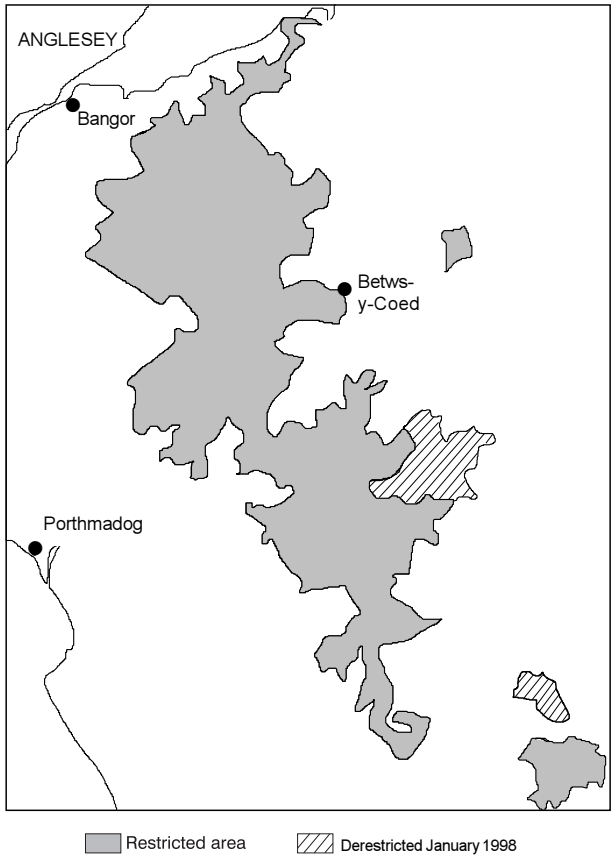

Figure 11.2. Areas of sheep restrictions related to radioactivity from the Chernobyl accident - Wales

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

1997 to those in 1996. Figure 11.4 shows a plot of mean total radiocaesium concentrations in brown trout from Ennerdale Water against time. Whilst it has not been possible to obtain samples of brown trout from this lake in recent years, the earlier data presented show how concentrations reduced in the immediate period after the initial deposition.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously (MAFF and SEPA, 1997). A consumption rate of brown trout of 37 kg year^{-1}, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is cautious (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish of much lower radiocaesium concentrations may contribute to the diet. In 1997, estimated doses were less than 0.15 mSv.

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

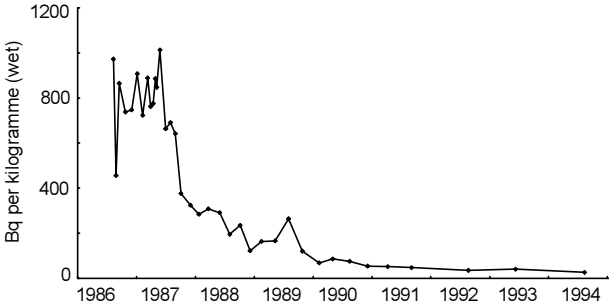

Figure 11.4. Radiocaesium in Brown Trout - Ennerdale water

11.2 Isle of Man

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

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

The results of monitoring for 1997 are presented in Table 11.2. Most radionuclides were present below the limits of detection of the methods used. Carbon-14 was detected in local milk and crops at activity concentrations similar to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Levels of strontium-90, caesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. These results demonstrate that there was no significant impact on Manx agriculture from operation of mainland nuclear installations in 1997.

These data are similar to results obtained in previous years. The dose to the most exposed group from consumption of Manx foodstuffs monitored in 1997 was 0.021 mSv or 2% of the dose limit of 1 mSv.

11.3 Channel Islands

Marine environmental samples provided by the Channel Island States have continued to be analysed, mainly in surveillance of the effects of radioactive liquid disposals from the French reprocessing plant at Cap de la Hague. The programme also serves to monitor the potential effects of historic disposals of solid waste in the Hurd Deep. Fish and shellfish are monitored in

relation to the internal irradiation pathway; sediment is analysed with relevance to external exposures. Sea water and seaweeds are sampled as indicator materials and, in the latter case, because of their use as fertilisers. A habits survey was undertaken in 1997 to establish local consumption rates of seafood and occupancies over intertidal areas. During the field work gamma and beta dose rates were measured on beaches and in harbours.

The results for 1997 are given in Tables 11.3 (a) and (b). Concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. However, no evidence for release of activity from the Hurd Deep site was found. Gamma dose rates were generally difficult to distinguish from natural background though there was evidence for a small enhancement in a few locations. Beta dose rates on fishermen's nets and pots were generally below the limit of detection of the method used.

An assessment based on the results of the habits survey gives a dose of less than 0.005 mSv in 1997 or 0.5% of the dose limit to the most exposed group of high-rate fish and shellfish consumers including a contribution from external exposure. Dose due to handling of fishermen's nets and pots based on the highest dose rate observed was 0.77 mSv in 1997 or 2% of the skin dose limit. The dose to construction workers in St Helier harbour was estimated to be 0.013 mSv in 1997 or 1% of the dose limit. Construction work in this harbour has now completed. This value has been calculated from the levels of artificial nuclides in the harbour sediment and an occupancy rate of 2300 hours per year.. The concentrations of artificial radionuclides in the marine environment of the Channel Islands therefore continued to be of negligible radiological significance.

11.4 General diet

As part of the Government's general responsibility for food safety, radioactivity in whole diet is determined on a regional basis. Measurements are made on samples of mixed diet from regions throughout the United Kingdom. These samples are analysed for a range of food components including radioactivity. The results for the measurements of radioactivity are presented here. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both natural and man-made origins were measured in samples in 1997. The results are provided in Tables 11.4 and 11.5.

All of the results for man-made radionuclides were low and of little radiological significance. Concentrations of tritium and sulphur-35 were less than the limits of detection. Strontium-90, caesium-137 and actinide concentrations were below or close to the limit of detection and were similar to levels in previous years.

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 weapon test fallout, and sulphur-35. The nationwide mean dose for all man-made radionuclides was low at 0.004 mSv. Similar doses were estimated for 1996 (MAFF and SEPA, 1997).

The mean concentration of carbon-14 in diet in 1997 was 39 Bq kg^{-1} with a range from 28 to 48 Bq kg^{-1}. In previous years, the mean values have been 33, 38, 43 and 54 Bq kg^{-1} for 1993, 1994, 1995 and 1996 respectively. The general expectation is for a small reduction from year to year due to the Suess effect (the diluting of carbon-14 by carbon-12 released by the burning of fossil fuels) and dispersion of weapon test fallout (Collins and Otlet., 1995). However, given the variability of results from region to region, it is not surprising that this trend is not evident.

The mean concentration of lead-210 increased from 0.018 Bq kg^{-1} in 1996 to 0.047 Bq kg^{-1} in 1997. This is due to a single unusually high result in 1997. Such results have been observed previously (MAFF, 1996). Concentrations of polonium-210 and uranium were similar to those in 1996. There was a single high result for radium-226 in 1996 which lowered the mean concentration from 0.067 Bq kg^{-1} in 1996 to 0.036 Bq kg^{-1} in 1997.

The mean dose due to consumption of natural radionuclides was 0.11 mSv. The most important radionuclide was polonium-210. Significant contributions would also have been made by other members of the uranium-238 and thorium-232 decay series which were not determined in this year's analytical schedule. Further data for these nuclides is provided by MAFF (1995). Nevertheless it remains true that the results demonstrate that natural radionuclides are by far the most important source of exposure in the average diet of consumers.

11.5 Milk

The programme of milk sampling in the United Kingdom continued in 1997. Samples were collected monthly and analysed for natural and man-made radionuclides. The programme, together with that for crops presented in the following sub-section, provides useful information with which to compare data from farms close to nuclear sites and other establishments which may enhance concentrations above background levels. The data from this programme is supplied to the European Commission as part of the requirements under the EURATOM treaty.

Where measurements are comparable, detected activity concentrations of all radionuclides in 1997 were similar to those for previous years. These results are summarised in Table 11.7. Sulphur-35, iodine-129, uranium and plutonium results were either very close to or below their respective limits of detection. Results for tritium were generally close to or below the limit of detection and similar to the value detected in rain of 4.8 Bq l^{-1} (Playford *et al*., 1995). Raised values of 12 and 10 Bq l^{-1} were found at Clwyd and Tyneside respectively. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels.

The concentration of strontium-90 was approximately 0.04 Bq l^{-1}, which is in good agreement with results from other surveillance studies (Smith *et al.*, 1994.).

The levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. The results were in good agreement with those from the NRPB surveillance programme which showed mean levels in England and Wales of 0.04 and 0.05 Bq l^{-1} respectively, Scotland 0.16 Bq l^{-1} and those in Northern Ireland to be 0.22 Bq l^{-1} (Smith *et al.,* 1994).

The assessed doses from consumption of dairy milk at average rates were highest to the one-year-old infant age group. For the full range of radionuclides analysed, the doses ranged from 0.023 to 0.046 mSv and were dominated by the presence of the natural radionuclides lead-210 and polonium-210. Man-made radionuclides contributed less than 5% to these exposures.

11.6 Crops, bread and meat

The programme of monitoring natural and man-made radionuclides in crops continued in 1997 (Table 11.8). Tritium activity was close to or below the limit of detection in all samples. The activities of carbon-14 detected in crop samples were those expected from consideration of background sources. The concentrations of other radionuclides in crops were similar to those observed in 1996.

Sampling of bread and meat continued in Scotland in 1997. The results, presented in Tables 11.9 and 11.10, show the presence of low-levels of man-made and natural radionuclides consistent with natural and weapon test and Chernobyl fallout sources. Similar levels to those in 1996 were observed (MAFF and SEPA, 1997).

11.7 Fresh water and air particulates

Sampling and analysis of fresh water throughout Scotland continued in 1997. Analyses were made for tritium, strontium-90, caesium-137 and total alpha and beta activity. The results, in Table 11.11, are similar to those found in England and Wales (DETR, 1997). The observed concentrations were typically at the low levels of recent years (MAFF and SEPA, 1997). A single measurement of tritium in Dumfries and Galloway was higher than is normally found. The radiological significance of this level was negligible. An assessment of the dose to high-rate consumers on the basis of the highest concentrations observed gives an estimated dose of less than 0.001 mSv in 1997.

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

11.8 Seawater surveys

Seawater surveys support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 1993b) and provide information which can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). In addition, the distribution of radioactivity in seawater around the British Isles is a major factor in determining the variation in individual exposures at coastal sites as well as collective doses. Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. Detailed historical data on radiocaesium in seawater have been published in a series of reports to aid model development (Camplin and Steele, 1991; Baxter *et al.,* 1992; Baxter and Camplin 1993(a-c)) and have been used 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 1997 cruises are presented in Figures 11.5 and 11.6. Data from shoreline sampling in the Irish Sea and Scottish waters in 1997 are given in Table 11.12.

Concentrations of caesium-137 typical of (i) the north-eastern Irish Sea and (ii) northern Scottish waters and the North Sea are of the order of 50-500 mBq kg^{-1} and 5-50 mBq kg^{-1} respectively. The 1997 data show similar levels to those observed from sampling in recent years (MAFF and SEPA, 1997), the general distribution being one of falling concentrations as the distance from Sellafield increases. This distribution is governed by recent disposals from the Sellafield site and the effects of activity previously discharged which had become associated with seabed sediments but is now being remobilised into the water column. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically 30,000 mBq kg^{-1} (Baxter *et al.,* 1992), when disposals were substantially higher.

A similar distribution to that for caesium-137 exists for tritium in the Irish Sea with Sellafield as the main source for this radionuclide. The general distribution of tritium in the Irish Sea in 1997 was similar to that in 1993 (Camplin, 1994) though levels could increase in future years as the THORP plant at Sellafield increases its throughput. Although the concentrations of tritium in sea water are higher than those of caesium-137, they are of much less radiological significance because tritium has very low radiotoxicity.

Technetium-99 concentrations in seawater have been increasing in recent years due to increases in disposals of this nuclide from Sellafield. The results of research cruises to study this radionuclide have been published by Leonard *et al.,* (1997a and b).

Measurements of beta and potassium-40 activity in water from the Clyde in 1997 gave results of <250 and <1700 mBq kg^{-1} respectively. These levels are similar to those for 1996.

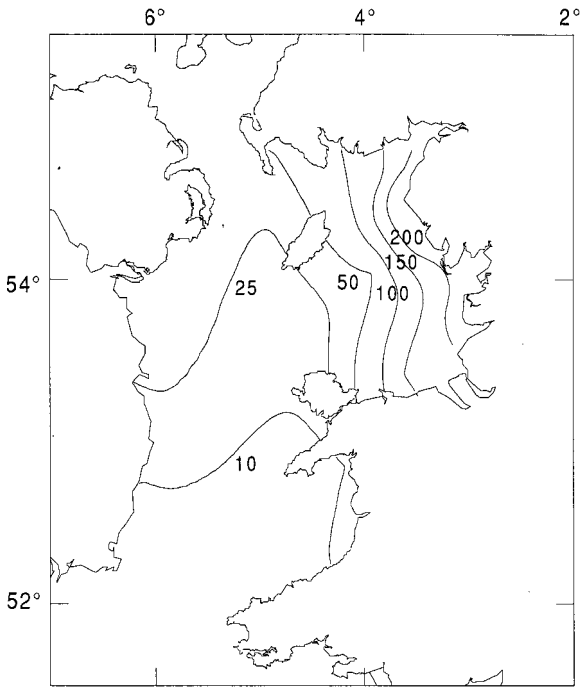

Figure 11.5. Concentrations (mBq kg^{-1}) of caesium-137 in filtered surface water from the Irish Sea, September-October, 1997

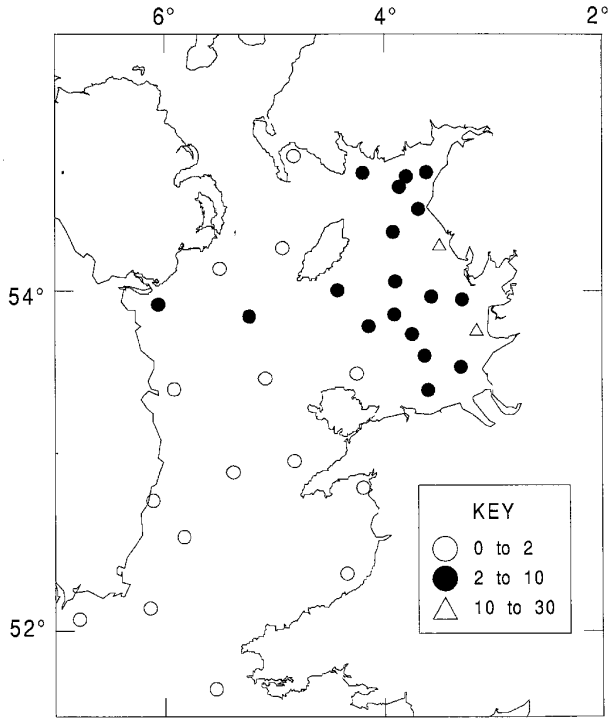

Figure 11.6. Concentrations (Bq kg^{-1}) of tritium in water from the Irish Sea, September-October, 1997

Table 11.1. Caesium radioactivity in the freshwater environment, 1997

Location	Material	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Branthwaite	Rainbow trout	1	<0.07	0.53
Narborough[b]	"	1	<0.09	0.38
Ennerdale Water	Elvers	1	<0.73	25
"	Water	1	*	0.0027
Devoke Water	Perch	1	4.5	400
"	Brown trout	1	0.45	33
"	Water	1	*	0.0099
Gilcrux	Rainbow trout	1	<0.07	0.16
Scotland				
Loch Dee	Brown trout	1	3.2	250
"	Water	3	*	0.016

* *not detected by the method used*
[a] *except for water where units are Bq l^{-1}*
[b] *Concentrations of 35, 0.000026, 0.000095. 0.00016 Bq kg^{-1} (wet) of carbon-14, plutonium-238, plutonium-239+240 and americium-241 were also detected in this sample*

Table 11.2. Radioactivity in terrestrial food from the Isle of Man, 1997

Material or selection[c]	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	Total Cs	^{147}Pm	^{144}Ce	^{238}Pu	$^{239+240}$Pu	^{241}Pu	^{241}Am
Milk	2	<3.0	15	<0.56	<0.41	0.077	<1.2	<1.7	<0.0060	<3.1	<0.84	<0.0090	0.18	<0.40	<2.1	0.00040	<0.00010	<0.072	0.00050
" max			17	<0.73	<0.43	0.11	<1.3	<1.8			<0.95		0.26						
Apples	1	<3.0	9.0	<0.70	<0.50	0.10	<0.40	<0.40	-	<3.0	<1.0	-	0.047	-	<1.9	-	-	-	-
Broccoli	1	<3.0	8.0	<0.40	<0.50	0.13	<1.0	<0.60	<0.030	<2.3	<0.50	<0.038	0.17	0.10	<2.1	<0.00030	<0.00020	<0.075	0.0012
Potatoes	1	<3.0	14	<0.70	<0.30	0.014	<0.70	<0.60	<0.030	<3.4	<0.90	<0.030	0.12	<0.10	<2.5	0.00030	0.00020	<0.068	<0.00040

- not analysed
[a] except for milk where units are Bq l^{-1}
[b] See section 3 for definition
[c] Data are arithmetic means unless stated as 'max in this column. 'Max' data are selected to be maxima If no 'max' value is given, the mean is also the maximum. See section 3 for definition

Table 11.3(a). Radioactivity in seafood and the environment near the Channel Islands, 1997

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{129}I	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Rays	Guernsey	1	-	-	<0.06	-	-	<0.58	<0.12	-	0.29	<0.17	<0.17	0.000037	0.00013	0.00029	*	*	71
Edible crabs	"	2	-	-	0.31	-	-	<1.2	<0.23	-	<0.13	<0.36	<0.21	0.00036	0.00098	0.0028	0.000039	0.00055	71
"	Jersey	1	-	-	0.36	-	-	<0.41	<0.08	-	0.05	<0.13	<0.07	0.00042	0.0011	0.0030	0.000027	0.00062	88
"	Alderney	2	-	28	0.33	-	0.99	<1.5	<0.28	-	<0.15	<0.41	<0.24	0.00058	0.0014	0.0038	0.000022	0.00077	67
Spiny spider crab	Guernsey	1	-	-	1.3	-	-	<2.0	<0.31	-	<0.18	<0.57	<0.43	-	-	<0.43	-	-	-
Lobsters	"	2	-	-	<0.16	-	-	<1.3	<0.22	-	<0.11	<0.35	<0.18	0.00026	0.0010	0.0082	0.00021	0.0016	39
"	Jersey	1	-	-	<0.24	-	-	<2.5	<0.45	-	<0.23	<0.63	<0.33	0.00024	0.00068	0.0044	0.000042	0.00086	65
"	Alderney	1	-	-	0.07	-	-	<0.68	<0.13	-	<0.06	<0.16	<0.19	0.00031	0.0013	0.0090	*	0.0018	52
Winkles	Alderney	1	-	26	0.91	0.059	-	2.0	<0.13	-	<0.06	<0.18	<0.15	0.012	0.028	0.045	0.00013	0.0086	71
Oysters	Jersey	1	-	-	0.24	-	-	<0.37	0.10	-	<0.04	<0.11	<0.09	0.0054	0.012	0.017	0.00012	0.0031	62
Limpets	Guernsey	1	-	-	<0.12	-	-	<1.1	<0.21	-	<0.09	<0.28	<0.15	-	-	<0.08	-	-	70
"	Jersey La Rozel	1	-	-	0.28	-	-	<0.60	<0.12	-	<0.06	<0.16	<0.16	0.0049	0.012	0.017	0.00010	0.0029	65
"	Alderney	1	-	-	0.44	-	-	1.8	<0.13	-	0.07	<0.17	<0.10	0.010	0.023	0.041	*	0.0082	86
Ormers	Guernsey	1	-	-	<0.11	-	-	<0.84	<0.18	-	<0.07	<0.26	<0.14	-	-	<0.09	-	-	88
Porphyra	Guernsey Fermain Bay	4	-	-	<0.14	-	-	<1.5	<0.25	-	<0.11	<0.37	<0.24	0.0020	0.0066	0.0086	<0.000063	0.0014	84
"	Jersey Plemont Bay	4	-	-	<0.15	-	-	<1.8	<0.15	-	<0.10	<0.24	<0.14	-	-	<0.14	-	-	230
"	Alderney Quenard Point	3	-	-	<0.07	-	-	3.3	<0.12	-	<0.05	<0.17	<0.09	-	-	<0.08	-	-	120

Table 11.3(a). continued

Material	Location[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}																
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{129}I	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Fucus vesiculosus	Alderney Quenard Point	2	-	-	-	-	-	-	-	0.71	-	-	-	-	-	-	-	-	-
Fucus serratus	Guernsey Fermain Bay	4	-	-	0.35	0.070	-	<0.46	<0.10	-	<0.07	<0.16	<0.10	0.0072	0.0022	0.010	0.000058	0.0019	130
"	Jersey La Rozel	4	-	-	0.76	0.10	-	<0.73	<0.13	-	0.13	<0.22	<0.15	0.021	0.047	0.025	0.00013	0.0049	230
"	Alderney Quenard Point	4	-	-	0.57	0.081	-	<0.51	<0.07	-	<0.05	<0.11	<0.20	0.010	0.027	0.010	0.00010	0.0022	96
Laminaria digitata	Jersey Verclut	4	-	-	<0.11	-	-	<0.72	<0.15	-	0.13	<0.26	<0.12	-	-	<0.10	-	-	340
Mud	Jersey St Helier	1	-	-	21	-	-	3.5	<0.45	-	4.9	0.90	1.7	1.1	2.5	4.2	0.014	0.69	630
"	Jersey Albert Marina	1	-	-	1.0	-	-	<3.0	<0.62	-	0.40	<0.73	2.7	-	-	<1.3	-	-	-
Mud and sand	Guernsey Bordeaux Harbour	1	-	-	0.61	-	-	<2.4	<0.47	-	1.7	<0.72	<0.53	0.091	0.34	0.31	*	0.042	410
Sand	Alderney Lt. Crabbe Harbour	1	-	-	0.26	-	-	<1.5	<0.30	-	1.8	<0.44	<0.37	-	-	0.26	-	-	250
Sea water	Guernsey	4	-	-	-	-	-	-	-	-	0.005	-	-	-	-	-	-	-	-
"	Jersey	1	-	-	-	-	-	-	-	-	0.003	-	-	-	-	-	-	-	-
"	Alderney	4	<4.0	-	-	-	-	-	-	-	0.005	-	-	-	-	-	-	-	-

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

Table 11.3(b). Monitoring of radiation dose rates in the Channel Islands, 1997

Location type			Ground sampling observations[a]	No. of	μGy h^{-1}
Gamma dose rates at 1 m over intertidal areas					
Guernsey					
Fermain Bay			Sand	1	0.078
Portelet			Mud and sand	1	0.062
Hommet			"	1	0.064
St Sampson Harbour			"	1	0.062
Jersey					
St Helier			Mud	1	0.10
Le Petit Etacquerel			Mud and sand	1	0.064
Le Pulec			Seaweed	1	0.090
Gouray			Mud and sand	1	0.059
Beta dose rates					μSv h^{-1}
Guernsey					
St Peter Port	"	Vessel D	Nets	1	*
"	"		Pots	1	*
"		Vessel E	"	1	*
"	"		Rope	1	*
Jersey					
St Helier	Vessel	A	Pots	1	0.32
"	Vessel	B	"	1	*
"			"	1	0.17
Le Pulec			Seaweed	1	0.33

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

Table 11.4. Radioactivity in regional diet in England and Wales, 1997

Region	No. of sampling observations[b]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}													
		^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	U	^{238}Pu	$^{239+240}$Pu	^{241}Am
Wales	1	<3.8	38	<1.0	76	0.15	<0.08	0.078	0.037	0.030	<0.0020	0.022	0.000034	0.00018	<0.00027
East Midlands	1	<3.8	28	<1.0	79	0.077	0.04	0.071	0.031	0.032	<0.0030	0.019	<0.00011	0.00040	<0.00013
South West	1	<3.0	45	<1.0	81	<0.20	<0.11	0.015	0.042	0.033	0.0027	0.020	<0.00010	0.00015	<0.00015
North East	1	<3.7	34	<1.0	70	0.27	<0.07	0.055	0.028	0.039	0.0011	0.025	<0.000045	0.00013	<0.00010
South East	1	-	44	-	80	<0.20	0.05	0.015	0.028	0.036	0.0020	0.029	<0.00021	0.00073	<0.00011
West Midlands	1	<3.8	34	<1.0	74	0.11	<0.06	0.026	0.043	0.039	0.0023	0.033	0.0024	0.0091	<0.00021
East	1	<3.3	48	-	72	0.087	0.13	0.016	0.049	0.041	<0.0020	0.029	<0.00010	0.00028	<0.00022
South	1	<3.7	34	<1.0	76	0.15	<0.10	0.12	0.038	0.040	<0.0010	0.016	<0.000066	0.00014	<0.00013
North West	1	<3.8	42	<1.0	75	0.10	0.06	0.027	0.032	0.034	<0.00090	0.018	<0.000044	0.00013	<0.00027

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

[b] *See section 3 for definition*

\- *not analysed*

Table 11.5. Radioactivity in regional diet in Scotland, 1997

Area	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}			
		^{3}H	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	12	<25	84	<0.10	<0.077
East Lothian (North Berwick)	12	<25	82	<0.10	<0.069
Highland (Dingwall)	12	<25	92	<0.10	<0.11
Renfrewshire (Paisley)	12	<25	79	<0.10	<0.10

Table 11.6. Estimates of radiation exposure from radionuclides in regional diet, 1997

Nuclide[a]	Exposure, mSv[b]	
	Mean	Range
Man-made radionuclides		
Tritium	0.0001	0.00003-0.0002
Sulphur-35	0.001	0.001-0.001
Strontium-90	0.002	0.001-0.005
Caesium-137	0.0002	0.00009-0.0003
Plutonium-238	0.00003	0.000003-0.0002
Plutonium-239+240	0.0001	0.00001-0.0007
Americium-241	0.00001	0.000007-0.00002
Sub-total	0.004	
Natural radionuclides		
Carbon-14	0.012	0.009-0.015
Lead-210	0.033	0.011-0.084
Polonium-210	0.062	0.048-0.084
Radium-226	0.007	0.006-0.008
Uranium	0.0006	0.0004-0.0008
Thorium-232	0.0002	0.0001-0.0003
Sub-total	0.11	
Total	0.11	

[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, 1997

Location	Selection[a]	No. of sampling observations[b]	Mean radioactivity concentration, Bq l^{-1}												
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{129}I	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+$ ^{240}Pu	Total alpha
Co. Antrim		12	<3.0	14	-	<0.029	-	0.32	<0.035	0.0060	<0.0065	<0.00010	<0.00010	-
	max			20		0.044		0.45						
Co. Armagh		12	<3.0	16	-	<0.033	-	0.10	<0.041	0.0080	<0.0065	<0.00010	<0.00010	-
	max			23		0.043		0.16						
Cambridgeshire[c]		12	<2.0	15	-	0.025	-	0.057	0.081	0.0040	<0.0065	<0.00010	0.00010	-
	max			22		0.030		0.12						
Clwyd		11	<3.8	15	-	0.034	-	0.039	0.058	0.0080	<0.0065	<0.00020	0.00010	-
	max		12	23		0.050		0.083						
Cornwall		18	<3.2	15	-	0.049	-	0.058	<0.036	0.011	<0.0065	<0.00010	<0.00020	-
	max		6.0	25		0.085		0.14	0.037				0.00020	
Devon		3	<3.0	12	-	0.053	-	0.054	0.032	0.010	<0.0065	<0.00020	0.00020	-
	max			16		0.064		0.059						
Co. Down		12	<3.3	14	-	0.043	-	0.13	<0.035	0.0090	<0.0065	<0.00010	<0.00010	-
	max		7.0	20		0.054		0.23						
Dumfries and Galloway		12	<25	14	<5.0	<0.10	<0.020	<0.083[d]	-	-	-	-	-	<0.33
	max			16			<0.026	0.36[d]						<0.37
Co. Fermanagh		12	<3.0	14	-	0.043	-	0.27	<0.031	0.0040	<0.0065	<0.00010	<0.00010	-
	max			21		0.076		0.61						
Gloucestershire		12	<3.0	16	-	0.034	-	0.047	<0.034	0.0070	<0.0065	<0.00020	<0.00010	-
	max			23		0.063		0.085						
Gwent[c]		11	<2.9	17	-	0.035	-	0.045	0.059	0.0090	<0.0065	<0.00010	<0.00010	-
	max		7.0	28		0.045		0.064						
Gwynedd		8	<3.3	14	-	0.044	-	0.075	0.048	0.0090	<0.0065	<0.00020	<0.00030	-
	max		5.0	21		0.064		0.10						
Hampshire		12	<3.0	15	-	0.030	-	0.039	<0.041	0.0050	<0.0065	<0.00010	<0.00010	-
	max			24		0.074		0.078						
Highland		12	<25	21	<5.0	<0.10	<0.020	<0.096[d]	-	-	-	-	-	<0.35
	max			37			<0.026	0.14[d]						<0.36
Humberside		12	<3.0	13	-	<0.022	-	0.043	0.044	0.0050	<0.0065	<0.00010	0.00010	-
	max			20		0.037		0.062						
Lancashire		11	<3.0	16	-	0.032	-	0.081	<0.035	0.0080	<0.0065	<0.00010	<0.00010	-
	max			24		0.051		0.12						
Lincolnshire		12	<3.0	16	-	0.019	-	0.034	0.073	0.0070	<0.0065	<0.00010	0.00080	-
	max			25		0.029		0.056						

Table 11.7. continued

Location	Selection[a]	No. of sampling observations[b]	Mean radioactivity concentration, Bq l^{-1}											
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{129}I	Total Cs	^{210}Pb	^{210}Po	Total U	^{238}Pu	$^{239}Pu+$ ^{240}Pu	Total alpha
Co. Londonderry		11	<3.0	17	-	0.036	-	0.15	<0.036	0.0060	<0.0065	<0.00010	<0.00010	-
	max			23		0.042		0.26						
Midlothian		12	<25	18	<5.0	<0.10	<0.020	<0.058[d]	-	-	-	-	-	<0.34
	max			30			<0.026	0.10[d]						<0.37
Norfolk		12	<3.0	16	-	0.026	-	0.052	<0.035	0.0050	<0.0065	<0.00020	<0.00010	-
	max			22		0.035		0.16						
North Yorkshire		12	<3.3	16	-	0.029	-	0.067	0.034	0.0070	<0.0065	<0.00010	<0.00020	-
	max		6.0	20		0.044		0.12						
Oxfordshire		12	<3.0	15	-	0.050	-	0.052	<0.040	0.010	<0.0065	<0.00010	<0.00020	-
	max			27		0.31		0.089						
Renfrewshire		12	<25	16	<5.0	<0.10	<0.020	0.20[d]	-	-	-	-	-	<0.31
	max			20			<0.026	0.50[d]						<0.33
Shropshire		12	<3.0	17	-	0.033	-	0.051	0.026	0.0060	<0.0065	<0.00010	0.00010	-
	max			21		0.039		0.089						
Somerset		12	<3.0	14	-	0.040	-	0.049	0.053	0.0040	<0.0065	-	-	-
	max			24		0.064		0.084						
Suffolk		12	<3.0	18	-	<0.013	-	0.044	0.071	<0.0070	<0.0065	<0.00020	<0.00020	-
	max			23		0.037		0.093						
Tyneside		12	<4.6	16	-	0.038	-	0.077	0.059	0.0080	<0.0065	<0.00010	<0.00010	-
	max		10	27		0.057		0.12						
Co. Tyrone[c]		12	<2.0	16	-	0.039	-	0.18	<0.042	0.0080	<0.0065	<0.00010	<0.00010	-
	max			26		0.047		0.32						
West Midlands		12	<3.0	16	-	0.026	-	0.064	<0.032	0.011	<0.0065	<0.00010	<0.00010	-
	max			23		0.087		0.15						
Mean values														
England			<3.0	15	-	<0.032	-	0.053	<0.045	<0.0070	<0.0065	<0.00012	<0.00022	-
Northern Ireland			<2.5	15	-	<0.038	-	0.19	<0.037	0.0068	<0.0065	<0.00010	<0.00010	-
Wales			<3.2	15	-	0.037	-	0.051	0.055	0.0087	<0.0065	<0.00017	<0.00017	-
Scotland			<25	17	<5.0	<0.10	<0.020	<0.11[d]	-	-	-	-	-	<0.33
United Kingdom			<8.4	16	-	<0.052	-	<0.10	<0.046	<0.0075	<0.0065	<0.00013	<0.00016	-

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima If no 'max' value is given, the mean is also the maximum. See section 3 for definition*
[b] *See section 3 for definition*
\- *Not analysed*
[c] *Sub-sets for ^{3}H, ^{90}Sr and Total Cs*
[d] *^{137}Cs only*

Table 11.8. Radioactivity in crops remote from nuclear sites, 1997[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
Bath and East Somerset																
Cheddar	Cabbage	1	<3.0	8.0	-	0.62	0.051	-	-	-	-	-	<0.00030	<0.00020	<0.00080	-
	Root Veg.	1	<3.0	6.0	-	0.054	0.040	-	-	-	-	-	<0.00020	0.00030	<0.00090	-
	Soft Fruit	1	<3.0	14		0.16	0.20	-	-	-	-	-	<0.00010	<0.00020	0.00080	-
Caernarfonshire																
Dolgellau	Cabbage	1	<3.0	<3.0	-	1.3	0.13	0.55	0.29	0.0040	<0.0030	<0.037	0.00030	<0.00030	<0.00070	-
	Plums	1	<3.0	15	-	0.17	0.52	-	-	-	-	-	0.00010	<0.00010	0.00080	-
	Potatoes	1	<3.0	16	-	0.041	0.13	0.093	0.021	0.0060	0.0040	<0.026	0.00010	<0.00020	<0.00090	-
Cardiganshire																
Lampeter	Apples	1	<3.0	8.0	-	0.17	<0.040	-	-	-	-	-	<0.00020	<0.00020	<0.00030	-
	Cabbage	1	<3.0	6.0	-	0.64	0.083	-	-	-	-	-	<0.00010	0.00010	0.00020	-
	Potatoes	1	<3.0	16	-	0.074	<0.030	-	-	-	-	-	<0.00030	<0.00020	0.0015	-
Cheshire																
Knutsford	Cabbage/ Brussel Sprouts	1	<3.0	6.0	-	0.19	<0.027	0.28	0.096	0.0090	<0.0040	<0.021	<0.00030	<0.00010	<0.00030	-
	Greengage	1	<3.0	11	-	0.096	<0.036	-	-	-	-	-	<0.00040	<0.00020	<0.00050	-
	Potatoes/Parsnips	1	<3.0	11	-	0.13	0.057	0.043	0.021	0.023	<0.004	<0.032	<0.00030	0.00020	<0.00040	-
Cornwall																
Camelford	Kale	1	<3.0	6.0	-	2.3	0.11	-	-	-	-	-	0.00030	0.00040	0.0020	-
	Root Veg.	1	<3.0	5.0	-	0.64	<0.037	-	-	-	-	-	<0.00020	<0.00020	0.0019	-
	Soft Fruit	1	<3.0	8.0	-	0.19	0.16	-	-	-	-	-	<0.00030	<0.00020	0.0020	-
Cumbria																
Kendal	Cabbage	1	<3.0	6.0	-	0.44	0.061	-	-	-	-	-	<0.00030	<0.00020	<0.00070	-
	Potatoes	1	<3.0	18	-	0.096	0.032	-	-	-	-	-	<0.00010	<0.00010	<0.00030	-
Devon																
Parracombe	Cabbage	1	<3.0	6.0	-	0.98	0.12	0.50	0.26	<0.0040	0.013	0.061	0.00040	0.00050	0.0011	-
	Potatoes	1	<3.0	13	-	0.057	0.042	<0.037	0.028	0.012	0.012	0.041	<0.00020	<0.00030	0.00050	-
	Gooseberries	1	<3.0	11	-	0.14	0.028	-	-	-	-	-	0.00010	<0.00020	<0.00060	-
Dumfries and Galloway																
Dumfries	Leafy Green Veg.	4	<25	4.4	<5.0	<0.10	<0.053[c]	-	-	-	-	-	-	-	-	<0.18
East Lothian																
North Berwick	Leafy Green Veg.	4	<25	4.9	<5.0	<0.10	<0.075[c]	-	-	-	-	-	-	-	-	<0.31
Gloucestershire																
Stroud	Cabbage	1	<3.0	12	-	0.53	<0.037	-	-	-	-	-	<0.00020	<0.00020	<0.00090	-
	Pears	1	<3.0	11	-	0.079	0.041	-	-	-	-	-	<0.00020	<0.00020	0.00070	-
	Potatoes	1	<3.0	16	-	0.048	<0.027	-	-	-	-	-	<0.00010	<0.00010	0.00010	-
Hertfordshire																
Royston	Leafy Green Veg.	1	<3.0	12	-	0.056	0.069	0.072	0.018	0.0080	<0.0020	<0.028	<0.00020	<0.00020	<0.00040	-
	Root Veg.	1	5.0	14	-	<0.015	<0.030	<0.033	0.021	0.0080	0.0040	<0.024	<0.00010	0.00020	<0.00060	-
	Strawberries	1	<3.0	10	-	0.058	0.18	-	-	-	-	-	0.00010	<0.00020	<0.00070	-

Table 11.8. continued

Location	Material	No of samples[a]	Mean radioactivity concentration (wet), Bq kg^{-1}													
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total Alpha
Highlands																
Dingwall	Leafy Green Veg.	4	<25	4.6	<5.0	<0.10	<0.060[c]	-	-	-	-	-	-	-	-	<0.26
Kent																
Canterbury	Cabbage	1	<3.0	10	-	0.26	<0.036	-	-	-	-	-	<0.00030	<0.00020	<0.00080	-
	Leeks	1	<3.0	12	-	0.46	0.048	-	-	-	-	-	<0.00010	0.00010	<0.00040	-
	Raspberries	1	<3.0	13	-	0.18	<0.040	-	-	-	-	-	0.00040	<0.00020	<0.00090	-
Lincolnshire																
Grantham	Apples	1	<3.0	8.0	-	0.066	0.031	-	-	-	-	-	0.00030	0.00010	<0.00050	-
	Cabbage	1	<3.0	8.0	-	0.53	0.16	-	-	-	-	-	<0.00030	<0.00040	<0.00080	-
	Potatoes	1	<3.0	17	-	0.036	0.035	-	-	-	-	-	<0.00020	<0.00010	<0.00070	-
Norfolk																
Thetford	Apples	1	<3.0	13	-	0.036	0.057	-	-	-	-	-	0.00020	<0.00020	0.00090	-
	Cabbage	1	<3.0	6.0	-	0.58	0.057	-	-	-	-	-	<0.00030	<0.00040	0.00040	-
	Turnips	1	<3.0	3.0	-	0.13	0.035	-	-	-	-	-	<0.00010	<0.00020	<0.00050	-
North East Lincolnshire																
Skegness	Apples	1	<3.0	15	-	0.26	<0.038	-	-	-	-	-	<0.00010	<0.00010	0.00020	-
	Cabbage	1	<3.0	8.0	-	0.098	0.088	0.11	0.043	0.023	<0.0020	<0.019	<0.00030	<0.00010	<0.0025	-
	Potatoes	1	<3.0	18	-	0.021	0.044	0.050	0.018	0.014	0.012	0.042	<0.00020	0.00030	<0.0010	-
Northumberland																
Alnwick	Blackberries	1	3.0	19	-	0.047	0.067	-	-	-	-	-	<0.00020	<0.00020	<0.00030	-
	Cabbage	1	<3.0	5.0	-	0.65	0.042	0.23	0.045	<0.0050	0.0040	<0.036	0.00010	<0.00030	0.00070	-
	Swede	1	<3.0	9.0	-	0.16	<0.032	0.059	0.0070	0.015	<0.0020	<0.015	<0.00010	<0.00010	0.00020	-
NorthYorkshire																
Richmond	Cauliflower/ Broccoli	1	<3.0	8.0	-	0.28	0.032	0.16	0.045	0.035	0.0020	<0.032	<0.00030	<0.00020	<0.00070	-
	Cauliflower		-	-	-	-	-	<0.029	0.0090	-	-	-	-	-	-	-
	Elderberries	1	<3.0	18	-	0.31	0.076	-	-	-	-	-	<0.00020	0.00010	<0.00060	-
	Potatoes	1	<3.0	25	-	0.030	<0.044	0.039	0.015	0.0090	0.0080	0.021	<0.00010	0.00020	<0.00020	-
Whitby	Crab Apples	1	<3.0	14	-	0.25	0.070	-	-	-	-	-	<0.00020	0.00010	<0.00030	-
	Leafy Green Veg.	1	<3.0	12	-	1.0	0.12	-	-	-	-	-	<0.00030	0.00040	<0.00060	-
	Turnips	1	<3.0	14	-	0.33	0.18	-	-	-	-	-	<0.00020	<0.00020	0.00050	-
Renfrewshire																
Paisley	Leafy Green Veg.	4	<25	4.2	<5.0	<0.10	<0.065[c]	-	-	-	-	-	-	-	-	<0.24

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
Somerset																
Chard	Carrots/Parsnips	1	<3.0	6.0	-	0.29	0.14	0.084	0.054	0.033	0.012	0.079	<0.00020	0.00040	0.00050	-
	Leafy Green Veg.	1	<3.0	<3.0	-	0.49	0.094	0.14	0.013	0.0090	<0.0020	0.0076	<0.00010	<0.00020	<0.00040	-
	Soft Fruit	1	<3.0	12	-	0.40	0.12	-	-	-	-	-	<0.00010	<0.00020	<0.00020	-
Warwickshire																
Nuneaton	Apples	1	<3.0	11	-	<0.016	<0.034	-	-	-	-	-	0.00020	<0.00040	<0.00070	-
	Cabbage	1	<3.0	4.0	-	0.26	<0.028	0.096	0.031	0.029	0.0020	<0.027	<0.00020	0.00020	<0.0010	-
	Potatoes	1	<3.0	8.0	-	0.038	<0.033	0.078	0.023	0.0080	0.0090	0.024	<0.00010	<0.00020	0.00040	-
West Sussex																
Crowborough	Cabbage	1	<3.0	9.0	-	0.55	<0.033	<0.034	0.017	<0.0030	0.0010	<0.019	<0.00010	<0.00020	<0.00040	-
	Carrots	1	<3.0	6.0	-	0.16	0.041	0.10	0.10	0.057	0.092	0.26	<0.00020	0.0010	0.0012	-
	Raspberries	1	<3.0	13	-	0.083	<0.037	-	-	-	-	-	0.00010	0.00030	<0.00040	-
Wigan																
Wigan	Carrots	1	<3.0	8.0	-	0.20	0.075	-	-	-	-	-	0.00030	0.00030	<0.00070	-
	Plums	1	<3.0	9.0	-	0.098	0.12	-	-	-	-	-	0.00010	<0.00020	0.00060	-
	Sprouts	1	<3.0	7.0	-	0.28	0.10	-	-	-	-	-	<0.00020	<0.00020	<0.00020	-
Mean values																
England			<3.0	<10	-	<0.29	<0.067	<0.11	0.046	<0.017	<0.010	<0.043	<0.00020	<0.00023	<0.00069	-
Wales			<3.0	<11	-	0.41	<0.15	0.32	0.15	0.0050	<0.0035	<0.032	<0.00018	<0.00018	<0.00073	-
Scotland			<25	4.5	<5.0	<0.10	<0.063[c]	-	-	-	-	-	-	-	-	<0.25
Great Britain			<10	<8.5	-	<0.27	<0.093	<0.22	0.10	<0.011	0.0068	<0.038	<0.00019	<0.00021	<0.00071	-

- not analysed

[a] *see section 3 for definition*

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

[c] *^{137}Cs only*

Table 11.9. Radioactivity in bread in Scotland, 1997

Area	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<25	68	<5.0	<0.10	<0.14	<0.90
East Lothian (North Berwick)	4	<25	66	<5.0	<0.10	<0.17	<0.94
Highland (Dingwall)	4	<25	65	<5.0	<0.10	<0.19	<0.97
Renfrewshire (Paisley)	4	<25	66	<5.0	<0.10	<0.16	<0.95

Table 11.10. Radioactivity in meat in Scotland, 1997

Area	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha
Dumfries and Galloway (Dumfries)	4	<25	46	<5.0	<0.10	<0.13	<0.44
East Lothian (North Berwick)	4	<25	71	<5.0	<0.10	<0.12	<1.1
Highland (Dingwall)	4	<25	32	<5.0	<0.10	<0.18	<0.43
Renfrewshire (Paisley)	4	<25	34	<5.0	<0.10	<0.16	<0.43

Table 11.11. Radioactivity in freshwater in Scotland, 1997

Area	Location	No. of sampling observ-ations[a]	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee	12	<1.0	<0.0039	<0.0075	-	-
Argyll and Bute	Auchengaich	1	<1.0	0.0015	-	<0.003	0.024
"	Helensburgh Reservoir	3	-	-	<0.0093	<0.0090	0.071
"	Loch Ascog	3	-	-	<0.0015	<0.0093	0.044
"	Loch Eck	1	<1.0	0.008	-	<0.003	0.025
"	Loch Finlas	3	-	-	<0.0087	<0.0083	0.036
"	Lochan Ghlas	3	-	-	<0.0087	<0.0087	0.036
Dumfries and Galloway	Black Esk	1	1.9	0.006	-	0.008	0.015
"	Purdomstone	3	-	-	<0.0093	<0.014	0.052
"	Winterhope	1	18	0.010	-	0.012	0.031
East Lothian	Hopes Reservoir	1	<1.0	<0.004	-	0.008	0.035
"	Thorters Reservoir	1	<1.0	0.006	-	<0.008	0.028
"	Whiteadder	3	-	-	<0.0090	<0.010	0.49
Fife	Holl Reservoir	1	<1.0	<0.004	-	<0.007	0.33
Highland	Loch Baligill	1	<1.0	0.009	-	<0.004	0.044
"	Loch Calder	3	-	-	<0.0090	<0.016	0.045
"	Loch Glass	12	<1.0	<0.0045	<0.012	-	-
"	Loch Shurrerey	1	<1.0	0.011	-	0.006	0.030
North Ayrshire	Camphill	1	<1.0	0.013	-	<0.004	0.012
"	Knockendon Reservoir	3	-	-	<0.012	<0.013	0.047
"	Munnoch Reservoir	1	<1.0	0.018	-	<0.004	0.036
"	Outerwards	1	<1.0	0.007	-	0.006	0.012
Perth and Kinross	Castlehill	3	-	-	<0.0097	<0.097	0.024
Scottish Borders	Knowsdean	12	<1.0	<0.0045	<0.0045	-	-
Stirling	Loch Katrine	7	<1.0	<0.0051	<0.0086	-	-
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0	0.009	-	<0.004	0.623
West Lothian	Morton No. 2	1	<1.0	0.007	-	<0.007	0.016

- not analysed or not available

[a] See section 3 for definition

Table 11.12. Radioactivity in sea water from the Irish Sea and Scottish waters, 1997

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
		^{3}H	^{99}Tc	^{134}Cs	^{137}Cs
Seascale	4	-	-	0.0020	0.27
St Bees	12	17	0.28	<0.0014	0.23
Whitehaven	1	-	-	*	0.19
Maryport	1	-	-	*	0.25
Silloth	1	-	-	*	0.38
Silecroft	1	-	-	0.0017	0.19
Walney-west shore	4	19	-	0.0015	0.21
Isle of Whithorn	1	-	-	*	0.087
Drummore	1	-	-	0.0013	0.056
Half Moon Bay	1	-	-	0.0016	0.27
Rossal (Fleetwood)	1	-	-	0.0015	0.24
Ainsdale	1	-	-	*	0.22
New Brighton	1	-	-	*	0.18
Ross Bay	1	-	-	0.0018	0.12
North of Larne	12	-	0.036	*	0.030
Seafield	4	29	-	*	0.16
Southerness	4	6.4	-	*	<0.24
Knock Bay	7	<2.0	-	*	<0.045
Prestatyn	1	-	-	*	0.084
Llandudno	1	-	-	*	0.073
Cemaes Bay	1	-	-	*	0.037
Holyhead	4	1.9	-	*	0.017
Cape Wrath	4	-	-	*	0.0069
Pentland Firth	4	-	-	*	0.0046
Fair Isle	3	-	-	*	0.0028
Aberdeen	4	-	-	*	0.0087

- not analysed
** not detected by the method used*

12. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMME

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

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

A list of related research projects completed in 1997 is presented in Table 12.1. Copies of the final reports for each of these projects are available from the MAFF library, Nobel House, 17 Smith Square, London, SW1P 3JR. A charge will be made to cover photocopying and postage. Table 12.1 also provides information on projects which are currently underway. The results of these projects will be made available in due course.

Table 12.1. Extramural projects in support of the monitoring programmes

	Target completion date
Potential variability of naturally occurring radionuclides in foodstuffs	Complete
Variability of concentrations between individual crabs and lobsters	"
Quality control for the determination of radionuclides in foodstuffs	"
Relative contribution of historical and current discharges to Sellafield exposures	"
Remobilisation from contaminated Irish Sea sediments	"
Variability of radionuclides in terrestrial foodstuffs	"
Free foods in the vicinity of nuclear sites	"
Food production and distribution surveys	Sep-98
Optimisation of MAFF's monitoring programme	Dec-98
Radioactivity from fish in animal feed	Mar-99
Samplers for radionuclides in freshwaters	Apr-99
Food and non-licensed sites	Apr-99
Iodine-129 losses during milk storage	Apr-99
Improved analysis of cerium-144	Apr-99
Methods for censored data sets	Sep-99
Dietary studies near nuclear installations	Mar-00
Accumulation of technetium-99 in the Irish Sea	Mar-01

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APPENDIX 1. Modelling of radioactivity in food

1.1 Introduction

There are three cases where the results of terrestrial monitoring in 1997 have been amended or supplemented when carrying out assessments of exposures to consumers. Firstly some data for Sellafield, Drigg, Ravenglass and the Isle of Man have been changed where relatively high limits of detection exist or where no measurements were made. Secondly, data for tide-washed pasture on the fringes of the Irish Sea have been converted to foodstuff concentrations to investigate the importance of sea-to-land transfer. Thirdly, data for Chapelcross, Dounreay, Hunterston and Torness have been supplemented to provide a more complete coverage of food groups. The methods and data are outlined below.

1.2 Sellafield, Drigg, Ravenglass and the Isle of Man

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

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

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

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

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

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

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

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

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

No direct account is taken of radionuclide decay or the intake by the animal of soil associated activity. The concentration in fodder is assumed to be the same as the maximum observed concentration in grass, or in the absence of such data, in leafy green vegetables. The foodchain data for the calculations are given in Table 1.1 (Simmonds *et al*., 1995; Brent *et al*., unpublished) and the estimated concentrations in milk, meat and offal are presented in Table 1.2.

1.3 Tide-washed pasture

Activities of technetium-99 in tide-washed pasture in various locations around the Irish Sea are reported in Section 4.1.5 of the main text. These were converted to predicted concentrations in milk, meat and offal using the method and data given above. Measured data for unwashed pasture were used. Activity asscociated with plant surfaces is therefore included in the assessment. The predicted concentrations are given in Table A1.3

1.4 Chapelcross, Dounreay, Hunterston and Torness

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

Table A1.1 Data for foodchain 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 A1.2 Predicted concentrations from foodchain 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]	$<2.42\ 10^{-4}$	$<2.69\ 10^{-3}$	[b]	$1.08\ 10^{-5}$
	Ravenglass	[a]	$<4.89\ 10^{-4}$	$<6.73\ 10^{-3}$	$8.77\ 10^{-3}$	$1.99\ 10^{-5}$
	Drigg	[a]	$<4.77\ 10^{-4}$	[b]	$3.47\ 10^{-4}$	$<1.54\ 10^{-5}$
	Isle of Man	[a]	$<3.99\ 10^{-4}$	$<7.28\ 10^{-3}$	$3.47\ 10^{-4}$	$<1.30\ 10^{-5}$
Beef	Sellafield	[a]	$<2.42\ 10^{-1}$	$<1.34\ 10^{-1}$	[b]	$1.08\ 10^{-3}$
	Ravenglass	[a]	$<4.89\ 10^{-1}$	$<3.36\ 10^{-1}$	2.19	$1.99\ 10^{-3}$
Lamb	Sellafield	[a]	$<2.79\ 10^{-1}$	$<1.55\ 10^{-1}$	[b]	$4.97\ 10^{-4}$
	Ravenglass	[a]	$<5.65\ 10^{-1}$	$<3.88\ 10^{-1}$	2.53	$9.18\ 10^{-4}$
	Drigg	[a]	$<5.50\ 10^{-1}$	[b]	1.28	$<7.10\ 10^{-4}$
Beef offal	Sellafield	[a]	$<2.42\ 10^{-1}$	[a]	[b]	[a]
	Ravenglass	[a]	$<4.89\ 10^{-1}$	[a]	17.5	[a]
Lamb offal	Sellafield	[a]	$<2.79\ 10^{-1}$	[a]	[b]	$3.72\ 10^{-2}$
	Ravenglass	[a]	$<5.65\ 10^{-1}$	[a]	15.2	$6.88\ 10^{-2}$
	Drigg	[a]	$<5.50\ 10^{-1}$	[b]	7.66	$<5.33\ 10^{-2}$

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

Table A1.3 Predicted concentrations[a] from foodchain model used in assessments of technetium-99 on tide-washed pasture

Foodstuff	Technetium-99 radioactivity concentration (wet weight), Bq kg^{-1}							
	Rockcliffe	Newton Arlosh	Low Shaw	Sandgate Marsh	High Foulshaw	Aldcliffe Marsh	Cockerham	Hutton Marsh
Milk	1.3	4.2	3.1	4.6	3.6	3.8	5.5	1.3
Beef	1.3	4.2	3.1	4.6	3.6	3.8	5.5	1.3
Lamb	1.4	4.8	3.6	5.3	4.2	4.4	6.3	1.5
Beef offal	5.0	17	13	18	15	15	22	5.2
Lamb offal	5.8	19	14	21	17	17	25	6.0

[a] *Based on unwashed grass measurements*

APPENDIX 2. Abbreviations

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

APPENDIX 3. Consumption, handling and occupancy rates

This appendix gives the consumption, handling and occupancy rate data used in the assessment of exposures. Consumption rates for terrestrial foods are given in Table A3.1. 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 A3.2.

Table A3.1 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 A3.2 Consumption, handling and occupancy rates for aquatic pathways

Site	Group[a]	Rates
Aldermaston		1 kg y^{-1} pike 360 h y^{-1} over riverbank
Amersham		1 kg y^{-1} pike 1600 h y^{-1} over riverbank
Barrow		1000 h y^{-1} over mud and sand
Berkeley and Oldbury		17 kg y^{-1} flounders 4.9 kg y^{-1} shrimps 980 h y^{-1} over mud
Bradwell	A	75 kg y^{-1} fish 5.0 kg y^{-1} crustaceans 2000 h y^{-1} over mud
	B	4.7 kg y^{-1} oysters
Capenhurst		0.0025 kg y^{-1} sediment 2.5 l y^{-1} water
Cardiff		28 kg y^{-1} flounders 2.9 kg y^{-1} mussels 650 h y^{-1} over mud

Table A3.2 continued

Site	Group[a]	Rates
Channel Islands	A	62 kg y^{-1} fish
		30 kg y^{-1} crustaceans
		30 kg y^{-1} molluscs
		1400 h y^{-1} over mud and sand
	B	2400 h y^{-1} handling nets, pots and sediment
	C	2300 h y^{-1} over sediment in St Helier
Chapelcross	A	8.7 kg y^{-1} flounders
		11 kg y^{-1} salmonids
		7.3 kg y^{-1} shrimps
		0.45 kg y^{-1} mussels
		1000 h y^{-1} over mud and sand
	B	1200 h y^{-1} over salt marsh
	C	250 h y^{-1} handling nets
Devonport		14 kg y^{-1} salmonids
		13 kg y^{-1} fish
		5 kg y^{-1} crustaceans
		2000 h y^{-1} over mud
Dounreay	A	1600 h y^{-1} handling pots
	B	54 kg y^{-1} cod
		20 kg y^{-1} crab and lobster
		0.40 kg y^{-1} winkles
	C	5.5 kg y^{-1} winkles
		380 h y^{-1} over winkle beds
	D	100 h y^{-1} in a Geo
Drinking water	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness		98 kg y^{-1} fish
		9.4 kg y^{-1} shrimps
		14 kg y^{-1} whelks
		2000 h y^{-1} over mud
Faslane	A	500 h y^{-1} over mud
	B	38 kg y^{-1} fish
		4.8 kg y^{-1} molluscs
		670 h y^{-1} over mud and sand
Hartlepool	A	42 kg y^{-1} fish
		23 kg y^{-1} crab
		18 kg y^{-1} winkles
	B	3000 h y^{-1} over sand/coal
Harwell		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham		54 kg y^{-1} fish
		21 kg y^{-1} shrimps
		22 kg y^{-1} mussels and cockles
		900 h y^{-1} over mussel beds
Hinkley Point	A	48 kg y^{-1} flounder
		6.5 kg y^{-1} shrimps
		780 h y^{-1} over mud
	B	1000 h y^{-1} over mud
Holy Loch		900 h y^{-1} over mud
Hunterston		82 kg y^{-1} fish
		41 kg y^{-1} Nephrops
		21 kg y^{-1} scallops
		860 h y^{-1} over sand and mud
Rosyth	A	2.7 kg y^{-1} crab
	B	1900 h y^{-1} over mud and sand
Sellafield	A	37 kg y^{-1} cod (75%) and plaice (25%)
		17 kg y^{-1} crab (50%), nephrops (10%) and lobster (40%)
		4.2 kg y^{-1} winkles (40%) and other molluscs (60%)
	B	1500 h y^{-1} handling nets and pots
	C (Whitehaven boat dwelling)	1100 h y^{-1} over mud
		35 kg y^{-1} cod and plaice
		23 kg y^{-1} winkles from north Solway

Table A3.2 continued

Site	Group[a]	Rates
Sellafield	D (farmers)	1900 h y^{-1} over saltmarsh (Rockcliffe)
	E (Whitehaven commercial)	57 kg y^{-1} plaice and cod
		21 kg y^{-1} Nephrops
		11 kg y^{-1} whelks
	F (Morecambe Bay)	See Heysham
	G (Fleetwood)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	H (Dumfries and Galloway)	38 kg y^{-1} fish
		15 kg y^{-1} Nephrops (50%), crabs (25%) and lobsters(25%)
		8.2 kg y^{-1} winkles and mussels
		1000 h y^{-1} over winkle beds
	I (Laverbread)	47 kg y^{-1} laverbread
	J (Trout)	6.8 kg y^{-1} rainbow trout
	K (typical fish consumer)	15 kg y^{-1} cod and plaice
	L (Isle of Man)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	M (Northern Ireland)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	N (angling)	1000 h y^{-1} over beaches and handling sediment
		28 kg y^{-1} cod and plaice
Sizewell		56 kg y^{-1} fish
		6.6 kg y^{-1} crustaceans
		3.8 kg y^{-1} molluscs
		260 h y^{-1} over mud
Springfields	A (boat dwelling)	3300 h y^{-1} over mud
	B	530 h y^{-1} handling nets
	C	360 h y^{-1} wildfowling
		16 kg y^{-1} wildfowl
	D	360 h y^{-1} angling
	E (warden)	730 h y^{-1} over saltmarsh
		550 h y^{-1} handling mud
	F	35 kg y^{-1} fish
		34 kg y^{-1} shrimps
		3.0 kg y^{-1} cockles and mussels
		5.1 kg y^{-1} samphire
		1100 h y^{-1} over sand
	G (farmers)	410 h y^{-1} over saltmarsh
Torness	A	58 kg y^{-1} fish
		11 kg y^{-1} crab and lobster
		10 kg y^{-1} Nephrops
		2.2 kg y^{-1} molluscs
	B	430 h y^{-1} over sand
	C	640 h y^{-1} over winkle beds
Trawsfynydd		1.8 kg y^{-1} Brown trout
		22 kg y^{-1} rainbow trout
		0.93 kg y^{-1} perch
		1000 h y^{-1} over lake shore
Upland lake		37 kg y^{-1} fish
Whitehaven		32 kg y^{-1} fish
		17 kg y^{-1} lobsters (40%) and crab (60%)
		3.0 kg y^{-1} winkles (20%) and mussels (80%)
Winfrith	A	77 kg y^{-1} cod
		26 kg y^{-1} crab
		39 kg y^{-1} whelks
	B	390 h y^{-1} over mud
Wylfa		94 kg y^{-1} fish
		23 kg y^{-1} crab
		1.8 kg y^{-1} molluscs
		370 h y^{-1} over sand

[a] *Where more than one group exists at a site the groups are denoted A, B, etc.*

APPENDIX 4. Dosimetric data

Radionuclide	Half Life (years)	Mean β energy (MeV per disintergration)	Mean γ energy (MeV per disintergration)	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-0
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 5. Estimates of concentrations of natural radionuclides

5.1 Aquatic foodstuffs

Table 5.1 gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis carried out by MAFF. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background. Similarly, natural levels of carbon-14 are subtracted when assessing exposures due to man-made sources of this radionuclide. The natural concentrations of carbon-14 are determined by measuring the carbon concentration in each sample and applying a specific activity of 250 Bq ^{14}C natural/kg C (Collins, *et al.*, 1995).

5.2 Terrestrial foodstuffs

The values of carbon-14 in terrestrial foodstuffs due to natural sources that are used in dose assessments are given in Table 5.2 (MAFF, 1995).

Table 5.1 Radioactivity in seafood due to natural sources

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

Table 5.2 Carbon-14 in terrestrial 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

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