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Radioactivity in Food and the Environment, 2005

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Scottish Environment Protection Agency

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Environment Agency
Radiological Monitoring and Assessment
Process Management
Lutra House, Off Seedlee Road, Walton Summit
Bamber Bridge
Preston PR5 8BX

Environment and Heritage Service
Industrial Pollution and Radiochemical Inspectorate
Calvert House
23 Castle Place
Belfast BT1 1FY

Food Standards Agency
Emergency Planning, Radiation and Incidents Division
Aviation House
125 Kingsway
London WC2B 6NH

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

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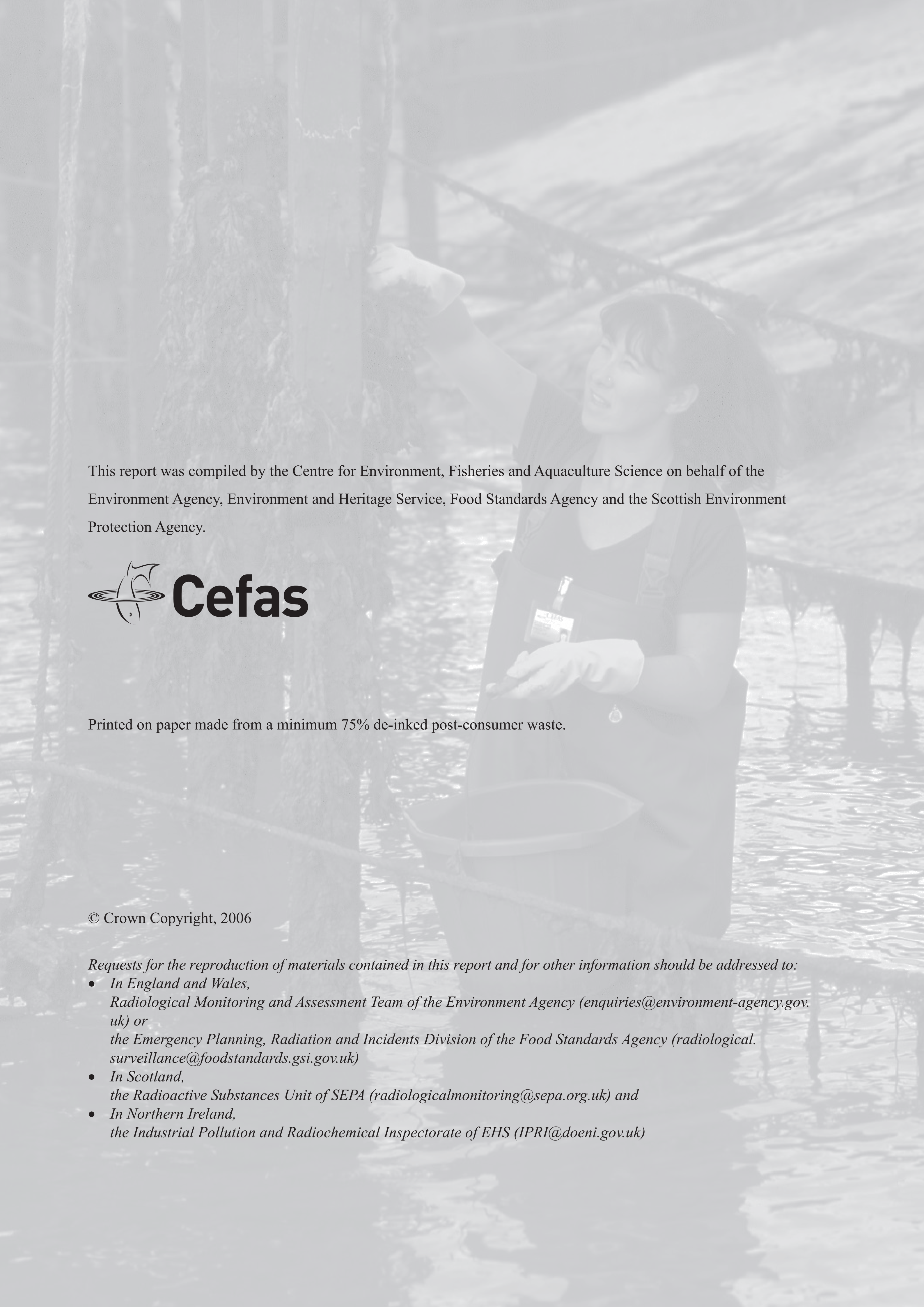

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PREFACE

Nuclear sites and other industries can create radioactive waste as a result of their routine operations. Some of the wastes are released into the air or discharged to water, the radioactivity can then enter the environment and from there the food chain. The releases and discharges are controlled by authorisations issued by the Environment Agencies. The Environment Agencies and the Food Standards Agency have separate monitoring programmes from the nuclear industry, permitting levels of radioactivity in the environment to be independently determined. These programmes allow us to check radiation exposures from food and the environment were within the legal limits. Our report presents the results of these nationwide monitoring programmes for 2005.

The main aims of our monitoring programmes are:

- to ensure that any radioactivity in food and the environment due to authorised radioactive releases and discharges did not compromise public health or the environment,
- to provide an independent check on data supplied from site operators,
- to provide an independent regular and comprehensive monitoring programme to assess the effects of radioactive releases and discharges,
- to establish long-term information on concentrations and trends so that any changes can be quickly identified and action taken if required.

Overall, the results from our monitoring programmes show that there was little change in radionuclide levels in food and the environment in 2005 compared with 2004. At many sites the levels of radionuclides remain close to, or below, limits of detection of the assessment techniques.

The 2005 monitoring data were used to make an assessment of doses to the public including, for the first time, prenatal children. In 2005, radiation doses to the public were similar to those seen in recent years and were well below national and European limits.

Reductions have been seen in environmental levels of radionuclides around many nuclear sites over the past 30 years. This is because of reduced discharges of gaseous and liquid wastes as a consequence of robust regulation, investment in treatment plants, closure of older plants and changes in practices. Examples include: cessation of reprocessing at Dounreay; the Enhanced Actinide Removal Plant and Site Exchange Effluent Plant treatment plants at Sellafield in the 1980's; and more recently diversion of wastes containing technetium-99 to the vitrification plant at Sellafield. Seven of the eleven Magnox stations are now closed. Gaseous and liquid discharges from Magnox nuclear power stations reduce or stop altogether once electricity generation ends and environmental levels are now beginning to fall around some of them. Significant reductions in levels of caesium-137 in samples have occurred around the Magnox station at Trawsfynydd, which is currently being decommissioned.

Further reductions in discharges will be required to conform with the Oslo and Paris Convention to which the UK is a signatory. The UK has also set out its strategy for radioactive discharges over the period 2001-2020. We intend to meet our obligations under the Oslo and Paris Convention and the related UK strategy by regulatory action and continuing to work with industry and the Nuclear Decommissioning Authority on their plans and integrated strategies and by regularly reviewing discharge authorisations.

In 2005, detailed investigations were carried out into localised radioactive contamination at Aberdeen Beach, Dalgety Bay in Fife and Sandside Bay near Dounreay. A one-off investigation of naturally occurring radionuclides near Hartlepool was also carried out. Additionally, special sampling was also carried out at nuclear sites where short-term increases in discharges and inadvertent releases occurred.
In 2005, contaminated materials were removed from beaches at Aberdeen, Chapelcross and Dounreay. A food protection order placing restrictions on fishing and seafood collection around the Dounreay pipeline continued because of the presence of fragments of irradiated nuclear fuel in the sea.

In 2005, concentrations of radioactivity in food were all found to be below guidance levels except in sheep in upland areas across Cumbria, Scotland and Wales, which are still affected by the 1986 Chernobyl accident. The number of farms affected by post-Chernobyl controls has reduced from 9700 in 1986 to 374 at the start of 2006.

As part of our continuing programme to assess total radiation doses to the public from all relevant pathways of exposure, arising from such discharges, specific assessments were made at fifteen sites, up from eleven in 2004. Our total dose assessments took into account exposures from radionuclides in food and the environment and from direct radiation from the nuclear sites where it occurs. At all fifteen sites, total doses to the public were confirmed as being well below the national and European dose limit for members of the public.

TECHNICAL SUMMARY

The technical summary is divided into sections which bring out the highlights within the report under a number of topics. These topics are:

- radiation exposures (doses) to people living around nuclear sites,
- radioactivity levels (activity concentrations) in samples collected around nuclear sites,
- external dose rates as a result of direct radiation from sediments, etc.,
- site incidents and non-routine surveys, and finally,
- radiation exposures and radioactivity levels at other UK locations not associated with nuclear sites.

Radiation exposures around nuclear sites

In 2005, radiation doses to people living around nuclear sites remained well below national and European limits.

Assessed doses for the most-exposed groups of the public near all major sites in the UK are shown in Figure S and listed in the Summary Table.

The highest dose was received by a group of high-rate consumers of fish and shellfish in Cumbria and estimated to be 0.46 milliSieverts (mSv) in 2005. This dose resulted from the combined effects of current and past liquid discharges from Sellafield and from past liquid discharges from the phosphate processing plant at Whitehaven. The dose to these consumers (which includes the contribution from external doses) from Sellafield discharges was estimated to be 0.22 mSv in 2005, the same as the dose in 2004. Most of the seafood and external exposure doses that can be attributed to Sellafield were from historic liquid discharges of caesium-137, plutonium isotopes and americium-241. Recent and current discharges of technetium-99 contributed 0.013 mSv, which was around 6% of the 0.22 mSv dose to the Sellafield seafood consumers, a reduction from 2004 when technetium-99 contributed 12% of the dose. This was due to lower concentrations of technetium-99 in seafood.

Although liquid radioactive discharges from Sellafield, particularly of technetium-99 have reduced in recent years, in some cases there has been a trend of increasing doses amongst seafood consumers. The dose to some groups has increased by 75% since 2000. This trend has been driven largely by the increasing amount of seafood eaten by local consumers around Sellafield, rather than an increase in concentrations of radionuclides in seafood. This trend has slowed in 2005. In addition to the dose from Sellafield discharges, the same group of consumers also received 0.23 mSv from so called technologically enhanced naturally occurring radionuclides due to previous industrial operations at the phosphate processing works at Whitehaven. This is a reduction from 0.41 mSv in 2004 due to reduced concentrations of these radionuclides in the environment. Taken together, the total dose to the seafood consumers group was 0.46 mSv* in 2005, which is well within the EU and UK limit for members of the public of 1 mSv per year.

In terms of radiation exposure, the second most significant group of people were those living near Dungeness nuclear power stations. Their dose was 0.11 mSv, the same as in 2004. Most of the dose was from the gaseous plume formed from discharges of argon-41, mainly from Dungeness A.

At Heysham, it was estimated that high-rate seafood consumers received 0.063 mSv, with most of this attributable to Sellafield discharges.

The next most significant power station site in terms of public dose was at Sizewell where gaseous discharges gave consumers a dose of 0.057 mSv.

** The 0.22 mSv (artificial radionuclides) and the 0.23 mSv (technologically enhanced naturally occurring radioactive material radionuclides) do not appear to add up to 0.46 mSv for the overall dose. They are expressed as two significant figures but when further significant figures and rounding are taken into consideration the overall dose is 0.46 mSv.*

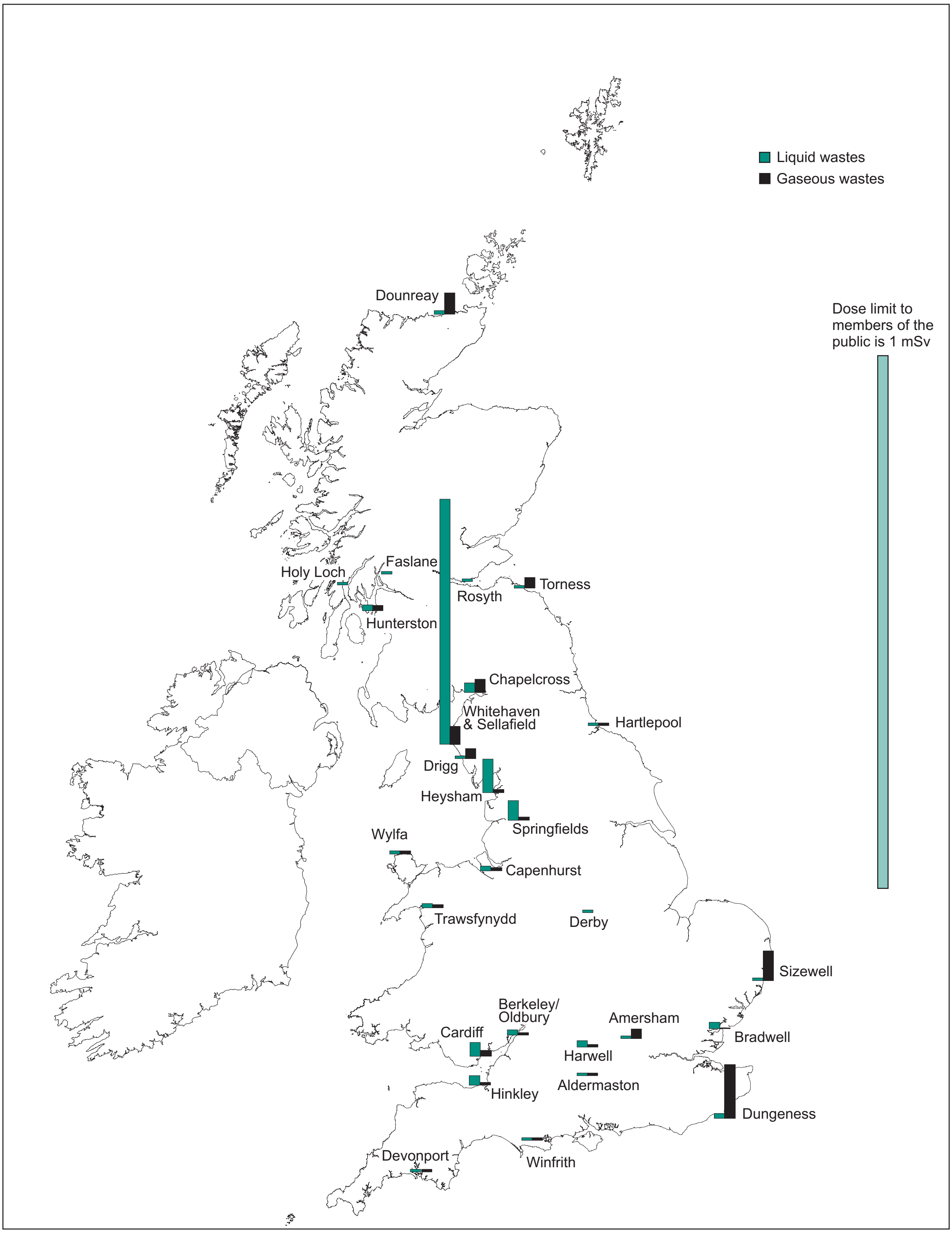


***Figure S. Radiation exposures in the UK due to radioactive waste discharges, 2005** (Exposures at Whitehaven and Sellafield are mostly due to technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)*

Summary Table: Radiation doses due to discharges of radioactive waste in the United Kingdom, 2005

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[g]	L	0.009	Ext ^{237}Np
	Terrestrial foods[i]	G	<0.005	
Springfields	External (skin) to fishermen	L	0.44[f]	Beta
	Fish and shellfish consumption	L	0.023	^{137}Cs ^{241}Am
	Terrestrial foods	G	<0.005[h]	^{90}Sr
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{234}Th
	Occupancy of houseboats[a]	L	0.037	Ext ^{241}Am
	External in intertidal areas (anglers)	L	0.007	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2001-2005 surveys) (excluding naturally occurring radionuclides)[k]	L	0.22	$^{239/240}Pu$ ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2001-2005 surveys) (including natural occurring radionuclides)[l]	L	0.46	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2005 surveys)	L	0.23	$^{239/240}Pu$ ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.034	^{90}Sr ^{106}Ru
	Terrestrial foods at Ravenglass[i]	G/L	0.018	
	External in intertidal areas (Ravenglass)[a]	L	0.036	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)[a]	L	0.037	Ext ^{241}Am
	External (skin) to bait diggers	L	0.26[f]	Beta
	Handling of fishing gear	L	0.066[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield	L	0.069	^{99}Tc
Research establishments				
Culham	Water consumption[n]	L	<0.005	
Dounreay	Fish and shellfish consumption	L	<0.005	^{90}Sr ^{241}Am
	External in intertidal areas	L	0.007	Ext
	Terrestrial foods[g]	G	0.040	
Harwell	Fish consumption and external to anglers	L	0.012	Ext
	Terrestrial foods[i]	G	<0.005	
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.018	Ext
	Terrestrial foods[i]	G	0.025	^{3}H
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.008	Ext ^{241}Am
	Occupancy of houseboats	L	0.009	Ext
	Terrestrial foods, external and inhalation near site[o]	G	0.11	^{14}C ^{41}Ar
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.063	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{35}S ^{137}Cs
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.018	Ext ^{3}H
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption	L	<0.005	^{137}Cs ^{241}Am
	External in intertidal areas	L	0.011	Ext
	Terrestrial foods[i]	G	0.010	^{35}S ^{90}Sr

Summary Table: continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear power production *continued*				
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	0.057	^{14}C ^{41}Ar
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods[i]	G	0.020	^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.008	Ext ^{137}Cs
	Terrestrial foods[i]	G	0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.006	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005	Ext ^{137}Cs
	Terrestrial foods	G	<0.005[h]	
Derby	Water consumption[n]	L	<0.005	
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
	Terrestrial foods	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	L	<0.005	Ext
Rosyth	Fish and shellfish consumption	L	<0.005	Ext
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.018	^{75}Se ^{222}Rn
Cardiff	Fish and shellfish consumption[o] and external in intertidal areas	L	0.027	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.011	^{14}C ^{32}P
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	Ext ^{137}Cs
Industrial and landfill				
Drigg	Terrestrial foods[i]	G	0.019	^{90}Sr
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.23	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.46	^{210}Po ^{241}Am

[a] *Includes a component due to inadvertent ingestion of water or sediment or inhalation of resuspended sediment where appropriate*

[b] *Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv (see section 3). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. Unless stated otherwise, the critical group is represented by adults*

[c] *The top two contributors to the dose; either 'ext' to represent the whole body external exposure from beta or gamma radiation, 'beta' for beta radiation of skin or a radionuclide name to represent a contribution from internal exposure. Some assessments for contributions are based on data being wholly at limits of detection. Where this is the case the contributor is not listed in the table. The source of the radiation listed as contributing to the dose may not be discharged from the site specified, but may be from those of an adjacent site or other sources in the environment such as weapons fallout*

[d] *Dominant source of exposure. G for gaseous wastes. L for liquid wastes or surface water near solid waste sites. See also footnote 'c'*

[e] *The estimates for marine pathways include the effects of liquid discharges from Drigg. The contribution due to Drigg is negligible*

[f] *Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see section 2)*

[g] *10 y old*

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

[i] *1 y old*

[j] *Excluding the effects of artificial radionuclides from Sellafield*

[k] *Excluding the effects of enhanced concentrations due to the legacy of discharges of naturally occurring radionuclides from a phosphate processing works, Whitehaven*

[l] *Including the effects of enhanced concentrations due to the legacy of discharges of naturally occurring radionuclides from a phosphate processing works, Whitehaven*

[m] *Including the effects of artificial radionuclides from Sellafield*

[n] *Water is from rivers and streams and not tap water*

[o] *Prenatal children*

Other significant sites in terms of doses included Springfields in Lancashire, where people living in houseboats in the Ribble estuary received 0.037 mSv in 2005. Most of this was from Sellafield-derived radionuclides in intertidal sediments.

The next highest dose was due to gaseous discharges from Sellafield and was 0.034 mSv, slightly less than the dose in 2004 of 0.036 mSv. Doses were assessed for people that consumed crops grown on land fertilised by seaweed from around Sellafield. Using maximising assumptions, the estimated dose for 2005 was 0.069 mSv.

Relatively high concentrations of tritium were found in food and the environment near GE Healthcare at Cardiff, where radiochemicals for life sciences are produced. The critical age group was prenatal children, considered formally for the first time in this year's report following new recommendations from the Health Protection Agency. Their dose was 0.027 mSv in 2005. The dose to adults in 2005, which is the next most important age group at Cardiff, was 0.020 mSv compared to 0.029 mSv in 2004. Most of the doses were due to the consumption of fish from the Severn Estuary containing tritium and carbon-14. The reduction in adult dose from 2004 was due to lower discharges of tritium from GE Healthcare at Cardiff.

The highest exposures in Scotland were to the group of terrestrial food consumers at Dounreay who received an annual dose of 0.040 mSv. In 2004, this group was estimated to have received a dose of 0.008 mSv. The increase was not due to a detected increase in concentrations or dose rates in the environment. It was largely due to an increase in the analytical limit of detection for iodine-129 in samples from the local area.

The dose estimates above apply to discharges from nuclear and other sites. There is another source of public radiation exposure near some of these facilities. This is radiation coming directly from operations on the sites. The Health and Safety Executive, which is the relevant regulatory authority, has provided estimates of direct radiation doses at sites in the UK, using information from the site operators.

In 2003, a new method was introduced to assess the total radiation dose to the public around the UK's nuclear sites, including for the first time doses from direct radiation. In 2005, total dose at 15 nuclear sites was assessed. For transparency, the data used in the total dose calculations have been included in the attached compact disc. In 2005, the total doses at these 15 sites were all less than the EU limit of 1 mSv per year. The number of these types of site assessments will be extended to all sites in future Radioactivity in Food and the Environment reports, as the required data become available.

Radioactivity levels in samples collected around nuclear sites

The preceding section highlighted any changes in doses in 2005, but this was not necessarily due to variations in concentrations of radioactivity in samples. Some changes in doses were the result of changes in consumers' diets for instance; others were due to reductions in concentrations of radionuclides.

This section summarises any changes in levels of radioactivity in food or environmental materials. In general, there were no major changes in levels of radioactivity in food or environmental materials in 2005, as compared to those in 2004.

The UK Radioactive Discharge Strategy was published in 2002. It describes how the UK will implement the agreements of the 1998 and later meetings of the Oslo and Paris Convention. One of the aims is to progressively and substantially reduce the amount of liquid radioactive discharges and discharge limits. This means that nuclear sites need action plans to achieve these goals, which will have a real impact on the amount of radioactive materials in the environment in future years. In 2005, the Environment Agency and the Scottish Environment Protection Agency took steps towards introducing more stringent conditions on radioactive waste disposal from Dounreay, Harwell, Winfrith, Drigg, Aldermaston, Burghfield and all nuclear power stations.

During 2005, discharges of technetium-99 from Sellafield were reduced very substantially due to successful operation of new abatement technology. Discharges are expected to remain low in future years. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and the North Sea. Levels of technetium-99 and ruthenium-106 showed a systematic decrease from those in 2004. Sea-to-land transfer of technetium-99 occurred on a small scale via the harvesting of seaweed for use as a soil conditioner and fertiliser. However, there was no evidence of a pathway for significant transfers of technetium-99 to man through animals feeding on seaweed. Further research on this topic is planned.

Concentrations of tritium in seafood near Cardiff remained at more than 10,000 Bq kg^{-1} (fresh weight) for flounder, although some reductions were noted compared to 2004. Tritium concentrations in seafood at other coastal locations around the UK were above the expected background tritium concentration of 1 Bq kg^{-1} showing the effect of some bioaccumulation. However, the degree of this bioaccumulation was of little significance and much lower than the levels found near Cardiff.

Abatement technology is also being introduced at Cardiff. A plant is being commissioned (the Paragon project) to recycle most of the site's unused carbon-14 and tritium, which currently has to be discharged or stored as waste. This will reduce discharges of organic tritium to the environment and should result in lower concentrations of tritium around Cardiff in the future.

Marine sediment samples are a useful indicator of trends in the environment. The radionuclide content of the sediments is also a source of external radiation to people who spend time on beaches. Near Sellafield, the environmental concentrations of most radionuclides have declined substantially over the last 20 years. In recent years, there has been a small increasing trend in the concentrations of caesium-137, plutonium isotopes and americium-241 in some mud samples near Sellafield. The trend is not associated with changes in discharges. For americium-241, there is a contribution due to 'in-growth' from plutonium-241 in the environment. Remobilisation of historical sediments containing higher activity concentrations or the increased presence of finer-grained sediments with high activity concentrations will also play a part in this trend. The increases are small and are not readily observed in fish and shellfish samples from Cumbria.

Releases of argon-41 gas from Dungeness 'A' and Sizewell 'A' Magnox power stations continued to have a significant local effect on concentrations in air near the station. As it is not practicable to monitor for argon-41, estimates of the effects of the discharges are made using dispersion modelling. These stations are scheduled to close at the end of 2006, when the discharges of argon-41 should cease.

Dose rates from around nuclear sites

Sediments in intertidal areas can make a significant contribution to the total exposure of members of the public. These external doses, as opposed to internal doses from ingested or inhaled radioactivity, are assessed by measuring dose rates.

No major changes in external dose rates in intertidal areas were found in 2005 compared with 2004. However some dose rates near Sizewell increased in the immediate vicinity of the power station, where direct radiation is known to have an effect.

Nuclear site incidents and non-routine surveys

There were nine occasions in 2005 where special sampling was required as a result of nuclear site operations.

During 2005, further fragments of irradiated nuclear fuel were recovered near Dounreay. Seven fragments of irradiated nuclear fuel were recovered from the site foreshore, one from Dunnet beach, five from Sandside Bay and 83 from the seabed near to the Dounreay site. The fishing restrictions under the Food and Environment Protection Act 1985 are therefore still in force.

There were seven other occasions where 'special' sampling (referred to as *ad hoc* sampling) was required because of concerns raised about site operations or because of higher than normal discharges, triggering reporting procedures that are a condition of the operator's authorisation. Most cases involved higher than normal gaseous releases of radioactivity. These cases occurred at Chapelcross, Dungeness, Hinkley Point, Oldbury, Sellafield and Wylfa. Generally, samples in the routine monitoring programme were collected earlier, and analysed more quickly than scheduled. No increases above normal levels were detected at any of the sites except at Sellafield where elevation in activity levels was very small, and at Chapelcross where radioactive particles of limescale were removed from beaches. In both of these cases, the increases were small and had negligible effects on local public radiation doses.

Ad hoc sampling was also required at Hartlepool to try and establish the extent of the enhancement of naturally occurring radionuclides from sources other than the nuclear power industry. Enhanced gamma dose rates have been observed for some time on the south bank of the Tees near Hartlepool. This year sampling and analysis of seafood, sediment and seaweed was extended for naturally occurring radionuclides. The results confirmed earlier findings of a local increase in gamma dose rates. However, with the exception of carbon-14, no widespread increase in concentrations of naturally occurring radionuclides in seafood was found. The concentrations observed were within the range expected in normal circumstances in the UK environment.

In 2005, the diets and occupancy habits of people near nuclear sites at Chapelcross, Dungeness, Sizewell, Sellafield, Rosyth and Trawsfynydd were surveyed. The results were used to update radiological assessments of the monitoring programmes.

Radiation doses and levels at other locations in the UK

Food and drinking water in the general diet and in sources of public drinking water were analysed across the United Kingdom. Results showed that radioactivity from naturally occurring sources was the most significant source of exposure to communities in areas remote from nuclear sites. Man-made radionuclides only contributed a small proportion of the total public radiation dose in general diet.

Monitoring artificial radioactivity on the Isle of Man and in Northern Ireland showed that consumer doses were all less than 3% of the annual limit of 1 mSv. A survey on the Channel Islands confirmed that doses due to discharges from the French reprocessing plant at Cap de la Hague and other local sources were less than 1% of the limit.

As mentioned earlier, concentrations of naturally occurring radionuclides in fish and shellfish near the site of past phosphate processing in Whitehaven continued to be elevated above expected ranges. Phosphogypsum used to be discharged from this site as liquid slurry and contained thorium and uranium in concentrations enhanced above natural background levels. This waste is called Technologically enhanced Naturally Occurring Radioactive Material. This site stopped operating at the end of 2001 and the plant has subsequently been demolished. The dose to high-rate seafood consumers, including the effects of artificial radionuclide discharges from the Sellafield site nearby, was estimated to be 0.46 mSv for the critical group. The contributions from artificial and technologically enhanced naturally occurring radioactive material radionuclides were 0.22 and 0.23 mSv, respectively. These figures are presented to two significant figures so do not appear to add up to 0.46 mSv but when further significant figures and rounding is taken into considerations they do.

The programme of monitoring the effects of enhanced levels of radioactivity at other non-nuclear sites was focused on Dalgety Bay in Fife and Aberdeen Harbour. At Dalgety Bay, environmental monitoring of intertidal areas confirmed earlier findings of items containing radium-226. These items were removed and it was recommended that public notice signs be erected in the area by the local authority to inform people of the potential hazard on the beach. The source of these items is not certain but it is likely to be due to wastes generated from past military operations at the Donibristle naval airbase, which closed in 1959. The data from the most recent monitoring exercise was used to produce a screening risk assessment, which is available on the SEPA website (http://www.sepa.org.uk/radioactivity/publications.htm).

At Aberdeen, monitoring of local beaches found a localised area, about 50 metres by 25 metres, where dose rates were up to approximately 10 times higher than normal background levels and concentrations of naturally occurring radionuclides in surface sediments were also enhanced. The increase in dose to people using the beach regularly was estimated to be less than 0.1 mSv in 2005. It was not considered necessary to close the beach on public health grounds. Some of the contaminated sand was removed.

Enhanced levels of tritium were found in leachate from some landfill sites but only at levels that were of very low radiological significance. It is thought this is due to past disposals of gaseous tritium light devices, such as fire exit signs and other similar items.

A programme of monitoring of the effects of the Chernobyl accident continued in 2005. Some upland areas of the UK still have restrictions on the movement, sale and slaughter of sheep.

Monitoring of distributions of radionuclides in coastal seas away from nuclear sites continues. This supports the UK's marine environmental policies and international treaty commitments. Government research vessels are used in the sampling programme and the results have been used to show trends in the quality status of the UK's coastal seas. These surveys, together with the results of monitoring at nuclear sites, form an essential evidence base for the UK submissions to the OSPAR Commission, under an international convention to prevent pollution of the seas of the north-east Atlantic. They also help measure progress towards the UK Government's targets for improving the state of our seas.

The monitoring programmes and additional research

The monitoring programmes in this report involved the collaboration of seven specialist laboratories, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised by the Environment Agency, the Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency and are independent of the industries discharging radioactive effluents. The programmes include monitoring on behalf of the Scottish Executive, Channel Island States, the Department for Environment, Food and Rural Affairs, the Manx Government and the Welsh Assembly Government. Overall, we completed around 20,000 analyses or dose rate measurements in 2005.

The results of the analysis of food samples collected near nuclear sites in England and Wales are published as quarterly summaries on the Food Standards Agency's website (www.food.gov.uk). There is more information about all programmes described in this report from the sponsoring agencies. Details of how to contact them are on the inner front cover and on the back cover.

The routine monitoring programmes were supported by a number of research studies investigating specific issues such as the behaviour of organically bound tritium in the marine environment. Results of the completed studies are in Section 10. The agencies are also funding work to improve the methods for estimating public exposure including site-specific surveys of people's dietary habits and way of life.

A summary of the research and links to the results are provided in the report.

1. INTRODUCTION

1.1 Background

This report contains the results of programmes for the radiological monitoring of food, environmental materials and dose rates in 2005 throughout the United Kingdom (UK), the Channel Islands and the Isle of Man. The results of the programmes have been assessed by the Centre for Environment, Fisheries and Aquaculture Science (Cefas) on behalf of the Environment Agencies, the Food Standards Agency, the Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, the Welsh Assembly Government, the Manx Government and the Channel Island States.

The purpose of the programmes is to demonstrate that any radioactivity present in foods does not compromise food safety and to check that public radiation exposure more generally is within national and international limits. The data reported here are also used to assess the environmental impact of radioactive discharges. The effect of changes in discharges from industry and in radiological pathways is taken into account.

The Food Standards Agency has responsibility for food safety throughout the UK. The Environment Agency, the Environment and Heritage Service and the Scottish Environment Protection Agency (SEPA), referred to collectively as the Environment Agencies in the report, are responsible for environmental protection matters in England and Wales, Northern Ireland and Scotland respectively. They act as regulators of radioactive waste disposal under the Radioactive Substances Act 1993 (United Kingdom - Parliament, 1993). The Environment Agency and the Scottish Environment Protection Agency also have a broad responsibility (under the Environment Act 1995 (United Kingdom - Parliament, 1995a)) for protecting (and determining general levels of pollution in) the environment.

The monitoring undertaken by the Environment Agencies and the Food Standards Agency is independent of monitoring programmes carried out by nuclear site operators as a condition of their authorisations to discharge radioactive wastes. Results from the monitoring programmes are used as a check on the monitoring programmes undertaken by the site operators. The majority of the report concerns the local effects of discharges from nuclear sites in the UK. 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 foods, environmental materials and dose rates in areas of the UK remote from nuclear sites, are 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. The most recent summary of the scope of all radioactivity monitoring programmes undertaken by nuclear site operators and local and central government can be found in the report from Department of the Environment, Transport and the Regions (2001).

The Commission of European Communities is undertaking a review of the implementation of Article 35 of the Euratom Treaty to which the UK is a signatory. This Article requires member states to have facilities to carry out monitoring for radioactivity and empowers the Commission to verify the operation and efficiency of these facilities. The aim of the review is:

(i) to produce guidance on the monitoring of discharges and their impact on the environment,
(ii) to produce a methodology for the Commission to use when verifying facilities in member states and
(iii) more generally, to consider improvements in the harmonised application of Article 35 throughout the Euratom Community.

The first stage of the review has begun and member states have been asked to provide detailed information to the Commission on the scope of the facilities they employ to monitor radioactivity. The Environment Agency and the Food Standards Agency have published their response in a report which summarises the scope of their monitoring for radioactivity in England and Wales (Rowe *et al*., 2005).

1. Introduction

To place the monitoring results from the programme in context, radioactive waste discharges from nuclear establishments in the UK for 2005 are addressed first in Section 1.2. An explanatory section follows giving details of methods of sampling and analysis and explains how results are interpreted in terms of public radiation exposures. In general, the doses reported around each nuclear establishment are for the critical group, i.e. those who receive the largest dose from artificially produced radionuclides due to their habits, diet or where they spend their time. Where practicable, the estimated doses exclude the dose from natural background radiation (see Section 2 and Appendix 6). Direct radiation from nuclear facilities is the primary regulatory responsibility of the Health and Safety Executive (HSE). The report considers the additivity of doses from direct radiation with doses from other pathways for most sites where data are available (see Appendix 7). The doses are compared with the annual limit for members of the public of 1 mSv applicable for controlled releases of radioactivity from artificial sources (see Section 2) and would be in addition to the average annual UK dose of approximately 2.2 mSv received by individual members of the public due to natural (uncontrolled) radiation (Watson *et al*., 2005). Dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP), which are embodied in EU and UK law.

A glossary of abbreviations is provided in Appendix 3.

This report primarily considers the effects of the UK nuclear industry and its discharges that affect the public at large. Radiation exposures to workers and from other sources such as medicine and radon in homes have been reviewed every few years, the most recent being published in 2005 (Watson *et al*., 2005).

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

As part of their operations, discharges of radioactive wastes as liquids and/or gases are made from nuclear sites in the UK. In addition, solid low-level wastes (LLWs) from nuclear sites can be transferred to the low-level waste repository (LLWR) at Drigg for disposal. These discharges and disposals are authorised by the Environment Agencies in the UK under the Radioactive Substances Act 1993 (RSA 93) (United Kingdom - Parliament, 1993). Details of discharges and disposals are available from public records held by the Environment Agencies. A summary of the discharges during 2005 from the nuclear sites and disposals at the low-level waste repositories at Drigg and Dounreay is included in Appendix 1.

The sites that are the principal sources of waste containing man-made radionuclides are shown in Figure 1.1. The programmes reported here include monitoring at each of these sites. For completeness, it should be noted that discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also authorised under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993) but are not subject to the Nuclear Installations Act 1965 (United Kingdom - Parliament, 1965). Occasionally, the presence of radioactivity in the environment resulting from such discharges is detected within this programme. For example, iodine-131 originating from hospitals is occasionally detected in some marine samples. Small amounts of very low-level solid waste are also disposed of in specified landfill sites. There is also a significant radiological impact due to the legacy of past discharges of naturally occurring radionuclides from the non-nuclear site at Whitehaven and monitoring is therefore undertaken near this site. Discharges from other non-nuclear sites are generally considered insignificant and as such environmental monitoring of their effects is usually not required. However, this situation is reviewed from time to time and where appropriate surveys are included in the programme. Discharges of radioactive substances by the non-nuclear industry into the sea have been reviewed by the members of the Oslo and Paris (OSPAR) Convention (OSPAR, 2002).

Appendix 1 presents the principal discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2005. The tables also list the discharge and disposal limits that are authorised or, in the case of the Ministry of Defence (MoD),

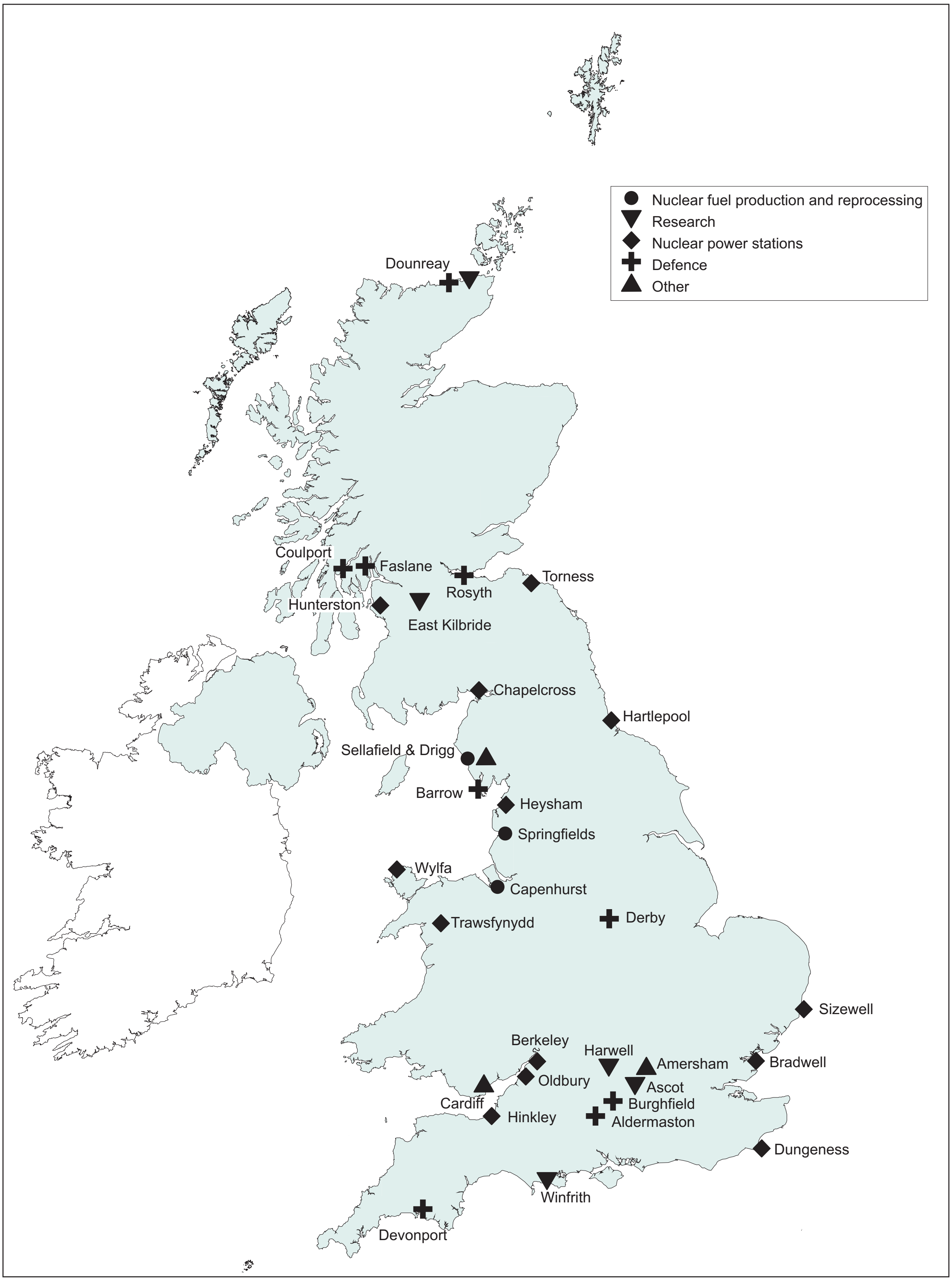


***Figure 1.1** **Principal sources of radioactive waste disposal in the UK.** (Showing main initial operation. Some operations are undergoing decommissioning)*

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 very much lower than discharge levels that would result in a dose equal to the 1 mSv dose limit. In addition, the authorisations require the use of best practicable means to minimise discharges still further; in practice actual discharges are often well below the authorised (or agreed) limits. The percentages of the authorised (or agreed) limits actually discharged in 2005 are also stated in the tables.

Where changes in discharge in 2005 have affected the levels of radioactivity in the environment, this is discussed in the relevant section of the report.

The discharges and disposals made by sites are in general fairly regular and consistent in each year. However, from time to time there may be unplanned events that cause unintended leakages, spillages or other emissions that are different to the normal or expected pattern of discharges. Such events are normally reported to the Environment Agencies and may lead to follow up action, including reactive monitoring by the site, the Environment Agencies or the Food Standards Agency. In cases where there has been a breach of authorisations, regulatory action may be taken. The events of this type in 2005 are summarised in Table 1.1. Where monitoring was initiated as a consequence of these events, the results are presented and discussed in the relevant site text later in this report.

1.2.2 International agreements and the UK discharge strategy

This subsection presents information on the context of UK radioactive discharges as they relate to international agreements. The UK has ratified the OSPAR Convention, which provides a framework for the prevention and elimination of pollution in the north-east Atlantic, including the seas around the UK (OSPAR, 2000a).

In July 1998, the Ministers of the UK government agreed a long term radioactive discharge strategy and signed the Sintra Statement which included the following commitment (OSPAR, 1998):

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

In July 2002, a UK strategy for radioactive discharges was published (Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). This provided a description of how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the strategy relate to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes. They are:

- progressive and substantial reduction of radioactive discharges and discharge limits. Targets for each industrial sector are set out.
- progressive reduction of human exposure to ionising radiation arising from radioactive discharges such that critical group doses will be less than 0.02 mSv from liquid discharges to the marine environment as a result of discharges made from 2020 onwards.
- progressive reduction of concentrations of radionuclides in the marine environment resulting from radioactive discharges such that by 2020 they add close to zero to historic levels.

The strategy stated that due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target would be set for this industrial sector, presuming that these discharges would continue to be tightly controlled and reduced wherever practicable. The Scottish Executive has consulted on its Statutory Guidance to be issued to SEPA on the application of the Strategy in Scotland (Scottish Executive, 2005). The Statutory Guidance will be issued in 2006.

Information on work in progress within the OSPAR Convention can be found on the OSPAR website (www.ospar.org). A recent report from the OSPAR Radioactive Substances Committee records work completed and planned relating to reporting of discharges, environmental measurements, standards and quality assurance (OSPAR, 2005). It also considers the relationship between OSPAR and its work on radioactivity and the separate initiative to develop a European Marine Strategy. An agreement has been reached on the basis for future monitoring of relevance to OSPAR by Contracting Parties (OSPAR, 2006). The programme includes sampling in fifteen divisions of the OSPAR maritime area and is supported by procedures for ensuring quality control. The European Commission (EC) has considered various options for a new policy instrument concerning the protection and conservation of the marine environment and has proposed that a binding legal commitment is required - a Marine Strategy Directive (Commission of the European Communities, 2005). Member states and the Commission are considering how best to take this initiative forward.

A UK technical report has assessed key marine indicators for study within the OSPAR context (Smith, 2002). The UK has also undertaken a modelling study to provide information to support implementation of the discharge strategy (Jones *et al*., 2003). The EC has published a full assessment of the radiological exposure of the European Community from radioactivity in North European marine waters (Commission of the European Communities, 2002).

The importance of taking an integrated approach to stewardship of the marine environment has been recognised in the UK and the strategy to achieve this aim has been published (Department for Environment, Food and Rural Affairs, Department of Environment, Northern Ireland, Scottish Executive and Welsh Assembly Government, 2002). The report "Safeguarding Our Seas" considers conservation and sustainable development of the marine environment and sets out how the UK is addressing those issues in relation to radioactive and other substances and effects. The UK completed a fully integrated assessment of the marine environment in 2005 (Department for Environment, Food and Rural Affairs, 2005a and 2005b; Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005).

The offshore oil and gas industry is the largest sector, in terms of the number of authorisations held, regulated by SEPA under the Radioactive Substances Act 1993. The regulatory approach to this sector was founded on the regulator's knowledge of the industry in the 1980's and the operational practices and environmental standards that prevailed at that time. SEPA has begun a review of the regulation of this sector and have published proposals designed to ensure (i) that the environment continues to be protected within the existing legislative and policy framework and (ii) that unnecessary bureaucratic burdens are removed (Scottish Environment Protection Agency, 2005). An assessment of alternative disposal options for radioactive oilfield wastes has been completed (Scottish and Northern Ireland Forum for Environmental Research, 2005).

The UK has ratified the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (International Atomic Energy Agency, 1997). This agreement aims to ensure that individuals, society and the environment are protected from harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. UK's first national report, demonstrating compliance with the Convention, was provided to the International Atomic Energy Agency (IAEA) in May 2003 (Department for Environment, Food and Rural Affairs, 2004a). An updated UK national report was submitted to the IAEA in October 2005 (Department for Environment, Food and Rural Affairs, 2005c).

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up by the introduction of legislation. The Energy Act 2004, which was enacted on 22nd July 2004, has enabled the establishment of the Nuclear Decommissioning Authority (NDA) which began operation in April 2005. The NDA has taken responsibility for nuclear sites currently operated by British Nuclear Fuels (BNFL), including ownership of its assets and liabilities, and United Kingdom Atomic Energy Authority (UKAEA). It is responsible for developing and implementing an overall strategy for cleaning up the civil public sector nuclear legacy safely, securely and in ways that protect the environment. The first strategy has been published following a consultation exercise in 2005 (Nuclear Decommissioning Authority, 2006). The legislation has also provided for improvements to the Radioactive Substances Act 1993, by streamlining the regulatory processes for transferring radioactive waste discharge authorisations relating to nuclear sites.

Whilst some low-level solid radioactive wastes are currently disposed of to landfill (see Section 8), there remains a considerable backlog of wastes which are being stored safely on nuclear sites. The existing policy for the management of low-level wastes is set out in the Government's 1995 White Paper, Cm 2919 (United Kingdom - Parliament, 1995b). There are now proposals for the long term management of such wastes and it is expected that the Government will issue a new policy following completion of a public consultation exercise (Department for Environment, Food and Rural Affairs, 2006).

In 2000, the Water Framework Directive (WFD) took effect (Commission of the European Communities, 2000b). Subsequently, legislation was enacted to transpose the Directive in the UK (see for example United Kingdom - Parliament, 2003). Defra, the Scottish Executive, Welsh Assembly Government and the Department of the Environment Northern Ireland have policy responsibility for the implementation of the WFD in the UK. Implementation is largely the responsibility of the Environment Agencies as competent authorities.

The aim of the Directive is to improve the quality of the aquatic environment of the European Community. It provides a framework for member states to work within and establishes a planning process with key stages for development towards reaching "good status" by 2015 for inland and coastal waters. The UK has undertaken the first stage which involved characterising the quality of freshwater, estuarine and coastal environments of the UK paying particular attention to describing ecosystems and to reviewing the presence of hazardous substances (Department for Environment, Food and Rural Affairs, 2005d). In relation to radioactivity, the Environment Agencies have characterised the aquatic environment using a screening tool which forecasts the environmental impact of radioactive waste sources. The outcome of the assessment has been published and provided to the Commission (Environment Agency, 2005a). Subsequent stages within this framework involve the design and implementation of monitoring programmes optimised to reflect the results of the initial characterisation, a subsequent review of environmental quality made with the benefit of the output from the monitoring programmes, the development of standards and the production of management plans to attain an improved environmental status for the UK aquatic environment.

1.2.3 Radioactive waste disposal at sea

In the past, disposals of packaged solid waste of low specific activity were mainly made to an area of the deep Atlantic Ocean. The last such disposal was in 1982. The UK Government announced the permanent cessation of disposal of such material at sea at the OSPAR Ministerial meeting in 1998. At that meeting, Contracting Parties agreed that there would no longer be any exception to a prohibition on the dumping of radioactive substances, including wastes (OSPAR, 1998). The environmental impact of the deep ocean disposals was predicted by detailed mathematical modelling and has been shown to be negligible (Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 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 2005 are presented in Section 9. They confirm that the radiological impact of these disposals was insignificant.

In the UK, Defra, Department of the Environment for Northern Ireland, Scottish Executive and National Assembly for Wales issue licences to operators for the disposal of dredge material under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom - Parliament, 1985). Since these dredge materials may contain radionuclides a small programme is run to analyse for naturally occurring and artificial radionuclides. This programme is discussed in Appendix 8. Results show that all exposures were very low.

1.2.4 Other sources of radioactivity

There are several other man-made sources of radioactivity that may affect the food chain and the environment. These include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas nuclear installations and the operation of nuclear powered submarines. Submarine berths in the UK are monitored by the MoD (DSTL, 2005). General monitoring 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 2005. Low levels of radionuclides were detected in the marine environment around the Channel Islands (Section 9) and these may be partly due to discharges from the nuclear fuel reprocessing plant at Cap de la Hague in France.

The Environment Protection Act 1990 provides the basis, through the Environment Act 1995, for a regulatory regime for the identification and remediation of contaminated land. Implementation of the regime has initially focused on non-radioactive contamination. However, Defra has now begun a consultation exercise to take forward implementation for land contaminated with radioactivity (Department for Environment, Food and Rural Affairs, 2006). The Scottish Executive and Welsh Assembly Government consulted on their proposals during 1995. Dose criteria for the designation of radioactively contaminated land have been published recently (Smith *et al*., 2006).

The contribution of aerial radioactive discharges from UK installations to concentrations of radionuclides in the marine environment has been studied (Department for Environment, Food and Rural Affairs, 2004b). The main conclusion was that aerial discharges do not make a significant contribution to levels in the marine environment. Tritium and carbon-14 were predicted to be at concentrations that were particularly high in relation to measured values in the Irish Sea. However, the study suggested that this was due to unrealistic assumptions being made in the assessment. On occasion, the effects of aerial discharges are detected in the aquatic environment, and conversely the effects of aquatic discharges are detected in the terrestrial environment. Where this is found, appropriate comments are made in this report.

All sources of ionising radiation exposure to the UK population have been reviewed every few years, the most recent being in 2005 (Watson *et al*., 2005). Sources of naturally occurring radiation and man-made radiation produced for medical usage predominate. The average annual dose from naturally occurring radiation was found to be 2.2 mSv and about half of this was from radon exposure indoors. The average annual dose from artificial radiation was 0.42 mSv, mainly derived from the use of x-rays in medical procedures. The overall average annual dose was 2.7 mSv. Exposures from non-medical man-made sources were very low and discharges of radioactive wastes contributed less than 0.1% of the total. These data represent the exposures of the average person. Much of the information in this RIFE report is directed at establishing the exposures of critical groups in the population who might have above average doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is these people who form the basis for comparisons with dose limits in EU and UK law.

1.2.5 Food irradiation

Food irradiation is a processing technique where food is exposed to ionising radiation in a controlled manner. The ionising radiation produces free radicals, which interact within the food to produce the desired effect. It does not make the food radioactive. The ionising radiation is either generated by machine, as is the case for electron beams or x-rays, or produced by the radioactive decay of caesium-137 or cobalt-60 (both unstable isotopes whose decay produces gamma radiation).

Irradiation may be used to eliminate or reduce food borne pathogenic organisms, extend shelf life by retarding food spoilage and inhibit ripening, germination or sprouting of certain food products. Irradiation may also be used as a phytosanitary measure to rid plants or plant products of harmful organisms.

1. Introduction

Food irradiation has been permitted in the UK for over 15 years, and UK legislation was amended in 2000 to implement two European Directives on food irradiation (Commission of the European Communities, 1999a and b).

In the UK, one facility in England is licensed to irradiate a range of dried herbs and spices and it is inspected regularly by the Food Standards Agency. Several other irradiation facilities are approved to irradiate food; most are located in Member States of the EU. Details of food irradiation facilities are available on the Internet at:

http://ec.europa.eu/food/food/biosafety/irradiation/comm_legisl_en.htm

Although few foods are irradiated in the UK, there is an increased interest in the technique in other countries, particularly in the United States of America. A Food Standards Agency survey identified a high proportion of dietary supplements as irradiated and in breach of the relevant labelling and food control of irradiation legislation (Food Standards Agency, 2002). There were no immediate food safety concerns arising from this survey. However, approval for the irradiation of dietary supplements had not been sought and none of the offending products were correctly labelled as "irradiated" or "treated with ionising radiation". Similar findings were found from a follow-up survey in 2003 (Food Standards Agency, 2006a).

The Agency's food irradiation research programme was reviewed in 2003 and a revised programme of research is planned. More details are available on the Internet at:

http://www.food.gov.uk/science/research/researchinfo/choiceandstandardsresearch/foodirradiation1/.

Table 1.1. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2005

Site	Month	Summary of incident	Consequences and actions taken
Aldermaston defence establishment	May	Unintentional release of tritium whilst handling legacy material. The releases occurred because a container, thought to be empty, was opened in an inappropriate building with insufficient precautions.	The consequences were very low – the release was less than the authorised discharge limit.The Environment Agency served an Enforcement Notice, requiring improvement to management systems.
Amersham, radiochemical production	August	The Site Operator identified tritium in the groundwater under the site. The source of this contamination is being investigated.	The impact on public drinking water supplies should be very low. Sampling is being carried out by the operator to provide further reassurance: to date the results confirm the initial findings.
Amersham, radiochemical production	August	Enhanced levels of alpha emitters were found in a small patch of soil just off the site in 2004. Radium has not been used on the site for many years. Following investigation in 2005, it has been determined that the activity is likely to be linked to historic operations on the site.	The enhanced levels were below the values in schedule 1 in the Radioactive Substances Act and do not represent a risk to the public. However, the site has decided to survey more widely to confirm that there are no other affected areas.
Bradwell Power Station	September	The failure of a filter in the extract ventilation system for the ponds building resulted in an elevated release of radioactivity to atmosphere. This was most likely due to a defective filter.	Very low because the release was less than the authorised discharge limit.
Capenhurst, Decommissioning fuel enrichment plant	October	The radioactive waste incinerator went into alarm, and shut down. The bypass damper opened as intended while the plant shut down. This allowed flue gas to bypass the abatement plant.	Very low because by the time the event occurred, any pollutant levels in the flue gas would have reduced to low levels.
Chapelcross		Radioactive limescale particles were found on the beach near the discharge point to the Solway Firth.	See Section 5. Monitoring on beaches enhanced. Removal of particles by Operator. Remedial action on plant commenced.
Dounreay		Radioactive particles were found on local intertidal areas and on the seabed.	See Section 4. FEPA ban on harvesting local seafood introduced. Monitoring on beaches enhanced. Monitoring on seabed introduced. Removal of particles by Operator required during monitoring. Source investigations and risk assessments commenced.
Hinkley Point A Power Station (Kilve Beach)	August	Member of the public claimed to have found elevated levels of activity on Kilve Beach.	Follow up monitoring by the Environment Agency with the person concerned was carried out in September. Further monitoring was also carried out in October and December. The monitoring assessed radiation at the strand line, at the low tide mark and across the beach in general. Activity above background was not detected.
Sellafield reprocessing plant	March	Member of the public was concerned that levels of radioactivity in tidal sediment at Kents Bank in South Cumbria may be increasing because of finer grained sediment accumulating in the area (changed from sand to mud over recent years). The possible health effects from sediment brought ashore on vehicle tyres was also raised as an issue.	Samples taken in the presence of the person concerned and analyses carried out. Concentrations were similar to those found elsewhere in South Cumbria. An assessment of doses from the sediment on roads was made which indicated doses were between 0.001 and 0.012 mSv y^{-1}.
Sellafield reprocessing plant	April	There was a temporary increase in uranium concentration in the liquid effluent discharge from the Site Ion Exchange Effluent Plant (SIXEP). This was in excess of the relevant plant limit set in the Integrated Pollution Control authorisation issued under the Environmental Protection Act 1990. The cause was a faulty caustic dosing valve.	SIXEP is a relatively minor contributor to the Sellafield Site's uranium discharges.The impact on members of the public from this event was estimated to be very low because the discharges were well within the typical site discharge range and the site discharge limits. A warning letter was served by the Environment Agency and plant improvements required.

Table 1.1. continued

Site	Month	Summary of incident	Consequences and actions taken
Sellafield reprocessing plant	April	Abnormal release of radioactive air from a ventilation system during routine maintenance in the Waste Vitrification Plant. Caesium-137 discharges were in excess of the relevant plant limit set in the authorisation.	Radiological impact assessment by the Environment Agency indicates a radiation dose of less than 0.001 mSv to any members of the public, well below the dose limit of 1mSv/y. Local grass samples were taken downwind. Levels of caesium-137 (the main radionuclide) were not significantly elevated above normal background concentrations. A warning letter was served by the Environment Agency and plant improvements required.
Sellafield reprocessing plant	June, September and November	The following were discovered during maintenance of Sealine 3 (the pipeline used to carry authorised disposals of liquid radioactive waste from the Site into the Irish Sea). Routine inspection and testing in June revealed that a patch put on to repair damage to the seabed pipe caused by an environmental pressure group 18 years ago had come adrift. This was repaired.Similar inspection in September discovered separate damage which was repaired. A further inspection in November indicated that the repair made in September required re-fixing.	The consequences of damage of this kind is that an unknown proportion (probably very small) of the authorised discharge may have been released closer to shore than the end of the 2 km pipeline. The impact of this is negligible. Beach monitoring has not indicated any abnormal results. The incidents were monitored by the Environment Agency. No enforcement action was taken.
Sellafield reprocessing plant	August	An operational perturbation led to an elevated release to atmosphere over a period of about 2 hours from the High Active Liquor Evaporation and Storage facility.	The Environment Agency and the Nuclear Installations Inspectorate investigated. Plant improvements made by the operator. No authorised limits were challenged. Grass samples were taken downwind and some milk monitoring carried out. See section 3.

2. METHODS OF SAMPLING, MEASUREMENT, PRESENTATION AND ASSESSMENT

This Section explains the scope of the monitoring programmes presented in this report and summarises the methods and data used to measure and assess radioactivity in food and the environment. The bulk of the programmes and assessment methods and data have continued from 2004 unchanged. The main differences are:

- sampling at non-nuclear sites in Scotland increased to reflect local concerns due to contamination at Dalgety Bay in Fife and at Aberdeen beach.
- analysis of samples of freeze-dried berries in a consignment being imported through Portsmouth Docks were undertaken because screening equipment detected unusually high results.
- special sampling was introduced at nuclear sites where there were unusual short-term increases in discharges and inadvertent releases.
- an *ad hoc* programme of monitoring naturally occurring radionuclides at Hartlepool was undertaken to assess potential local enhancement in the marine environment.
- a further five sites have been assessed using a new Total Dose assessment methodology. This brings together information on all sources of exposure at nuclear sites, including direct radiation. Currently 16 sites are assessed in this manner and it should be possible to assess all sites in this way within the next three years.
- maps of sites and sampling locations have been revised and updated.
- dose coefficients have been reviewed and updated with new information for the uptake and retention of tritium in seafood near Cardiff.
- assessments of exposures of prenatal children have been introduced following recommendations of the Health Protection Agency (HPA).
- consumption and occupancy rates for critical groups have been updated with the benefit of recent habit survey results at Sellafield, Chapelcross, Rosyth, Trawsfynydd, Dungeness and Sizewell.
- assessment of doses from consumption of general diet and drinking water have been extended to give an improved geographical breakdown.

2.1 Sampling programmes

The primary purpose of the programmes is to check on levels of radioactivity in food and the environment. The results are used to demonstrate that the safety of people is not compromised and that doses, as a result of discharges of radioactivity, are below the dose limit. The scope extends throughout the UK and the Insular States (the Channel Islands and the Isle of Man) and is undertaken independently of the industries which discharge wastes to the environment. Samples of food, water and other materials are collected from the environment and analysed in specialist laboratories. In situ measurements of radiation dose rates and contamination are also made and the results of the programme are assessed in terms of limits and trends in this report. Subsidiary objectives for the programmes are to:

- provide information to assess the impact on non-human species
- enable indirect confirmation of compliance with authorisations for disposal of radioactive wastes
- determine whether undisclosed releases of radioactivity have occurred from sites
- establish a baseline from which to judge the importance of accidental releases of radioactivity should they occur
- demonstrate compliance with OSPAR obligations

Sampling is focused on nuclear sites licensed by the HSE under the Nuclear Installations Act, 1965 (United Kingdom - Parliament, 1965) since these generally discharge more radioactivity and have a greater impact on the environment. The programmes also serve to provide information to assist the Environment Agencies to fulfil statutory duties under the Radioactive Substances Act, 1993 (United Kingdom - Parliament, 1993). Additional sampling is carried out in areas remote from nuclear sites to establish the general safety of the food chain, drinking water and the environment. Results from this sampling generate data that are used as background levels to compare with results from around nuclear sites and to show the variation in levels across the UK. Levels in the environment can also be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from both past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

The programmes can be divided into three main sectors largely on the basis of the origin of radioactivity in the environment:

1. Nuclear sites discharging gaseous and liquid radioactive wastes
2. Industrial and landfill sites and
3. Chernobyl and regional monitoring

2.1.1 Nuclear sites

Nuclear sites are the prime focus of the programme as they are responsible for the largest individual discharges of radioactive waste. Sampling and direct monitoring is carried out close to each of the sites shown in Figure 1.1. In the case of Sellafield some radionuclides discharged in liquid effluent can be detected in the marine environment in many parts of north-European waters and so the programme for this site extends beyond national boundaries.

The frequency and type of measurement and the materials sampled vary from site to site and are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from surveys of local peoples' diets and way of life. As a result the programme varies from site to site and from year to year. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring when necessary, for example, in response to incidents or reports of unusual or high discharges of radioactivity with the potential to get into the food chain or the environment. The results of both routine and additional monitoring are included in this report.

The main aim of the programme is to monitor the environment and diet of people who live or work near nuclear sites in order to estimate exposures for those small groups of people who are most at risk from disposals of radioactive waste (the critical group). It is assumed that if the most exposed group have a dose below the legal limit then all others should be at an even lower level of risk. For liquid wastes, the pathways that are the most relevant to discharges are the ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. For gaseous wastes, the effects are due to the ingestion of terrestrial foods, inhalation of airborne activity and external exposure from material in the air and deposited on land. Inhalation of airborne activity and external exposure from airborne material and surface deposition are difficult to assess by direct measurement but can be assessed using environmental models. The main thrust of the monitoring is therefore directed at a wide variety of foodstuffs and measurements of external dose rates on the shores of seas, rivers and lakes. The programme also includes some key environmental indicators, in order that levels can be put in an historic context.

2.1.2 Industrial and landfill sites

Whilst the main focus of the programme is the nuclear industry, a watching brief is kept on other activities which may have a radiological impact on people and the food chain. This part of the programme considers the impact of disposals of naturally occurring and man-made radionuclides from non-nuclear industries and of disposal into landfill sites other than at Dounreay (which is considered separately in Section 4.2).

The impacts of the non-nuclear industry at three sites were studied in 2005. They were at Aberdeen (offshore equipment decontamination and fertiliser production), Dalgety Bay, Fife (defence operations) and Whitehaven (phosphate processing). In each case the sampling and analysis was directed at materials potentially containing technically enhanced levels of naturally occurring radionuclides (i.e. Technologically enhanced Naturally Occurring Radioactive Materials (TNORM)).

About fifty landfill sites were monitored in England, Scotland and Wales. The distribution of landfill sites considered in 2005 is shown in Figure 8.1. They were studied to assess the extent, if any, of the contamination leaching from the site and re-entering the terrestrial environment in leachates collected in surface waters close to the sites. The most significant site is the engineered facility operated by British Nuclear Group (BNG) at the LLWR at Drigg, in Cumbria.

2.1.3 Chernobyl fallout and regional monitoring

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

The programme of regional monitoring considers the levels of radionuclides in the environment in areas away from specific sources as an indication of general contamination of the food supply and the environment. The component parts of this programme are:

- monitoring of the Channel Islands, the Isle of Man and Northern Ireland
- dietary surveys
- sampling of milk, crops, and meat
- drinking water sources, rain and airborne particulates
- seawater surveys.

Channel Islands, Isle of Man and Northern Ireland

The programmes for the Insular States and Northern Ireland are designed to complement that for the rest of the UK and to take account of the possibility of long-range transport of radionuclides.

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

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

The Northern Ireland programme is directed at the far-field effects of disposals of liquid radioactive wastes into the Irish Sea. Dose rates are monitored on beaches and seafood and indicator materials are collected from a range of coastal locations including marine loughs.

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information that is useful in interpreting site-related measurements and also helps ensure that all significant sources of contamination form part of the site-related programme. As part of the Total Diet Study (TDS), representative mixed diet samples are collected from towns throughout the UK (see Section 9). Normal culinary techniques are used in preparing samples (e.g. removal of outer leaves of leafy vegetables if necessary) and samples are combined in amounts that reflect the relative importance of each food in the average UK diet. Some samples are analysed for a range of contaminants including radionuclides. Some of these data are also supplied to the EC in support of the Euratom Treaty*. The EC compile data into a report of results from all Member States. At the time of writing, the last report covered data for 1996 – 2000 (Joint Research Centre, 2005). The TDS was supplemented with a study of canteen meals in 2005. Together they account for the 'dense' and 'sparse' networks for mixed diet (Commission of the European Communities, 2000a) required by the EC.

Specific foods, freshwater, rain and airborne particulates

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

Milk sampling took place at dairies throughout the UK in 2005. Samples were taken monthly and some of the results are reported to the EC to allow comparison with those from other Member States. At the time of writing, the last report covered data for 1996 – 2000 (Joint Research Centre, 2005).

Other food sampling complements the regional dairy programme described above. Crop samples were taken from locations throughout the UK. The results are used to give an indication of background levels of radioactive contamination from naturally occurring and man-made sources (nuclear weapon tests and Chernobyl fallout) for comparison with samples collected from around nuclear sites. Sampling of freeze-dried berries was undertaken from a consignment being transported through Portsmouth Docks, which had triggered port screening equipment.

Freshwater used for the supply of drinking water was sampled throughout England, Scotland and Wales (Figure 9.2). Regular measurements of radioactivity in air and rain water were also made. Both programmes are partially sponsored by Defra and provide information to the EC under Article 36 of the Euratom Treaty. Similarly, in Northern Ireland, the Environment and Heritage Service funds analysis of freshwater used for drinking water. These data are sent to the EC under Article 36 of the Euratom Treaty.

Seawater surveys

Seawater surveys are carried out in the seas around the UK on behalf of Defra to provide information on radionuclide levels and fluxes in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the aegis of the OSPAR Conventions (OSPAR, 2000b), to which the UK is a signatory and in support of research on the fate of radionuclides discharged to sea. These surveys are mounted using government research vessels and are supplemented by a programme of spot sampling of seawater at coastal locations.

2.2 Methods of measurement

There are two basic types of measurement made: (i) samples collected from the environment are 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 separation techniques to quantify the alpha and beta emitting radionuclides

** The treaty establishing the European Atomic Energy Community (EURATOM) was signed in Rome on 25th March 1957.*

under study. They are sensitive but more labour intensive. They are, therefore, only used when there is clear expectation that information is needed on specific radionuclides that are not detectable using gamma-ray spectrometry (see Section 2.4 for discussion on limits of detection).

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

- Cefas — Centre for Environment, Fisheries and Aquaculture Science,
  analysis of food related aquatic samples in England, Wales, Northern Ireland, Isle of Man and the Channel Islands

- SL — Scientifics Ltd,
  analysis of environment related samples in England and Wales

- IC — Imperial College, University of London,
  total uranium analysis of terrestrial samples in England, Wales and the Channel Islands

- HPA — Health Protection Agency*,
  gamma-ray spectrometry and radiochemistry of samples from Scotland, Total Diet and canteen meals from England and Wales and freshwater for Northern Ireland

- LGC — Laboratory of the Government Chemist,
  analysis of drinking water in England and Wales

- VLA — Veterinary Laboratories Agency,
  gamma-ray spectrometry and radiochemistry (excluding total uranium analysis) of food related terrestrial samples in England, Wales, the Channel Islands and the Isle of Man

- WELL — Winfrith Environmental Level Laboratory (Amec NNC Ltd)
  gamma-ray spectrometry and radiochemistry of air and rain samples in England, Wales, Northern Ireland and the Shetland Islands

Each laboratory operates quality control procedures to the standards required by the Environment Agencies and the Food Standards Agency. In most cases, contractors are third-party assessed for their operating procedures, i.e. they are accredited by an agency such as the UK Accreditation Service that certifies they meet the requirements of the international standard ISO 17025 (International Organisation for Standardisation, 2005). Regular calibration of detectors is undertaken and intercomparison exercises are held with participating laboratories. The quality assurance procedures and data are made available to the UK Environment Agencies and the Food Standards Agency for auditing. The methods of measurement include alpha and gamma-ray spectrometry, beta and Cerenkov scintillation counting and alpha and beta counting using proportional detectors.

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

** On 1st April 2005 the National Radiological Protection Board merged with the Health Protection Agency to form its Radiation Protection Division.*

The analysis of foodstuffs is carried out on that part of the sampled material that is normally eaten, for example, the shells of shellfish and the pods of some of the legumes are discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish samples are boiled soon after collection to minimise losses from the digestive gland. Although some activity may be lost, these generally reflect the effects of the normal cooking process for shellfish. Most other foodstuffs are analysed raw it is conceivable that all of the activity in the raw foodstuff could be consumed.

2.2.2 Measurement of dose rates and contamination

Measurements of gamma dose in air over intertidal and other areas are normally made at 1 m above the ground using Mini Instruments* environmental radiation meters type 680 and 690 with compensated Geiger-Muller tubes type MC-71. For certain key public activities, for example for people living on houseboats or for wildfowlers lying on the ground, measurements at other distances from the ground may be made. External beta doses are measured on contact with the source, for example fishing nets, using Berthold* LB 1210B or Mini 900/EP 15* contamination monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all others. In this report we have presented the total gamma dose rate. The HPA reports terrestrial gamma dose rates to the Scottish Environment Protection Agency. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 $\mu Gy\ h^{-1}$ which is an approximation of the contribution made by cosmic radiation (Her Majesty's Inspectorate of Pollution, 1995).

Beta/gamma monitoring of contamination on beaches or river banks is undertaken using similar instrumentation to that for measurements of dose rates. In England and Wales, a Mini Instruments series 900 mini monitor with a beach monitoring probe is used. The aim is to cover a large area including strand-lines where radioactive debris may become deposited. Any item found with activity levels in excess of the action levels is removed for analysis. An action level of 100 counts per second (equivalent to 0.01 $mSv\ h^{-1}$) is used in England and Wales.

During 2005, no items were found above the action level at any site in England and Wales. At Dounreay, in Scotland, special monitoring procedures are in place due to the potential presence of fragments of irradiated fuel. Further information regarding Dounreay is provided in Section 4.

2.3 Presentation of results

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

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

** 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.*

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean in the year sampled for the farm where the highest single concentration is observed. This is labelled 'max' in the tables of results to distinguish it from the values that are averaged over a range of farms. For other terrestrial foods, an alternative approach is adopted since it is recognised that the possible storage of foods harvested during a particular time of the year has to be taken into account. Greater public exposures would be observed when foods are harvested at times when levels of contamination are high. For such foods, we have presented the maximum concentration observed of each radionuclide at any time in 2005 as well as the mean value. The maximum is labelled 'max' in the tables and forms the basis for the assessment of dose.

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

The numbers of farms that were sampled to provide information on activities in milk at nuclear sites are indicated in the tables of results. Milk samples collected weekly or monthly are generally bulked to provide four quarterly samples for analysis each year. For some radionuclides weekly, monthly or annual bulks are taken for analysis. Otherwise, the number of sampling observations in the tables of concentrations refers to the number of samples that were prepared for analysis during the year. In the case of small animals such as molluscs, one sample may include several hundred individual animals.

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

2.4 Detection limits

There are two main types of results presented in the tables (i) positive values and (ii) values preceded by a 'less than' symbol. Where the results are not averages, they are positive values, or values at the limit of detection (LoD) or minimum reporting level (MRL) respectively. Where the results are an average of more than one datum, and each datum is positive, the result is positive. Alternatively, where there is a mixture of data, or all data are at the LoD or MRL, the result is preceded by a 'less than' symbol. Gamma-ray spectrometry can provide a large number of 'less than' results. In order to minimise the presentation of redundant information for gamma-ray spectrometry, 'less than' values are only reported when (i) either the radionuclide is one which is in the relevant authorisation, (ii) or it has been analysed by radiochemistry, (iii) or it has been reported as being a positive value in that table in the previous 5 years, (iv) or a positive result is detected in any other sample presented in the table in 2005. Naturally occurring radionuclides measured by gamma-ray spectrometry are not usually reported unless they are intended to establish whether there is any enhancement above the expected background levels.

Limits of detection are governed by various factors relating to the measurement method used and these are described in earlier reports (Ministry of Agriculture, Fisheries and Food, 1995). The MRL is a quantity related to the radiological significance of a particular concentration of activity. In certain cases, whilst a LoD 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. Ministry of Agriculture, Fisheries and Food, 1995).

There are also a few results quoted as 'not detected' (ND) by the methods used. This refers to the analysts' judgement that there is insufficient evidence to determine whether the radionuclide is present or absent.

2.5 Additional information

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

The main categories of additional data are:

- data for individual samples prior to averaging
- uncertainties in measurements
- data for very short-lived radionuclides supported by longer-lived parents
- data which are not relevant to a site's discharges for naturally occurring radionuclides and for artificial radionuclides below detection limits
- measurements carried out as part of the research programme described in Section 10.

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

2.6 Radiation protection standards

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

Current UK practice relevant to the general public is based on the recommendations of the ICRP as set out in ICRP Publication 60 (International Commission on Radiological Protection, 1991). The dose standards are embodied in national policy on radioactive waste (United Kingdom - Parliament, 1995b) and in guidance from the IAEA in their Basic Safety Standards for Radiation Protection (International Atomic Energy Agency, 1996). Legislative dose standards are contained in the Basic Safety Standards Directive 96/29/Euratom (Commission of the European Communities, 1996) and subsequently incorporated into UK law in the Ionising Radiations Regulations 1999 (United Kingdom - Parliament, 1999). In order to implement the Basic Safety Standards Directive, Ministers have provided the Environment Agency and the Scottish Environment Protection Agency with Directions concerning radiation doses to the public and their methods of estimation and regulation for all pathways (Department of the Environment, Transport and the Regions, 2000 and Scottish Executive, 2000). In Northern Ireland, regulations were made to implement the requirements of the BSS Directive in the Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland) 2003 (Northern Ireland Assembly, 2003). The methods and data used in this report are consistent with the Directions.

The relevant dose limits for members of the public are 1 mSv (millisievert) per year for whole-body (more formally 'committed effective') dose and 50 mSv per year specifically for skin. The latter limit exists to ensure that specific effects on skin due to external exposure are prevented. It is applicable, for example, in the case of handling of fishing gear. The dose limits are for use in assessing the impact of direct radiations and controlled releases (authorised discharges) from radioactive sources.

The mean dose received by the 'critical group' is compared with the dose limit. The critical group represents those who are most exposed to radiation and in this report are generally people who eat large quantities of locally grown food (high-rate consumers) or who spend long periods of time in areas where radioactive contamination may exist. The limits apply to all age groups. Children may receive higher doses than adults because of their physiology, anatomy and dietary habits. The embryo/fetus can also receive higher doses than its mother. Consequently doses have been assessed for different age groups, i.e. adults, 10-year-old children, 1-year-old infants and prenatal children, and from this information it is possible to determine which of these age groups forms the critical group.

The ICRP is currently revising its recommendations and is undergoing a consultation process on its proposals. The draft documents, which provide the foundation for the system of protection, can be viewed at www.icrp.org. When the new ICRP recommendations are issued, the implications concerning EU and UK radiation protection standards will be taken into account in future issues of this report.

For drinking water, the World Health Organisation (WHO) has provided screening levels to compare with the results of measurements of gross alpha and gross beta activity (World Health Organisation, 2004). The screening levels are 0.5 and 1.0 Bq l^{-1}, respectively, and are based on consideration of the dose that would result from radium-226 (alpha) and strontium-90 (beta) intakes. These were chosen as representative of the most radiotoxic radionuclides likely to be present in significant quantities. The values represent concentrations below which water can be considered potable without any further radiological examination. The Commission of the European Communities (CEC) has prepared a directive on the quality of water intended for human consumption, which includes parameters for tritium (with a reference value of 100 Bq l^{-1}) and total indicative dose with a reference value of 0.1 mSv per year (Commission of the European Communities, 1998).

Accidental releases may be judged against EU and ICRP standards in emergency situations (Commission of the European Communities, 1989 and International Commission on Radiological Protection, 1993). In addition, it is Government policy that EU food intervention levels will be taken into account when setting discharge limits.

As discussed in last year’s RIFE report, the Codex Alimentarius Commission (CAC) has been producing revised guideline levels for radionuclides in foods following accidental nuclear contamination for use in international trade. The proposals were the subject of a consultation in the UK led by the Food Standards Agency. Subsequently, a drafting group led by the IAEA and the EC was set up to revise the draft guidelines. These revised guidelines were discussed at the Codex Committee on Food Additives and Contaminants in April 2006 and at the CAC meeting in July 2006. The final decision is awaiting publication and will be available as part of the full report on the Codex website at ‘www.codexalimentarius.net/web/archives.jsp?lang=en’.

The main focus of this report and radiological regulation and monitoring more generally is towards protection of man. The Habitats Directive (Commission of the European Communities, 1992) requires a 3-stage approach to the assessment of the impact of radioactive discharges on sensitive habitats. The Environment Agencies have completed initial assessments using the methods and data in Copplestone *et al*. (2001). Further research is being undertaken to provide methods and data to enable more complete and systematic assessments to be made in the UK (Commission of the European Communities, 2004). The initial assessments have shown that, for important habitats in England and Wales such as Special Areas of Conservation SAC and Special Protection Areas SPA, for all but one of these sites there are no adverse effects on the integrity of the sites from authorised discharges of radioactive substances. The one exception is the Ribble estuary where the assessed dose is 690 μGy h^{-1} in excess of the assessment threshold of 40 μGy h^{-1}. The Environment Agency is considering what action, if any, is required. SEPA undertook a Pressures and Impacts Assessment on Scotland’s Water Environment from radioactive substances. The report concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data from some locations to support this conclusion. The report is available from http://www.sepa.org.uk/pdf/publications/technical/ wfd_Assessment_pressures_impacts.pdf

2.7 Assessment methods and data

Calculations of exposures of members of the public from waste disposals are primarily based on the environmental monitoring data for 2005 shown in this report. The methods used are compatible with the principles endorsed by the UK National Dose Assessment Working Group (National Dose Assessment Working Group, 2004). The data provide information on two main pathways:

- ingestion of foodstuffs and
- external exposure from contaminated materials in the aquatic environment.

Monitoring data are also used to assess doses from pathways, which are generally of lesser importance:

- drinking water
- inadvertent ingestion of water and sediments and
- inhalation of resuspended soil and sediment

In addition, atmospheric dispersion models are used to estimate doses for gaseous discharges from a few sites where monitoring is not an effective method of establishing concentrations and dose rates in the environment. Full details are given in Appendix 2. This Section describes how the data are chosen for each assessment of dose. For pathways involving intakes of radionuclides, the data required are:

- concentrations in foodstuffs, drinking water sources, sediments or air
- the amounts eaten, drunk or inhaled
- the dose coefficients that relate an intake of activity to a dose.

For external radiation pathways, the data required are:

- the dose rate from the source, for example a beach or fishermens' nets, and
- the time spent near the source.

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.

2.7.1 Concentrations of radionuclides in foodstuffs, drinking water sources, sediments and air

In nearly all cases, the concentrations of radionuclides are determined by monitoring and are given later in this report. The terrestrial assessments for Sellafield, the LLWR at Drigg and Isle of Man are supplemented by information from foodchain models (see Appendix 2). The concentrations chosen for the assessment are intended to be representative of the intakes of the most exposed consumers in the population. All of the positively determined concentrations tabulated are included irrespective of the origin of the radionuclide. In some cases, this means that the calculated exposures include contributions due to disposals from other sites as well as from weapon test fallout and activity deposited following the Chernobyl accident. Where possible, corrections for background concentrations of naturally occurring radionuclides are made in the calculations of dose (see Section 2.7.5).

For aquatic foodstuffs, drinking water sources, sediments and air, the assessment is based on the mean concentration near the site in question. For milk, the mean concentration at a nearby farm with the highest individual result is used in the dose assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers.

For other foodstuffs, the maximum concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak levels in a year may have been present in the environment.

The tables of concentrations include 'less than' values as well as positive determinations. This is particularly evident for gamma-ray spectrometry of terrestrial foodstuffs. Where a result is presented as a 'less than' value, the dose assessment methodology treats it as if it were a positive determination as follows: (i) when that radionuclide is specified in the relevant authorisation (gaseous or liquid), (ii) when that radionuclide was determined using radiochemical methods or (iii) when a positive result is reported for that radionuclide in another sample from the same sector of the environment at the site (aquatic or terrestrial). Although this approach may produce an overestimation of dose, particularly at sites where levels are low, it ensures that estimated exposures are unlikely to be understated.

2.7.2 Consumption, drinking and inhalation rates

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

In assessments of terrestrial foodstuffs, the amounts of food consumed are derived from national surveys of diet and are defined for three ages: adults, 10-year-old children and 1-year-old infants (based on Byrom *et al*., 1995). Adult consumption rates are used in the assessment of fetal doses. For each food type, consumption rates at the 97.5th percentile of consumers have been taken to represent the people who consume a particular foodstuff at a high level (the 'critical group' consumption rate).

Drinking and inhalation rates are general values for the population, adjusted according to the times spent in the locations being studied.

The consumption, drinking and inhalation rates are given in Appendix 4. Estimates of dose are based on the most up to date information available at the time of writing the report. New survey data were introduced at Chapelcross, Dungeness, Rosyth, Sellafield, Sizewell and Trawsfynydd in 2005. Where appropriate, the data from site-specific surveys are averaged over a period of 5 years following the recommendation of the report of the Consultative Exercise on Dose Assessments (CEDA) (Food Standards Agency, 2001a).

The assessment of terrestrial foodstuffs is based on two assumptions: (i) that the foodstuffs eaten by the most exposed individuals are those that are sampled for the purposes of monitoring; and (ii) that the consumption of such foodstuffs is sustained wholly by local sources. The two food groups resulting in the highest dose are taken to be consumed at 'high level' consumption rates, while the remainder are consumed at mean rates. The choice of two food groups at the higher consumption rates is based on statistical analysis of national diet surveys. This shows that only a very small percentage of the population were critical rate consumers in more than two food groups (Ministry of Agriculture, Fisheries and Food, 1996). Locally grown cereals are not considered in the assessment of exposures as it is considered highly unlikely that a significant proportion of cereals will be made into locally consumed (as opposed to nationally consumed) foodstuffs, notably bread.

2.7.3 Dose coefficients

Dose calculations for intakes of radionuclides by ingestion and inhalation are based on dose coefficients taken from ICRP Publication 72 (International Commission on Radiological Protection, 1996a), ICRP Publication 88 (International Commission on Radiological Protection, 2001) and National Radiological Protection Board (2005).

These coefficients (often referred to as 'dose per unit intake') relate the committed dose received to the amount of radioactivity ingested or inhaled. The dose coefficients used in this report are provided in Appendix 5 for ease of reference.

Calculations are performed for four ages: adults, 10-year-old children, 1-year-old infants and prenatal children as appropriate to the pathways being considered. The prenatal age group is introduced routinely for the first time this year following the publication of recommendations by the National Radiological Protection Board in 2005 (National Radiological Protection Board, 2005). We have assumed that a member or members of the adult critical group is/are pregnant in order for the dose assessment of the embryo and fetus to be valid. This assumption is considered reasonable in the context of making comparisons with dose limits because it is difficult to demonstrate otherwise. When applied in practice, the doses estimated for the pre-natal group are rarely larger than the values for other age groups.

The dose assessments include the use of appropriate gut uptake factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut uptake factors for a radionuclide, we have generally chosen the one that results in the highest predicted exposure. In particular where results for total tritium are available, we have assumed that the tritium content is wholly in an organic form. However, we have also taken into account specific research work of relevance to the foods considered in this report. This affects the assessments for tritium, polonium, plutonium and americium radionuclides as discussed in Appendix 5.

2.7.4 External exposure

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

For external exposure of skin, the measured quantity is contamination in Bq cm^{-2}. In this case, dose rate factors in Sv y^{-1} per Bq cm^{-2} are used which are calculated for a depth in tissue of 7 mg cm^{-2} (Kocher and Eckerman, 1987). The times spent near sources of external exposure are determined by site-specific habits surveys in a similar manner to consumption rates of seafood. The occupancy and times spent handling fishing gear are given in Appendix 4.

2.7.5 Subtraction of 'background' levels

When assessing internal exposures due to ingestion of carbon-14 and radionuclides in the uranium and thorium decay series in seafood, concentrations due to natural background levels are subtracted. Background carbon-14 concentrations in terrestrial foods are also subtracted. The estimates of background concentrations are given in Appendix 6. When assessing the man-made effect on external exposures to gamma radiation, dose rates due to background levels are subtracted. On the basis of measurements made previously as part of the programmes reported here, the gamma dose rate backgrounds in the aquatic environment are 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 is used (Hunt, 1984). Estimates of external exposures to beta radiation include a component due to naturally occurring (and un-enhanced) sources because of the difficulty in distinguishing between naturally occurring and man-made contributions. Such estimates are therefore conservative when compared with the relevant dose limit that excludes natural sources of radiation.

2.7.6 Summation of doses from different pathways

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

The environmental data and the individuals affected that are assessed in this report naturally fall into two separate groups: those affected by liquid waste disposal and those by gaseous waste disposal. We have therefore calculated doses separately in these two cases and within each group we have summed contributions from the different pathways involved. The simple further addition of 'liquid' and 'gaseous' doses will overestimate the dose received at that location due to radioactive waste disposal because the population groups most affected by atmospheric and liquid discharges tend to be different. An individual is unlikely to consume both aquatic and terrestrial foods at high rates. With the benefit of new habits survey information gained for all pathways of significance, an assessment of the total dose at specific nuclear sites is provided in Appendix 7. Direct radiation from nuclear sites is considered with the benefit of information provided by the HSE.

2.7.7 Uncertainties in dose assessment

Various methods are used to reduce the uncertainties in the process of dose estimation for critical groups from monitoring programmes. These address the following main areas of concern:

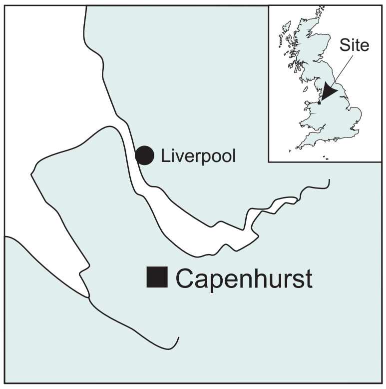
- programme design
- sampling and *in situ* measurement
- laboratory analysis
- description of pathways to man
- radiation dosimetry
- calculational and presentational error

Quantitative estimation of uncertainties in doses is beyond the scope of this report.

3. NUCLEAR FUEL PRODUCTION AND REPROCESSING

There are four sites in the UK associated with nuclear fuel production and reprocessing. The sites are at: Capenhurst, where there are 2 nuclear sites carrying out uranium enrichment; Springfields, where fuel for nuclear power stations is fabricated; and Sellafield, where irradiated fuel from nuclear power stations is reprocessed. All but one of the sites (the site at Capenhurst owned by Urenco (Capenhurst) Limited) are now owned by the NDA and are operated under licence. Sellafield and the other site at Capenhurst are operated by British Nuclear Group (Sellafield) Limited (BNGSL). The site at Springfields is operated by Springfields Fuels Limited. The NDA also owns the Windscale nuclear site, which is adjacent to the Sellafield site and is currently operated by UKAEA. Windscale is discussed in Section 4.4. The LLWR at Drigg is discussed in Section 8.1.

3.1 Capenhurst, Cheshire



There are two sites at Capenhurst, one owned by the NDA and one by Urenco (Capenhurst) Limited. BNGSL operate the NDA site, involving the dismantling and decommissioning of redundant facilities including a gaseous diffusion plant and a tritium gas processing plant. Urenco operate a facility involving centrifuge enrichment of uranium.

Radioactive waste arisings consist of: tritium; uranium plus its daughter products; and technetium-99 and neptunium-237 from enrichment of recycled fuel. In 2005, BNGSL had authorisations to dispose of radioactivity in gaseous wastes via stacks and in liquid wastes to the Rivacre Brook. Urenco had an authorisation for discharge of gaseous wastes via stacks on site. Independent monitoring of the environment around the site is carried out by the Food Standards Agency and the Environment Agency.

Gaseous discharges and terrestrial monitoring

The authorisations held by BNGSL and Urenco limit gaseous discharges of tritium and uranium. In 2005, discharges were well below the limits (see Appendix 1). The environmental effects of the gaseous discharges around the site are checked by the Food Standards Agency and the Environment Agency. Concentrations of tritium, technetium-99 and uranium are monitored by the Food Standards Agency in milk, fruit, vegetables and silage. The Environment Agency monitors levels of technetium-99 and uranium in grass and soil. Results for 2005 are presented in Table 3.1(a). Concentrations of radionuclides in samples of milk, fruit and vegetables around the site were very low, similar to previous years, as were concentrations of technetium-99 and uranium in soils. Figure 3.1 shows the trend of technetium-99 concentrations in grass from 2001, and reflects the reductions in discharges of technetium-99 from recycled uranium.

Liquid waste discharges and aquatic monitoring

The authorisation held by BNGSL places limits on liquid waste discharges to the Rivacre Brook of tritium, uranium and daughters, technetium-99 and non uranium alpha (mainly neptunium-237). In 2005 the discharges were well below the limits set by the Environment Agency (Appendix 1).

The effects of liquid discharges on the Brook were monitored by the Environment Agency. Samples of Brook water and sediments were analysed for tritium, technetium-99, gamma emitting radionuclides, uranium, neptunium-237, total alpha and total beta. Dose rate measurements were taken on the banks on the Rivacre Brook. Fish and shellfish from the local marine environment were sampled and measured for a range of radionuclides by the Food Standards Agency.

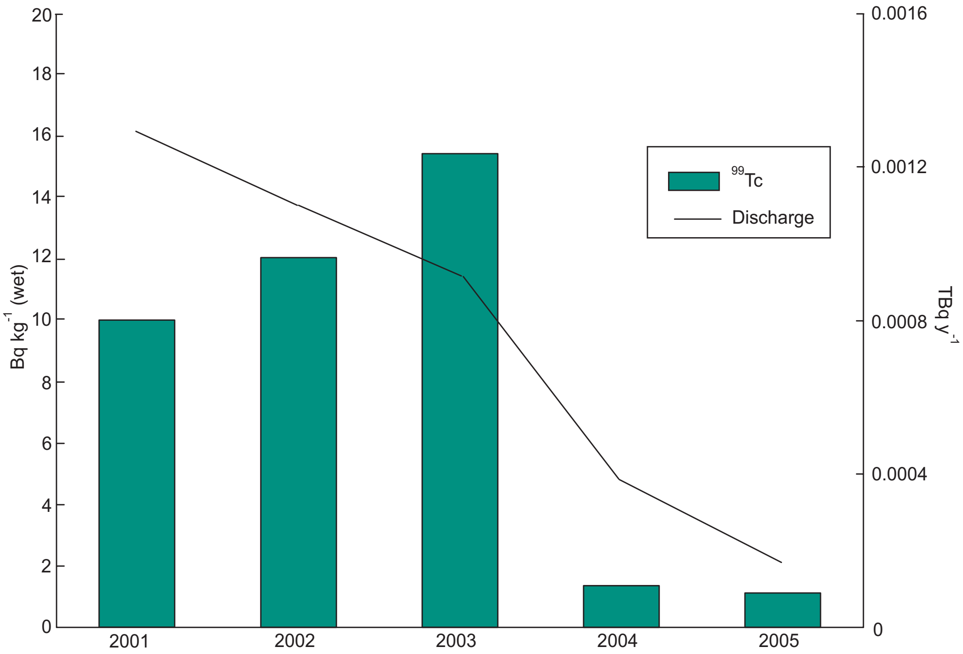


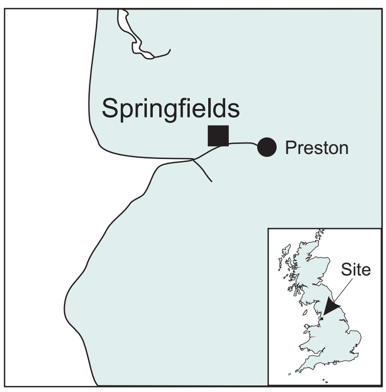
Figure 3.1 Technetium-99 concentration in grass at Capenhurst

Results for 2005 are presented in Tables 3.1(a) and (b). Concentrations of radionuclides and dose rates were very low and similar to those in 2004. Sediment samples from the Rivacre Brook contained very low but measurable concentrations of technetium-99; also of uranium, which was enhanced above natural levels close to the discharge point. Variations in concentrations in sediment from the Brook are to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in waters were also very low. Measured dose rates were slightly enhanced relative to natural background near to the discharge point. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides; these reflected the distant effects of discharges from Sellafield.

Doses to the public

The measured concentrations of radionuclides and dose rates were used to assess doses to the public due to the Capenhurst sites' operations. Doses were assessed for children playing in and around Rivacre Brook and consumers of local milk and vegetables. The highest dose was assessed as 0.009 mSv to children who play near the Brook and may also inadvertently ingest water and sediment (Table 3.2). The dose was estimated assuming a high occupancy of the bank of the Brook, relatively high inadvertent ingestion rates of water and sediment and the slightly enhanced gamma dose rates near the discharge point. Doses to consumers of locally grown food were less than 0.005 mSv in 2005.

3.2 Springfields, Lancashire



This site is operated by Springfields Fuels Limited (SFL) which is part of the BNFL group of companies. The main function carried out is the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Nexia Solutions Limited (NSL) is a tenant operator on the Springfields site, carrying out analytical and laboratory services.

In November 2004, the Environment Agency issued a new authorisation with revised discharge limits to BNFL at Springfields. The authorisation permits the discharge of radioactivity in gaseous wastes via stacks on site; liquid wastes by pipelines to the Ribble

Estuary; and solid waste disposals to a nearby landfill site and to the LLWR near Drigg. In April 2005, the authorisation held by BNFL was transferred to SFL.

Monitoring programmes are carried out by the Environment Agency, who check environmental concentrations and dose rates around the site, and the Food Standards Agency, who monitor concentrations in local foods. The monitoring locations are shown in Figure 3.2.

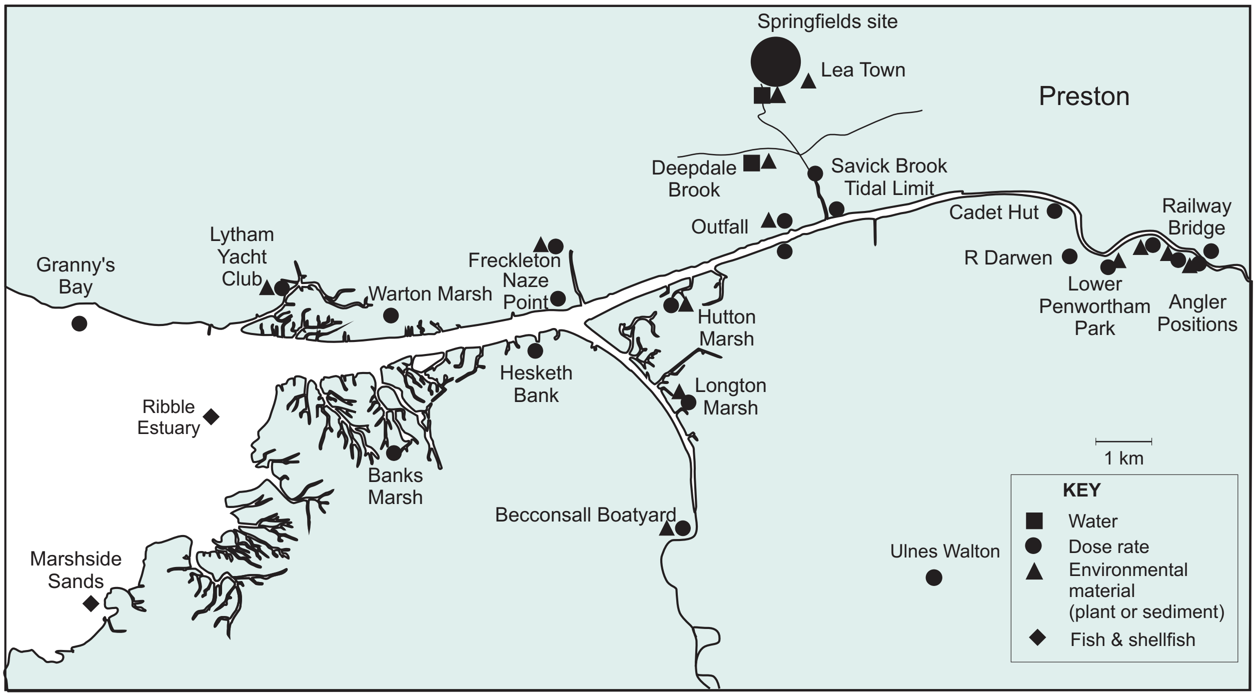


Figure 3.2 Monitoring locations at Springfields (excluding farms)

Gaseous discharges and terrestrial monitoring

For many years the site has been authorised to discharge small amounts of uranium to atmosphere. The new discharge authorisations, which came into force in November 2004, place lower limits on discharges of uranium from the fuel manufacturing and decommissioning operations. The new authorisations have also set limits on discharges of tritium, carbon-14, total alpha and total beta from NSL. The new limits and the discharges in 2005 are shown in Appendix 1. The gaseous discharges made in 2005 by SFL and NSL were well below the authorised limits.

Monitoring of foods, including milk, fruit and vegetables potentially affected by gaseous discharges around the site is carried out by the Food Standards Agency. The food samples are analysed for uranium, tritium, carbon-14, strontium-90, iodine-129, and isotopes of thorium, plutonium and americium. Gamma-ray spectrometry is also carried out and results are reported for cobalt-60, ruthenium-106 and caesium-137. Grass and soil are analysed by the Environment Agency for isotopes of uranium.

The concentrations of radionuclides found in 2005 are shown in Table 3.3(a). Slightly elevated concentrations of uranium isotopes, compared with those at greater distance, were found in soils around the site. Low levels of thorium were found in fruit and vegetables. Most other concentrations of radionuclides were at limits of detection. Results were broadly similar to those of previous years.

Liquid waste discharges and aquatic monitoring

Authorised discharges of liquid waste are made from the Springfields site to the Ribble Estuary by two pipelines. The new authorisation for liquid wastes that came into force in November 2004 sets limits on total alpha, total beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides. The revised limits are lower for all the radionuclides except technetium-99 and neptunium-237, which stayed the same. During 2005, discharges were below the limits set (see Appendix 1). The largest discharge was of short half-life beta-emitting radionuclides, mostly thorium-234.

The Ribble Estuary monitoring programme carried out by the Environment Agency consists mainly of in situ measurement of dose rates, and collection and analysis of sediments for isotopes of uranium and thorium and for gamma emitting radionuclides.

Locally obtained fish, shellfish and samphire are sampled by the Food Standards Agency and analysed by gamma-ray spectrometry (including cobalt-60, caesium-137, ruthenium-106, antimony-125 and amercium-241) and radiochemically for isotopes of uranium, thorium and plutonium.

Results for 2005 are shown in Tables 3.3(a) and (b). As in previous years, radionuclides due to discharges from both Springfields and Sellafield were found in the Ribble estuary sediment and biota. Radionuclides detected which were partly or wholly due to Springfields discharges were isotopes of thorium, uranium and their decay products. Total beta measurements were dominated by the presence of thorium-234. This radionuclide has a relatively short half life of 24 days; observed concentrations are closely linked to recent discharges from Springfields, tidal movements and river flow. In 2005, concentrations were similar to those observed in recent years (Figure 3.3).

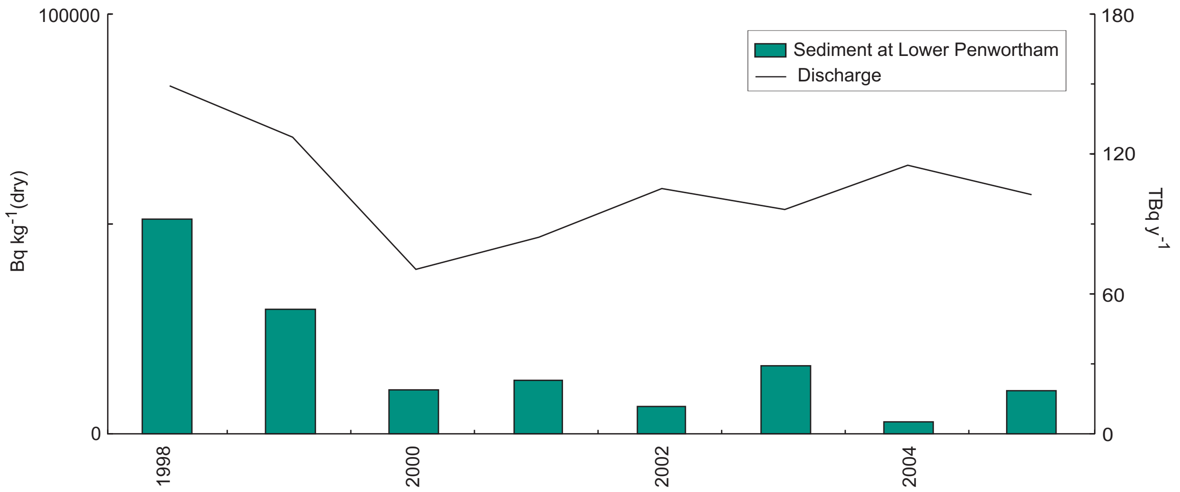


Figure 3.3 Total beta liquid discharge from Springfields and concentration in sediment at Lower Penwortham

Technetium-99, caesium-137, americium-241 and isotopes of plutonium and curium were found in biota from the Ribble estuary. Caesium-137 and americium-241 were also found in the Ribble estuary sediments. The presence of these radionuclides is due to past liquid discharges from Sellafield, carried from west Cumbria into the Ribble estuary by sea currents and adsorbed on fine-grained muds. The concentrations observed were similar to those in recent years.

Gamma dose rates in the estuary were generally elevated above those to be expected due to natural background (the UK average for muddy estuaries is 0.07 µGy h^{-1}). The elevated dose rates are due to the presence of gamma emitting radionuclides, partly from Springfields (mainly thorium-234 and protactinium-234m) and partly from Sellafield (mainly caesium-137, americium-241 and cobalt-60). Some gamma dose rates, notably those affecting the occupants of houseboats, were lower in 2005 than in 2004. Beta dose rates on fishing nets were, as for gamma dose rates, enhanced above those expected due to natural background. This was due to the concentrations of beta emitting radionuclides such as thorium-234 and protactinium-234m from Springfields. Beta dose rates in 2005 were similar to those in 2004.

Solid waste disposals and related monitoring

The Springfields authorisations also permit controlled burial of solid LLW to Clifton Marsh landfill site. Until 1983, BNFL had also disposed of LLW to the Ulnes Walton landfill site. The Environment Agency monitors waters from near the landfill sites at Ulnes Walton and Clifton Marsh. The results are shown in Section 8, Table 8.4 (landfill sites).

Doses to the public

Concentrations of radioactivity in environmental materials and dose rates have been used together with data on people's habits to assess doses to a number of groups of the public who might be subject to higher rates of exposure. Doses were calculated to the following groups: those consuming foods such as fruit and vegetables grown around the site; fish and shellfish consumers; people living on houseboats in the Ribble estuary; anglers spending time on the banks of the estuary; children playing on the banks of the estuary; and fishermen handling their gear.

In 2005, the dose to high-occupancy houseboat dwellers in the Ribble Estuary was 0.037 mSv, much less than the dose limit for members of the public of 1 mSv. The dose to houseboat dwellers was mostly from enhanced gamma dose rates in the estuary combined with a small contribution from inhalation of resuspended sediments and inadvertent ingestion of sediments. A study carried out by Rollo *et al.* (1994) showed that exposures due to airborne radionuclides that may have come from discharges to the estuary were very small. The dose to houseboat dwellers in 2005 was lower than in 2004, due to reduced gamma dose rates and a reduction in assumed occupancy based on the use of a five year moving average. The trend in doses over the period 2001 – 2005 is shown in the context of Sellafield discharges in Figure 3.4.

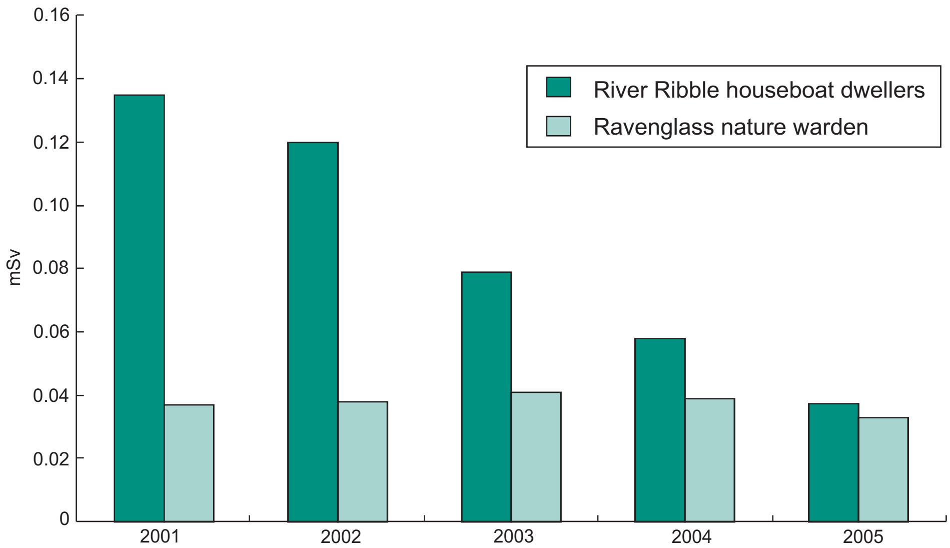


Figure 3.4 External gamma radiation doses in the Ribble Estuary and near Sellafield, 2001-2005

The dose to high-rate seafood consumers in 2005 was 0.023 mSv, the same as in 2004. The majority of this dose was attributable to americium-241 and caesium-137 from Sellafield discharges. Doses to the anglers and children who may play on the river banks were 0.007 mSv and less than 0.005 mSv respectively. The skin dose for fishermen handling nets was estimated to be 0.44 mSv, much less than the skin dose limit of 50 mSv. The dose to the group consuming terrestrial foods grown around the site was less than 0.005 mSv. These doses were generally similar to those in 2004.

3.3 Sellafield, Cumbria

The main operations on the BNGSL Sellafield site are: fuel reprocessing at the Magnox Reprocessing Plant and the Thermal Oxide Reprocessing Plant (THORP); decommissioning and clean-up of redundant nuclear facilities; and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in March 2003 and is now being decommissioned. The UKAEA Windscale site adjoins the Sellafield site, and is discussed in Section 4.

Discharges to atmosphere are made under authorisation from the fuel element storage ponds, the reprocessing plants and waste treatment plants, and from Calder Hall. Discharges from Calder Hall are now much reduced since the power station ceased generating electricity.

Liquid discharges are made under authorisation from the fuel element storage ponds, the reprocessing plants, and from Calder Hall. Wastes from these sources are treated and then discharged to the Irish Sea via the sea pipelines which terminate 2.1 km beyond low water mark. Liquid wastes are also discharged from the factory sewer and the laundry. Reprocessing of Magnox fuel was stopped between April and November 2005 for plant maintenance. Reprocessing at THORP was also shutdown in April 2005 because of the discovery of a leak from primary into secondary containment. The leak did not result in any discharge to the environment. THORP did not resume reprocessing in 2005. Discharges from these plants were therefore reduced during 2005.

Following the agreement of Ministers, the Environment Agency issued a new Sellafield authorisation, which came into force on 1 October 2004. This new authorisation reduced the limits on atmospheric and liquid discharges for most radionuclides, and follows particularly the work to reduce liquid discharges of technetium-99 from the site. Since July 2003, Medium Active Concentrate (MAC) waste from the Magnox reprocessing plant has been processed by routing it to the vitrification plant. This has removed the need for storage of further liquid MAC containing technetium-99 and other radionuclides and has reduced the discharges to the Irish Sea of stored MAC. In 2005, further progress in reducing technetium-99 discharges was achieved, involving the use of tetraphenylphosphonium bromide (TPP) in the Enhanced Actinide Removal Plant (EARP) treatment plant to remove technetium-99 from the MAC already in store, as announced by the Environment Agency and HSE (Environment Agency, 2004a). Implementation of this procedure has allowed a reduction of discharges of technetium-99 by more than 90% from 2002 levels.

A number of minor occurrences are recorded for 2005 at Sellafield in Table 1.1 and where relevant these are referred to later in this section. In addition, on 6 June 2005, the Environment Agency served an enforcement notice requiring BNGSL to better manage liquid low-level radioactive waste at the site (Environment Agency, 2005b). This followed an inspection of the site in February 2005 during which a number of areas of improvement were identified, including the management arrangements to minimise liquid waste discharges. A plan to address the issues has been put in place, and is being invigilated by the Environment Agency.

Monitoring of the environment and food around Sellafield reflects the historic and present day site activities. In view of the importance of this monitoring and the assessment of public radiation exposures, the components of the programme are considered in depth. The discussion is provided in four sub-sections, relating to the effects of gaseous discharges, the effects of liquid discharges, unusual pathways of exposure identified around the site, and dose assessments.

3.3.1 Gaseous discharges

The new gaseous discharge authorisation for the Sellafield site came into force on 1 October 2004. This authorisation placed limits on discharges to atmosphere of total alpha, total beta and 12 named radionuclides. Three radionuclides in the previous authorisation, which were produced in the Calder Hall power station, are no longer discharged from the station following shutdown, and are not now specified: argon-41, sulphur-35 and cobalt-60. Discharges of gaseous wastes from Sellafield in 2005 are summarised in Appendix 1. Because of the smaller amounts of fuel reprocessed in 2005, discharges were much less than the authorised limits and in most cases were lower than the corresponding values in 2004. In November 2005, BNGSL reported that gaseous iodine-129 discharges from two effluent streams from THORP had been underestimated since June 2003. This was due to an inappropriate correction factor being used during sample analysis. BNGSL have now revised upwards their calculated discharges of iodine-129 made since June 2003 - however, their discharges remained below the iodine-129 discharge limit during the period.

Monitoring around the site related to gaseous discharges

There is a substantial programme of monitoring of terrestrial foods in the vicinity of Sellafield carried out by the Food Standards Agency. This programme is the most extensive of those for the nuclear sites in the UK in order to reflect the scale of the discharges from the site. A wide range of foodstuffs was sampled in 2005 including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials such as grass and soil. Samples were obtained from different locations around the site to allow for variations due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses undertaken included gamma-ray spectrometry and specific measurements for tritium, carbon-14, strontium-90, technetium-99, iodine-129, uranium and transuranic radionuclides.

The results of monitoring in 2005 are presented in Table 3.4. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. Concentrations in terrestrial foodstuffs were generally similar to those in 2004.

Concentrations of radionuclides in meat and offal from cattle and sheep were low, with only limited evidence of the effects of Sellafield's atmospheric discharges detected in data for tritium, carbon-14, strontium-90 and iodine-129. Plutonium concentrations when detectable were very low and much lower than those found in seafood.

A wide range of fruit and vegetables was sampled in 2005 including apples, blackberries, broccoli, cabbage, carrots, cauliflower, elderberries, potatoes, runner beans, swede and turnips. The results were similar to those found in previous years. In common with meat and offal samples, only limited evidence was found in some of these foods arising from the atmospheric discharges from Sellafield. Concentrations of transuranic radionuclides, when detectable in these foods, were very low.

There was a minor incident on 25 August 2005, recorded in Table 1.1, involving an abnormal release to atmosphere over an approximately 2 hour period from the High Active Liquor Evaporation and Storage (HALES) facility. In response to this incident grass samples were taken downwind at the site fence by the Environment Agency; these indicated an elevation in the activity concentration of caesium-137, but the levels were within the range normally seen at other locations on the site fence. Additional milk monitoring was carried out by the Food Standards Agency and the results are included in Table 3.4; this revealed only a very minor elevation in activity levels. The radiological impact was therefore very small. The Environment Agency continues to monitor the situation with the use of evaporators at HALES and its impact on discharges to atmosphere.

3.3.2 Liquid discharges

Discharges from the Sellafield pipelines during 2005 are summarised in Appendix 1. Liquid discharges are authorised from the main sea pipelines and the factory sewer to the Irish Sea. The new authorisation from 1 October 2004 sets limits on total alpha and total beta and 15 named nuclides (See Appendix 1). In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site (Segregated Effluent Treatment Plant, Site Exchange Effluent Plant (SIXEP), EARP and THORP). The new overall site limits are lower than before for: total beta, tritium, cobalt-60, zirconium and niobium-95, technetium-99, caesium-134, caesium-137 and cerium-144. Lower limits have also been set for the factory sewer. All of the discharges in 2005 were well below the limits in the new authorisation. Discharges of tritium, carbon-14, ruthenium-106 and iodine-129 were noticeably less in 2005 than in 2004. This reflects the reduced amounts of fuel reprocessed because of the THORP and Magnox reprocessing plant shutdowns in 2005. Discharges of technetium-99 continued their long term downward trend, from their peak of 192 TBq in 1995, to 85 TBq in 2002, 37 TBq in 2003, 14 TBq in 2004 and 6.7 TBq in 2005. The reduction of technetium-99 discharges was due to the diversion of the MAC waste stream to vitrification and use of TPP to remove technetium-99 from the waste stream at the EARP plant (Section 3.3).

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was carried out during 2005. The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 3.5 and 3.6. Smith *et al*. (2004) have carried out a review of recent changes in liquid discharges from the site and their effects.

Monitoring of fish and shellfish

Concentrations of beta/gamma activity in fish from the Irish Sea and from further afield are given in Table 3.5. Data are listed by location of sampling or landing point, north to south in Cumbria, then in approximate order of increasing distance from Sellafield. Concentrations in samples taken near other nuclear establishments that reflect Sellafield discharges are described elsewhere in this report. Concentrations of specific naturally occurring radionuclides in fish and shellfish in the Sellafield area are presented in Section 8. The 'Sellafield Coastal Area' extends 15 km to the north and to the south of Sellafield, from St Bees Head to Selker, and 11 km offshore; most of the fish and shellfish consumed by the local critical group is taken from this area. Specific Cefas 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.

Concentrations of caesium-137 in 2005 were generally similar to those in 2004. They generally reflect progressive dilution with increasing distance from Sellafield. However, the rate of decline of caesium-137 concentrations with distance is not as marked, as was the case when significant reductions in discharges were achieved some years ago. There is therefore a greater contribution from historical sources. Caesium-137 in fish from the Baltic Sea is not due to Sellafield discharges but is substantially from the Chernobyl accident. Concentrations of caesium-137 in fish known to have been caught in Icelandic waters remained typical of those from weapons test fallout, at a value of about 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea are similar.

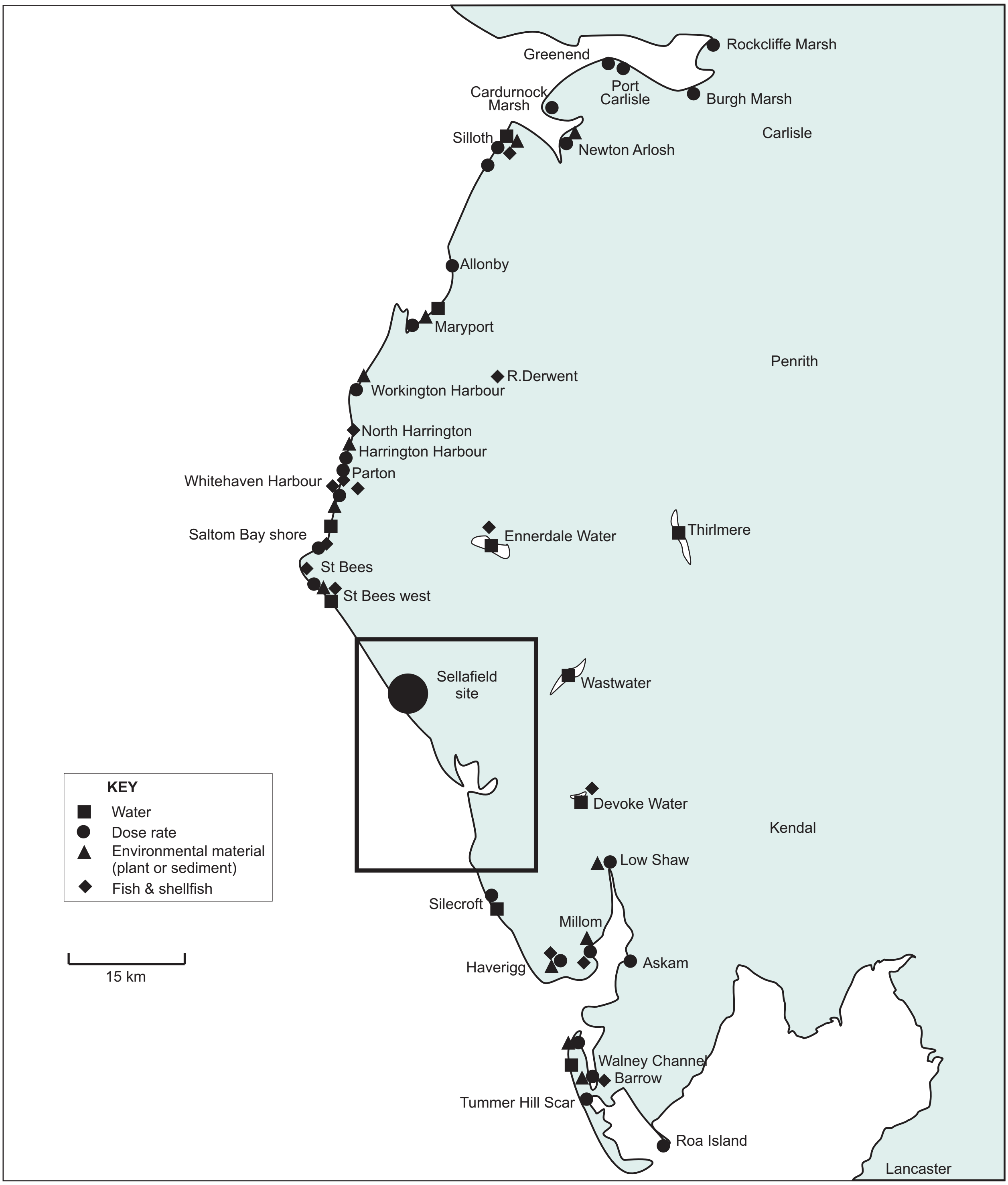


Figure 3.5 Monitoring locations in Cumbria (excluding farms)

Other than caesium-137, artificial beta/gamma emitting radionuclides detected in fish included carbon-14 and tritium. With an expected carbon-14 concentration from natural sources of about 25 Bq kg^{-1}, the data suggest there is a local enhancement of carbon-14 due to discharges from Sellafield. Tritium, which is of low radiotoxicity, gives the highest concentrations of radioactivity in marine fish at about 100 – 200 Bq kg^{-1}, with similar concentrations of organically associated tritium. Concentrations of tritium in local seawater at St Bees are less than 30 Bq l^{-1} (Table 9.18). This indicates that some bioaccumulation of tritium is taking place. However, its extent is much smaller than observed in the Severn Estuary near Cardiff (see Section 7).

Figure 3.6 Monitoring locations at Sellafield (excluding farms)

For shellfish, a wide range of radionuclides is detectable as a result of Sellafield discharges to the Irish Sea, owing to generally greater uptake of radioactivity than by fish. Table 3.6 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 critical group near to Sellafield, as described later. In addition to sampling by Cefas, supplies of winkles, mussels and limpets were obtained from consumers who collected them in the Sellafield coastal area.

Concentrations of artificial radionuclides in shellfish, as with fish, generally diminish with increasing distance from Sellafield. There can be substantial variations between species: for example, lobsters tend to concentrate more technetium-99 than crabs (see also Knowles *et al*., 1998; Swift and Nicholson, 2001). However, as a general rule, molluscs tend to contain higher levels of radionuclides than crustaceans, which in turn tend to contain more than fish. The highest concentrations due to Sellafield discharges are found for tritium, carbon-14 and technetium-99. When comparing 2004 and 2005 data across a wide range of sampling locations and shellfish species, concentrations for 2005 were broadly similar to those in 2004 except for technetium-99 and ruthenium-106, both of which showed systematic decreases. The decreases for technetium-99 were due to the recent progressive reductions in discharges. The decreases for the relatively short-lived ruthenium-106 were due to lower discharges following reduced rates of reprocessing in 2005. Seaweeds are a sensitive indicator of technetium-99 and further information from samples collected throughout the UK is given later in this section.

Analyses for transuranic radionuclides such as plutonium, americium, neptunium and curium are often labour-intensive because they involve chemical separation techniques to quantify the radionuclides present and they are counted for a long time in order to detect the very low levels. Therefore a specific selection of samples of fish and shellfish, chosen mainly on the basis of potential radiological significance, were analysed for these nuclides. The data for 2005 are presented in Table 3.7. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish. Concentrations in shellfish in 2005 were generally similar to those in 2004; those from the north-eastern Irish Sea were the highest concentrations of transuranics found in foodstuffs in the UK.

Trends in concentrations of radionuclides in seafood near Sellafield are shown in Figures 3.7 – 3.12 with the corresponding discharge profiles. Concentrations have generally reflected changes in discharges, over time periods characteristic of radionuclide mobility and organism uptake. There is variability from year to year, particularly for the more mobile species. For the transuranics (Figures 3.11 – 3.12), the long-term trend in reductions of concentrations appears to be slowing.

Monitoring of sediments

A further important pathway leading to radiation exposure as a result of Sellafield liquid discharges arises from uptake of 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 radionuclides more readily.

Concentrations of radionuclides in surface sediments from a range of coastal locations in the Sellafield vicinity and further afield are regularly monitored, both because of relevance to exposures and in order to keep distributions of adsorbed radioactivity under review. The results for 2005 are shown in Table 3.8. Radionuclides detected included cobalt-60, ruthenium-106, caesium-137 and transuranics. The highest concentrations found are close to the site and in fine particulate materials in estuaries and harbours. The concentrations of long-lived radionuclides, particularly caesium-137 and the transuranics, reflect past discharges from Sellafield, which were considerably higher than in recent years. Over the last 30 years discharges have fallen significantly as the site provided enhanced treatment to remove radionuclides prior to discharge. Overall, concentrations in sediments in 2005 were generally similar to those in 2004. An exception to this was at Ravenglass and the River Mite estuary where results are included from analysis of samples collected by a different contractor. These samples may have contained non-surface material, higher in radioactivity concentrations typical of a period of greater discharges from Sellafield.

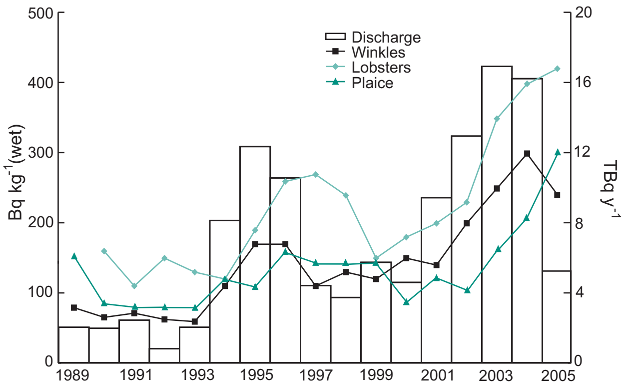


Figure 3.7 Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

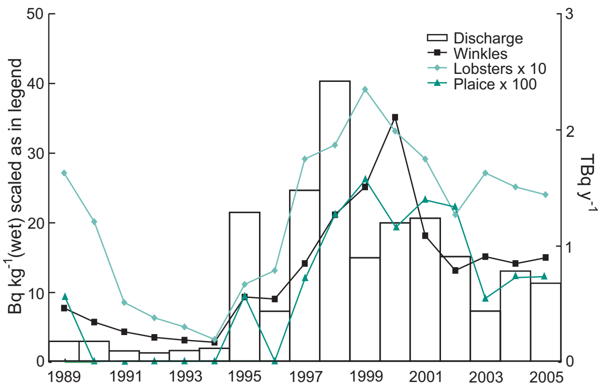


Figure 3.8 Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

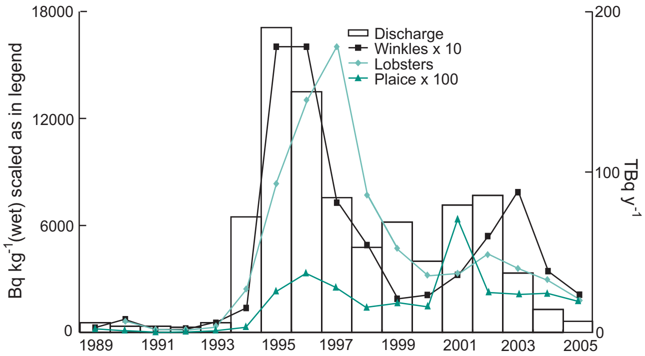


Figure 3.9 Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

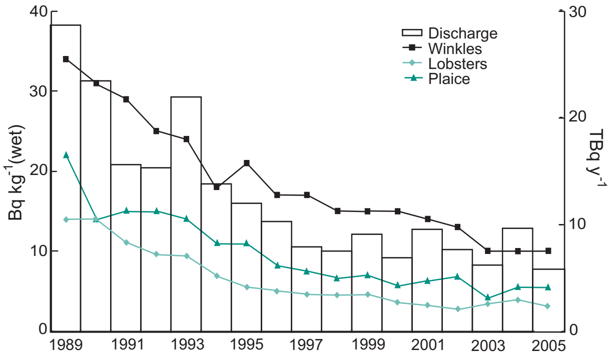


Figure 3.10 Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

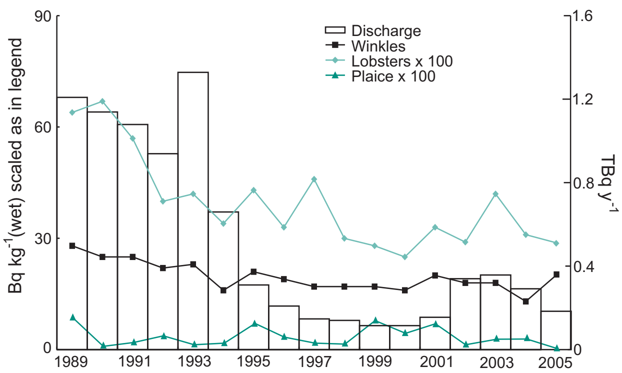


Figure 3.11 Plutonium-239/240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

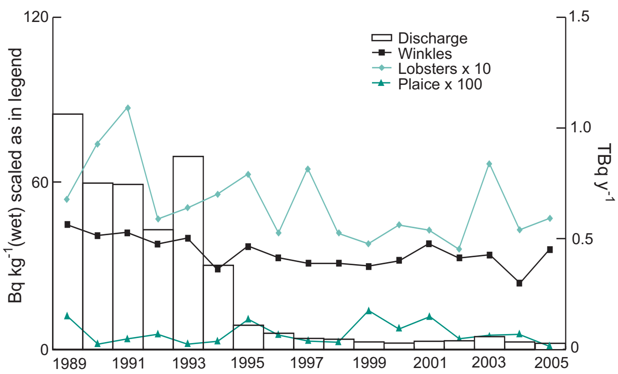


Figure 3.12 Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

The trends over the last two decades of discharges from Sellafield and concentrations in mud from Ravenglass are shown in Figures 3.13 – 3.16. The concentrations of most radionuclides have decreased over the past 25 years in response to decreases in discharges. In particular there have been sustained reductions in discharges of caesium-137 and transuranics; these reductions are reflected in the decreases in concentrations of these radionuclides at Ravenglass. Discharges of cobalt-60 have been variable in recent years, as reflected in the sediment concentrations at Ravenglass (Figure 3.15). Since the mid 1990s, discharges of caesium-137, plutonium isotopes and americium-241 have been maintained at low levels, but there has been some variability and even a suggestion of progressive increases in the concentrations in sediments. This result could be due to remobilisation and subsequent accretion of fine-grained sediments containing higher activity concentrations. For americium-241, there is also an additional contribution due to radioactive ingrowth from the parent plutonium-241 already present in the environment. The effect is as yet less apparent in fish and shellfish (Figures 3.10 – 3.12) and will continue to be monitored.

Monitoring of dose rates

Dose rates are regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation dosemeters. Table 3.9 lists the locations monitored by the Environment Agencies and the Food Standards Agency together with the gamma dose rates in air at 1 m above ground. Dose rates near other nuclear establishments that reflect Sellafield discharges are given in the relevant sections of this report. The general decrease in dose rates with increasing distance from Sellafield, which was apparent under conditions of higher discharges several decades ago, is no longer so apparent, but there is variability depending on ground type, generally higher dose rates being recorded over areas with finely divided sediments. Dose rates measured above mud and salt marsh, shown in Figure 3.17, fluctuate quite markedly with ground type, and illustrate the current low dependence on distance from Sellafield within the Irish Sea. Dose rates over intertidal areas throughout the Irish Sea in 2005 were similar to those data for the same locations in 2004. The longer term reduction of gamma dose rates at Ravenglass and St. Bees since the 1980s can be seen in Figure 3.18; this has occurred primarily as a result of the reduction of gamma emitting radionuclides from Sellafield.

Gamma dose rates measured on the banks of the River Calder, which flows through the Sellafield site, continued to show a significant excess above natural background downstream of the site. This may be due to small patches of sediment. Occupancy by the public, mainly anglers, is low in this area, and unlikely to be more than a few tens of hours per year. On this basis the resulting doses were much less than those at other intertidal areas as discussed later in this section.

Monitoring of fishing gear

During immersion in seawater, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored by the Food Standards Agency using surface contamination meters. Results for 2005 are presented in Table 3.10. Measured dose rates were generally similar to those for 2004.

Contact dose-rate monitoring of intertidal areas

A programme of measurements of beta dose rates on shoreline sediments using contamination monitors continued in 2005 to allow the exposure to be estimated for people who handle sediments regularly and the results are presented in Table 3.11. Dose rates were similar to those observed in 2004. In addition, more general beta/gamma monitoring of contamination on beaches using portable probes continued in 2005. About 50 km of beach was surveyed including areas close to the discharge point, in the Ravenglass estuary and further afield to establish whether there are any localised 'hot spots' of activity, particularly in strand lines and beach debris. In 2005, no material was found in excess of the action level equivalent to 0.01 mSv h^{-1} and no material was therefore removed.

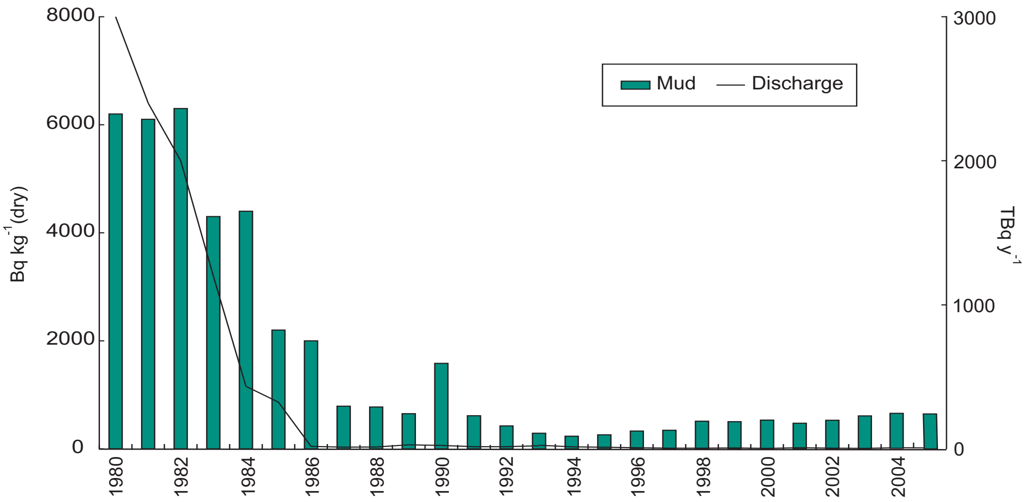


Figure 3.13 ***Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass*** *(data prior to 1988 are from BNFL surveys)*

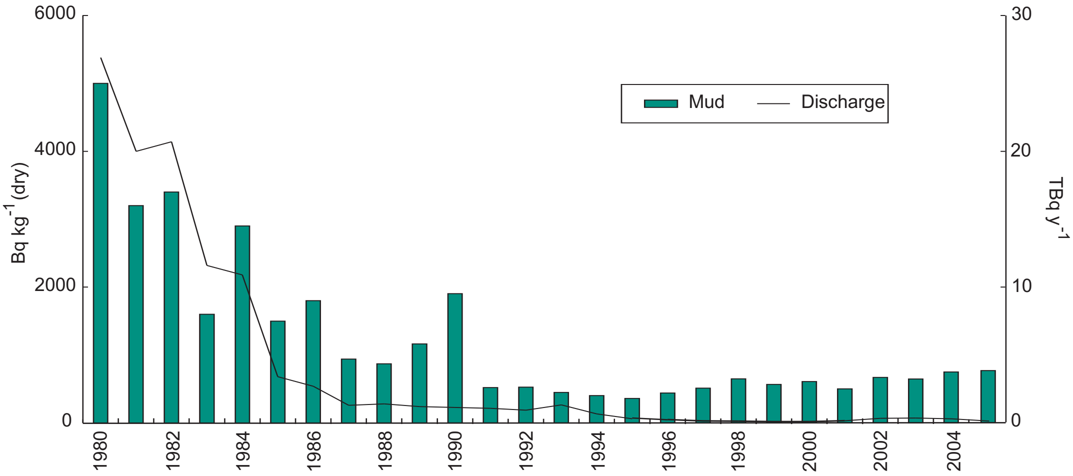


Figure 3.14 ***Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass*** *(data prior to 1988 are from BNFL surveys)*

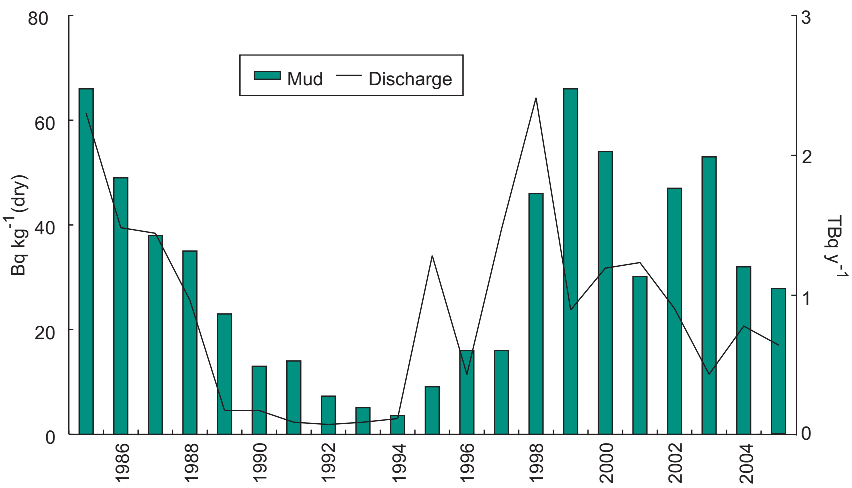


Figure 3.15 ***Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass*** *(data prior to 1988 are from BNFL surveys)*

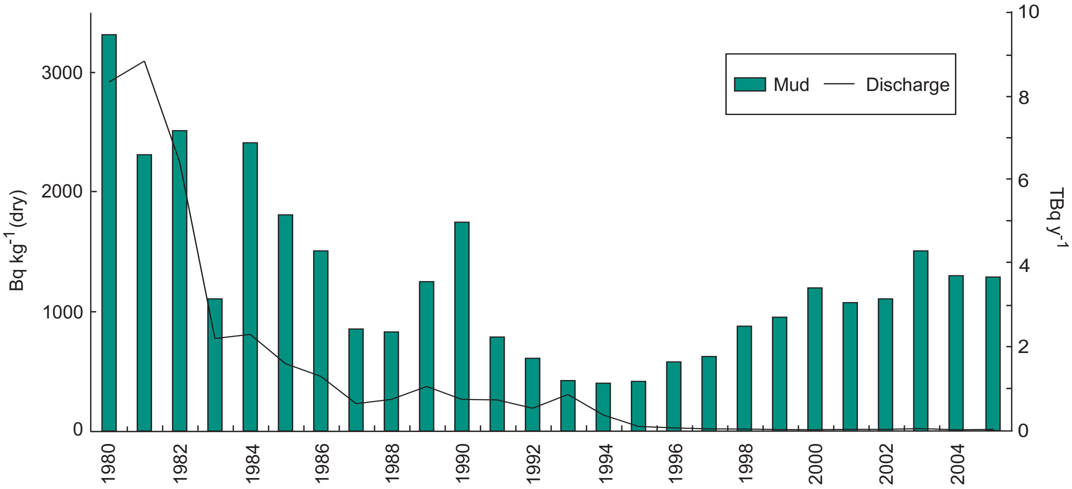


***Figure 3.16 Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass** (data prior to 1988 are from BNFL surveys)*

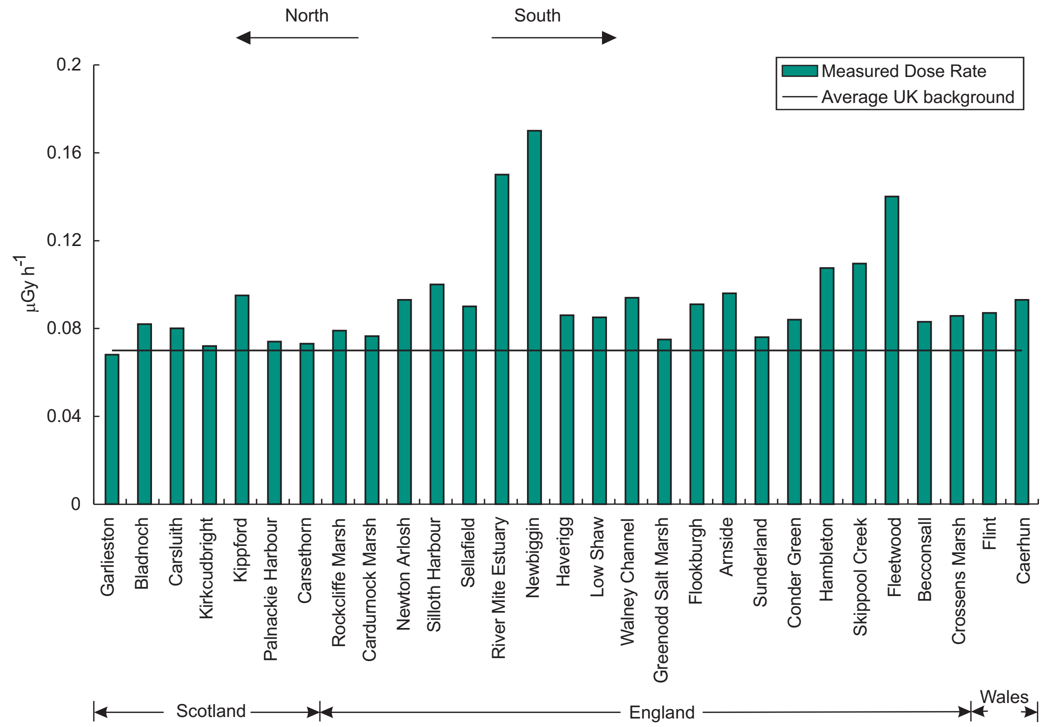


Figure 3.17 Gamma dose rate above mud and salt marsh with distance from Sellafield

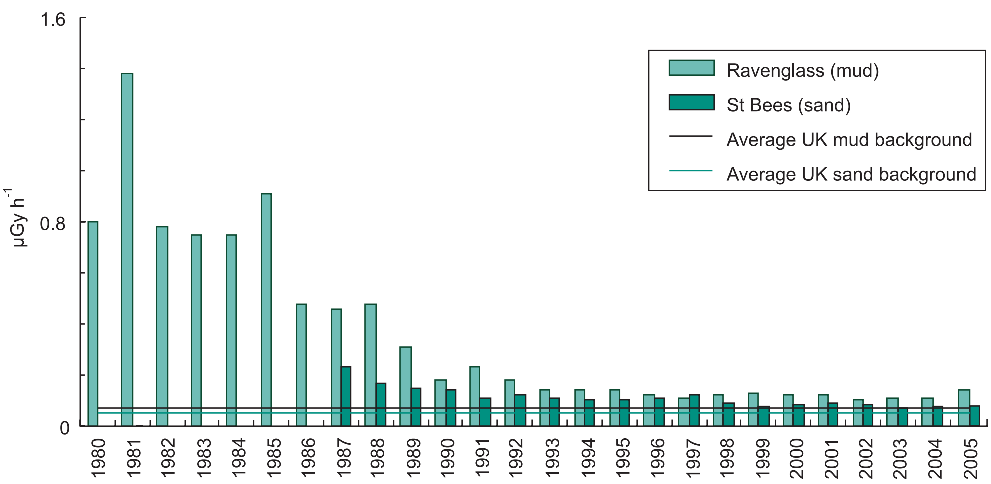


***Figure 3.18 Gamma dose rate at Ravenglass and St Bees** (data prior to 1988 are from BNFL surveys)*

As part of the decommissioning operations at Sellafield, BNGSL has removed three redundant sea discharge pipelines. Two of the pipes are of steel construction and one of plastic. This work continued in 2005 and was completed in 2006 without further incident.

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials; they concentrate particular radionuclides, so they greatly facilitate assessments and assist in the tracing of these radionuclides in the environment. Table 3.12 presents the results of measurements in 2005 of seaweeds from shorelines of the Cumbrian coast and further afield.

Fucus seaweeds are particularly useful indicators of fission product radionuclides other than ruthenium-106; samples of *Fucus vesiculosus* were collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. Monitoring clearly showed the effects of discharges of technetium-99 from Sellafield. In the north-east Irish Sea there was a continued general decrease in concentrations of technetium-99 in *Fucus vesiculosus* in 2005; the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s (Figure 3.19). There is still a large reduction in concentrations of technetium-99 in *Fucus vesiculosus* with distance from Sellafield as the effect of the discharges becomes diluted in moving further afield. However, at Fishguard there appears to have been an increase in concentrations of technetium-99 in *Fucus vesiculosus* and seaweed in 2004 and 2005; there is similar evidence at Cemaes Bay on the Isle of Anglesey and possibly at Porthmadog. At Carlingford Lough in Ireland there was an increase in technetium-99 concentrations in *Fucus* in 2004 but this returned to lower levels in 2005. This effect could be the result of increased

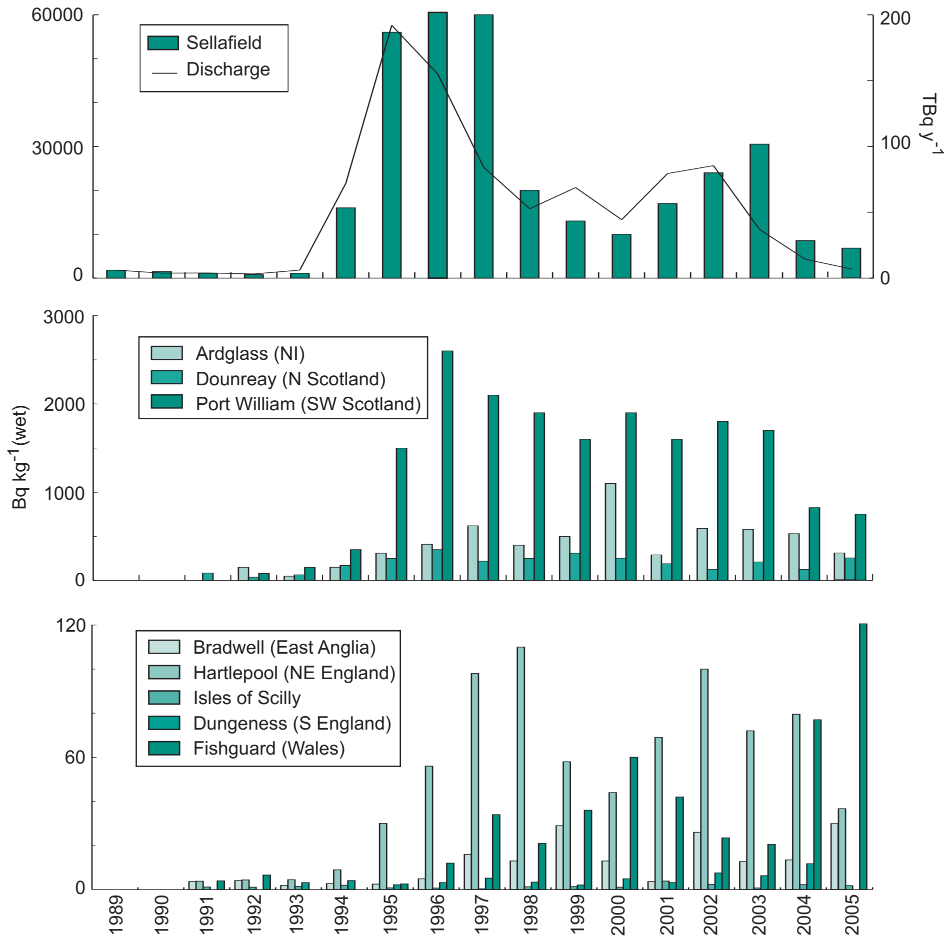


Figure 3.19 Technetium-99 liquid discharge from Sellafield and concentration in seaweed, Fucus vesiculosus

water movement southwards in the Irish Sea during 2004. It may also be noted that as the effects of the high technetium discharges of the 1990s continue to disperse, there is the potential for areas distant from Sellafield to exhibit concentrations greater than those in closer proximity, as was observed in sea water in Liverpool Bay for 1998 (McCubbin *et al.*, 2002).

During a study of radionuclides on the coast of North Wales funded by the Welsh Assembly Government (Welsh Assembly Government, 2006; Bryan *et al.*, 2006), referred to later in this section in relation to doses from sea to land transfer, elevated concentrations of technetium-99 in sediments were reported for 2004 and 2005 in the Menai Strait. Concentrations in seaweed from the same vicinity were consistent with those reported for Cemaes Bay (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005). Further measurements were carried out on behalf of the Environment Agency (Environment Agency, 2005c; Carpenter, 2005) who reported lower levels in sediments than in the Welsh Assembly Government funded study, and that the radiological significance of technetium-99 in North Wales is very low, and is decreasing generally.

Seaweeds are sometimes used as fertilisers and soil conditioners and this pathway was the subject of a continuing research study in 2005. The results are shown in Table 3.13. The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al*., 2000). In 2005, seaweed harvesting in the Sellafield area continued to be rare. However, several plots of land previously fertilised by seaweed were identified and investigated further. Samples of soil were analysed for a range of radionuclides by gamma-ray spectrometry and for technetium-99. The soil and compost data show enhanced levels of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. The technetium-99 concentrations in vegetables ranged up to 1200 Bq kg^{-1} in edible parts. Low concentrations of gamma-emitting radionuclides were found in some vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2005; this pathway has therefore remained essentially dormant. However, monitoring of *Porphyra* has continued in view of its potential importance, historical significance and the value of *Porphyra* as an environmental indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2005 are presented in Table 3.12. *Porphyra* from the Cumbrian coast in 2005 clearly showed reduced concentrations of ruthenium-106 compared with 2004 due to the decreased discharges of this radionuclide. Samples of laverbread from the major manufacturers are regularly collected from markets in South Wales and analysed. Results for 2005 are also presented in Table 3.12; concentrations of radionuclides were either undetectable or at very low levels.

In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. Investigations have shown that this does not take place to a significant extent in the Sellafield area.

Monitoring of seawashed pasture

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow up sampling of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2005 (Table 3.13) suggests that this dose estimate remains valid.

Monitoring of sea to land transfer

Terrestrial foodstuffs are monitored near Ravenglass to check on the extent of transfer of radionuclides from sea to land in this area. Samples of milk, crops, fruit, livestock and environmental indicator materials were collected and analysed for radionuclides which were released in liquid effluent discharges from Sellafield.

The results of measurements in 2005 are presented in Table 3.14. In general, the data are similar to those for 2004 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. The evidence for sea to land transfer is limited. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. Where detectable, concentrations of transuranic radionuclides indicated an observed isotopic ratio for $^{239+240}Pu$:^{238}Pu somewhat lower than about 40:1 which would be expected from only fallout. This may suggest a Sellafield influence.

Monitoring of fishmeal

Low concentrations of man-made radioactivity were found in fishmeal, which is fed to farmed fish, poultry, pigs, cows and sheep (Table 3.5). A theoretical study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is unlikely to be of radiological significance (Smith and Jeffs, 1999). A detailed survey was undertaken in 2003 to confirm these findings. Samples were obtained from 14 fish farms in Scotland and 3 in Northern Ireland. They demonstrated that concentrations of radionuclides are indeed very low, most being less than the limits of detection, and the few that were positively determined were all less than 1 Bq kg^{-1} (Food Standards Agency, 2003). Results in farmed salmon from the west of Scotland in 2005 in Tables 3.5 and 3.7 confirm that this remains the case.

Monitoring of waters

Evidence of the effects of liquid discharges from Sellafield on concentrations of radionuclides in seawater is determined by sampling from research vessels and the shore. The results of the seawater programme are presented in Section 9.

Sampling of fresh water from rivers and lakes in west Cumbria is carried out as part of the regular environmental monitoring programme around Sellafield; however, other environmental materials would be likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2005 are included in Table 3.15. The levels of gross alpha and gross beta activity were below the WHO recommended values of 0.1 Bq l^{-1} and 1.0 Bq l^{-1} respectively.

Small amounts of activity are discharged from Sellafield under authorisation via the factory sewer outfall at the mouth of the River Calder. There was some evidence of tritium at the outfall (Table 3.15). However, the waters are not potable and the low concentrations are of no radiological significance. In addition, Table 3.15 includes the results of monitoring from the Ehen Spit (see Figure 3.6) near Sellafield where water issues from the ground at low tide. This release is not due to authorised discharges of liquid wastes but to ground water migration from the Sellafield site. The water is brackish so it will not be used as a drinking water source and therefore the only consumption would be inadvertent. Enhanced gross beta and tritium concentrations were observed in 2005 with levels similar to previous years. The dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant (Environment Agency, 2002a).

3.3.3 Monitoring of unusual pathways

In 1998, high levels of caesium-137 (of up to 110,000 Bq kg^{-1}) were found in feral pigeons sampled in Seascale by the Ministry of Agriculture, Fisheries and Food (MAFF). Consumption of the breast meat of 20 birds contaminated at the highest level would have been needed to give a resultant dose of 1 mSv. Advice issued by MAFF on 14 February 1998 was that people should not handle, slaughter or consume pigeons within a 10 mile radius of the site. A full review of the incident was published in 1999 (Copeland Borough Council *et al*., 1999). It was found that pigeons had access to the roof spaces in buildings on the Sellafield site and had become contaminated with radionuclides including caesium-137. The pigeons were also congregating in large numbers at a bird sanctuary in Seascale village and the environment around had become contaminated. Since then, BNFL have undertaken remedial measures, including a substantial cull of feral pigeons in the area and preventing access to the loft spaces in buildings on the Sellafield site. Results of the analysis of wood pigeon samples collected in 2005 are included in Table 3.4. The concentrations of artificial radionuclides, including radiocaesium, were low and would add little to the exposure of local consumers. In view of the limited numbers of feral pigeons now on the site, the Food Standards Agency will be reviewing the need for the precautionary advice to continue. A sample of deer was also taken in 2005, and again the concentrations of artificial radionuclides were low.

Following the review of the pigeon incident the Environment Agency began to sample and analyse sediments from road drains (gully pots) in Seascale and Whitehaven in 1999. Gully pots in road drains collect sediments washed off road surfaces and provide good indicators of contamination of urban environments. In 2005 samples were taken from the same drains as in previous years - one drain at Whitehaven and four drains in Seascale village, two near the site of remediation. The results of analyses in 2005 are shown in Table 3.16. Concentrations have generally fallen significantly since remedial measures to reduce contamination were taken.

3.3.4 Doses to the public

Doses from gaseous discharges

The dose received by the critical group who consume terrestrial food and are exposed to external and inhalation pathways from gaseous discharges was calculated using the methods and data presented in Section 2 and Appendix 2. The results are presented in Table 3.17. Calculations were performed for four ages (adult, 10y, 1y and prenatal); doses received by 1 year olds were found to be the highest, at 0.034 mSv (adult: 0.021; 10y: 0.023; prenatal 0.015). The most significant contributions to the 1-year-old's dose were from strontium-90 and ruthenium-106, but it should be noted that the dose assessment used ruthenium-106 levels in foods at the limits of detection and are thus maximising. The most important foodstuff was milk, which accounted for 46% of the dose.

The assessed dose due to high-rate food consumption by infants in 2005 (0.033 mSv) was slightly less than the corresponding dose in 2004 (0.035 mSv). Doses as a result of environmental non-food pathways (mostly inhalation of radionuclides and external dose from noble gases) were low in 2005 at less than 0.001 mSv.

The pathway (food and external/inhalation) and radionuclide contributions to dose from gaseous discharges from Sellafield for the period 2002 – 2005 are shown in Figure 3.20. The trend has been a generally declining one with reductions in doses of about 10% over the last 4 years. The downward trend is mainly due to the permanent shut down of Calder Hall and the resulting cessation of discharges of argon-41 and sulphur-35.

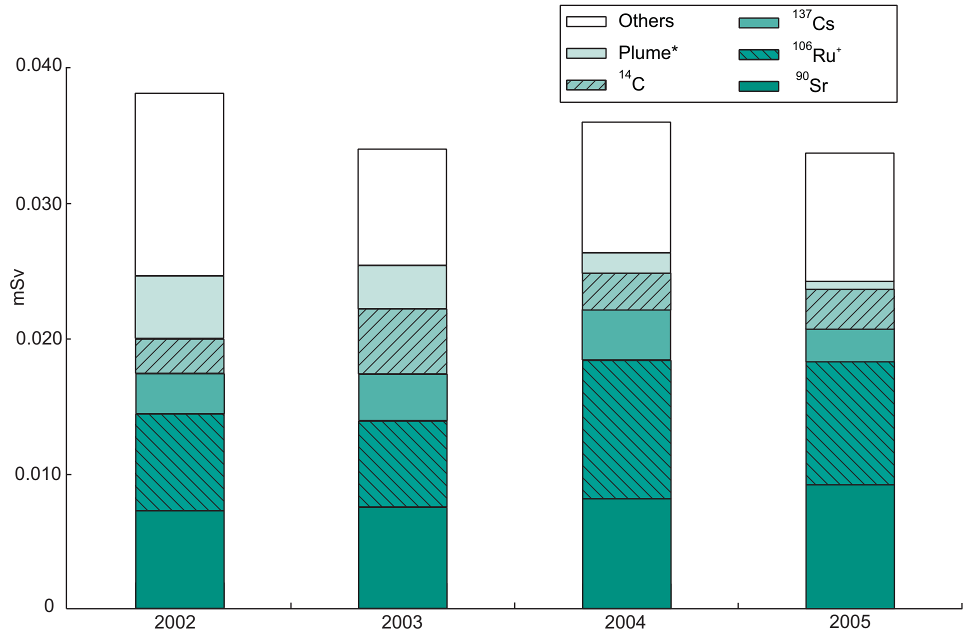


Figure 3.20 Contributions to dose due to gaseous discharges from Sellafield, 2001-2005 (* External and inhalation pathways, + Based on limits of detection for concentrations in foods)

Doses from liquid discharges

Important radiation exposure pathways as a result of liquid radioactive waste discharges from Sellafield continued to be due to consumption of fish and shellfish and to external exposure from gamma rays and beta particles during people's occupancy over sediments and/or handling fishing gear. Other pathways were kept under review, particularly the potential for sea-to-land transfer at the Ravenglass estuary to the south of the site.

Doses from seafood consumption

The consumption and occupancy rates of the local critical group were reviewed in 2005; small changes were found in the amounts and mixes of species consumed. There was a decrease in occupancy over sediments. The habits data are given in detail in Appendix 4. Two sets of habit data were used in the assessments. One was based on the habits seen in the area each year (2005 habits survey). The second was based on a 5 year rolling average using habit data gathered from 2001 to 2005. Aquatic pathway habits are normally the most important in terms of dose at Sellafield and are surveyed every year. This allows generation of a unique yearly set of aquatic habit data and also rolling 5 year averages for aquatic habits. The rolling averages are intended to smooth the effects of sudden changes in habits and provide an assessment of dose that follows more closely changes in radioactivity concentrations in food and the environment. The 5 year averages are used for the main assessment of doses from liquid discharges and follows the recommendations of the report of the CEDA (Food Standards Agency 2001a).

Table 3.17 summarises doses to seafood consumers in 2005. The dose to the local critical group of high-rate consumers from artificial radionuclides, using the moving average habits data, was 0.22 mSv. This dose includes a contribution due to external radiation exposure over sediments. This is the same dose as was reported for 2004. Most of this dose was due to historic discharges from Sellafield. The breakdown by nuclide of the contributions to dose is shown in Figure 3.21. Recent and current discharges of technetium-99 contributed about 6% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose (66%) were plutonium-239/240 and americium-241.

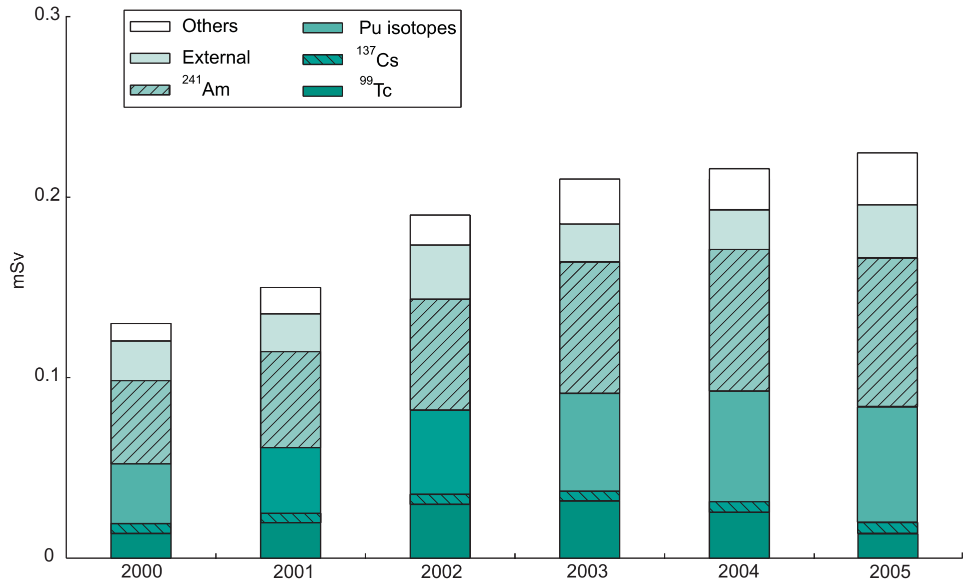


Figure 3.21 Contributions to dose to seafood consumers at Sellafield, 2000-2005

A single-year dose assessment for the Sellafield seafood consumers based on consumption rates and habits survey data for 2005 is provided in Table 3.17 for comparison with the assessment using the five year moving average habits data.

Data for naturally occurring radionuclides in fish and shellfish are discussed in Section 8. However, the effects on the Sellafield critical group of the historic discharges of naturally occurring radionuclides from another west Cumbrian source, the former phosphate works at Whitehaven, are also considered here. These works were demolished in 2004 and the authorisation to discharge radioactive wastes revoked. The increase in concentrations of naturally occurring radionuclides due to the historic discharges is difficult to determine above a variable background (see Appendix 6). However, using maximising assumptions for the dose coefficients, the dose to the local group of seafood consumers due to the enhancement of concentrations of naturally occurring radionuclides in the Sellafield area in 2005 was estimated to be 0.23 mSv. Most of this was due to polonium-210 and lead-210 in shellfish. Taken with the 0.22 mSv dose from artificial radionuclides from Sellafield this gives, when rounded again to two significant figures, a total dose to the critical group of 0.46 mSv. These doses may be compared with an average dose of approximately 2.2 mSv to members of the UK public from all natural sources of radiation (Watson *et al*, 2005) and to the annual dose limit to members of the public of 1 mSv.

Exposures of groups representative of the wider communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland, north Wales and the Isle of Man have been kept under review (Table 3.17). Where appropriate, the dose from consumption of seafood has been summed with a contribution from external exposure over intertidal areas. The doses received by all these groups are significantly less than for the local Sellafield group because of the lower concentrations and dose rates further afield. There were small changes in the doses in each area when compared with those in 2004 (see table in following text and Figure 3.22). It is expected that there will be fluctuations in concentrations due to normal sampling variability. Whilst there have been changes in the concentrations of some radionuclides in seafood, their effect is relatively minor. All doses were well within the dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, equivalent to a consumption rate of 15 kg $year^{-1}$ of fish from landings at Whitehaven and Fleetwood, is also given in Table 3.17. This consumption rate represents an average for typical fish-eating members of the public. The dose to such a person was very low, less than 0.005 mSv in 2005.

Figure 3.22 Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2005

Doses from artificial radionuclides in the Irish Sea			
Group	Dose, mSv		
	2003	2004	2005
Isle of Man	0.006	0.007	0.008
Northern Ireland	0.013	0.010	0.020
Dumfries and Galloway	0.036	0.038	0.031
Whitehaven	0.031	0.013	0.008
Sellafield (average consumption 2001 – 2005)	0.21	0.22	0.22
Morecambe Bay	0.075	0.068	0.063
Fleetwood	0.018	0.018	0.019
North Wales	0.012	0.012	0.015

The exposure of potential consumers of trout from a tarn at farm local to Sellafield was not considered, as there continued to be no evidence of consumption of trout from the lake in 2005.

Doses from sediments

The main radiation exposure pathway associated with sediments is due to external dose from gamma-emitting radionuclides adsorbed on intertidal sediments in areas frequented by the public. This dose can make a significant contribution to the total exposure of members of the public in coastal communities throughout the Irish Sea but particularly in Cumbria and Lancashire. Gamma dose rates currently observed in intertidal areas are mainly due to radiocaesium and naturally occurring radionuclides. For some groups, the following pathways may also contribute to doses from sediments: exposure due to beta-emitters during handling of sediments or fishing gear; inhalation of resuspended beach sediments; and inadvertent ingestion of beach sediments. These pathways are considered later: in the main, they give rise to only minor doses compared with those due to external gamma emitters.

Gamma radiation dose rates over areas of the Cumbrian coast and further afield in 2005 are presented in Table 3.9. The results of the assessment of external exposure pathways are included in Table 3.17. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, are received by people who live in houseboats in the Ribble estuary in Lancashire. In 2005, their dose was 0.037 mSv or about 4% of the dose limit for members of the public. This was less than the value of 0.058 mSv in 2004 due to reduced dose rates in the vicinity of the houseboats and the effect of using a moving average occupancy time over the period 2001 – 2005. A small contribution due to inadvertent ingestion of sediments and inhalation of resuspended sediments is included. Other groups received lower external doses in 2005. The most important of these were found in the Ravenglass estuary; exposures over salt marsh and mud ranged up to 0.036 mSv for high levels of recreational use and 0.033 mSv for a nature warden. The assessed dose for recreational use was higher than in 2004 (0.030 mSv) due to inclusion of elevated concentrations of radionuclides from Ravenglass estuary samples from another contractor, referred to in Section 3.3.2. The dose for a typical occupancy of a sandy beach close to Sellafield was estimated to be much less than 0.005 mSv. Dose rates in areas relevant to the Ravenglass nature warden have remained broadly similar over the period.

Doses from handling fishing gear and sediment

Exposures can also arise from contact with beta-emitters during handling of sediments or fishing gear on which fine particulates have become entrained. 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 730 h year^{-1} was appropriate. The skin dose from handling of fishing gear in 2005, including a component due to naturally occurring radiation, was 0.066 mSv, which was less than 1% of the appropriate annual dose limit of 50 mSv specifically for skin. Handling of fishing gear is therefore a minor pathway of radiation exposure. The skin dose to bait diggers and shellfish collectors, based on a time handling sediment of 1000 h year^{-1}, was 0.26 mSv in 2005 which was also less than 1% of the skin dose limit.

Doses from atmospheric sea to land transfer

The exposure due to consumption of terrestrial foods potentially affected by sea to land transport by seaspray of radionuclides at Ravenglass in 2005 is given in Table 3.17 . The 1-year-old age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was calculated to be 0.018 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. Sea-to-land transfer therefore is not of radiological importance in the Ravenglass area.

During 2004 and 2005 a study of sea to land transfer of artificial radionuclides was carried out on the North Wales coast by Westlakes Scientific Consulting Ltd on behalf of the Welsh Assembly Government (Bryan *et al*, 2006). This study provided an updated radiological assessment for that area, and showed that for the critical group of terrestrial food consumers, dose rates on the North Wales coast were less than 0.005 mSv.

Doses from seaweed and seawashed pasture

Although small quantities of Samphire, Porphyra and Rhodymenia (a red seaweed) may be eaten, concentrations of radioactivity were of negligible radiological significance. The dose to high-rate laverbread consumers in south Wales was much less than 0.005 mSv, confirming the low radiological significance of this exposure pathway.

Seaweeds are sometimes used as fertilisers and soil conditioners. Assuming that high-rate vegetable consumers obtain all of their supplies from monitored plots near Sellafield, the dose in 2005 was estimated to be 0.069 mSv. This was higher than in 2004 (0.015 mSv) because the dose assessment made use of concentrations of radionuclides in spinach, which concentrates technetium-99 to a greater extent than other vegetables. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and north Wales would be much lower than near Sellafield. The seaweed/vegetable pathway will be kept under review but it is likely that the doses due to direct consumption of seafood and external radiation from intertidal areas will remain more important.

Animals may graze on seaweeds at the upper tidal limit of coastal areas; however, there is no evidence of this taking place significantly near Sellafield. The Food Standards Agency undertook an assessment of the potential dose to a high-rate consumer of meat and liver from sheep grazing the seaweed using data relevant to the Shetlands and Orkneys. This showed that doses would have been well within the dose limit of 1mSv per year for members of the public in 1998 when concentrations of technetium-99 would have been at substantially higher levels than in 2005 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999).

Table 3.1(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{3}H	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{155}Eu	^{233}Pa	^{234}Th	^{234}U
Aquatic samples												
Flounder	Liverpool Bay	2	<30									
Flounder	Mersey Estuary	2	<25									
Shrimps	Wirral	2	<25	<0.05	2.7	<0.48	<0.13	2.0	<0.10	*	*	
Mussels	Liverpool Bay	2	<25									
Mussels	Mersey Estuary	2	<28									
Cockles	River Dee	4		0.21	9.9	<0.48	0.37	1.9	<0.13	<0.27	6.2	
Elodea canadensis	Rivacre Brook	2		<0.07	3.1	<0.71	<0.14	<0.12	<0.10	<1.7	12	4.0
Sediment	Rivacre Brook	2[E]			280			3.3			200	110
Sediment	Rivacre Brook (1.6 km downstream)	2[E]			130			3.2			380	73
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			67			<1.0			<39	28
Sediment	Rossmore (4.3 km downstream)	2[E]			160			4.3			<170	68
Freshwater	Rivacre Brook	2[E]	14		<0.13							0.11
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.0		<0.12							0.055
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.2		<0.13							0.046
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.0		<0.13							0.044
Freshwater	Dunkirk Lane Pond	2[E]	<4.0		<0.14							0.011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{235}U	^{238}U	^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples											
Shrimps	Wirral	2						<0.06			
Cockles	River Dee	4				0.17	1.1	2.7	0.0031		
Elodea canadensis	Rivacre Brook	2	0.19	2.2	0.033			<0.05			
Sediment	Rivacre Brook	2[E]	4.0	66	32					610	1100
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	2.6	38	13					410	840
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	<1.1	19	<9.7					200	610
Sediment	Rossmore (4.3 km downstream)	2[E]	2.4	34	14					360	810
Freshwater	Rivacre Brook	2[E]	<0.0055	0.050	<0.25					0.12	0.47
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<0.0055	0.027	<0.25					0.060	0.38
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<0.0050	0.028	<0.25					<0.054	0.34
Freshwater	Rossmore (4.3 km downstream)	2[E]	<0.0050	0.030	<0.25					0.070	0.36
Freshwater	Dunkirk Lane Pond	2[E]	<0.0070	<0.0090	<0.25					<0.086	2.2

Table 3.1(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H[c]	^{99}Tc	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk		5	<2.8	<0.0060				<0.0061
Gooseberries		1		0.037				<0.030
Lettuce		1		<0.033				<0.034
Potatoes		1		<0.023	0.0036	<0.00080	0.0019	<0.034
Grass		4		<0.012				0.081
Grass	max			0.018				0.11
Grass/herbage	North of Ledsham	1[E]		<1.0	1.0	<0.19	1.1	
Grass/herbage	South of Capenhurst	1[E]		<1.0	0.14	<0.090	0.24	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<1.5	<0.40	<0.30	<0.30	
Grass/herbage	East of station	1[E]		<1.0	0.46	<0.12	0.47	
Silage		2		<0.012				0.37
Silage	max				0.27	0.015	0.27	0.49
Soil		2						56
Soil	max				8.1	0.31	7.7	62
Soil	North of Ledsham	1[E]		<3.0	21	<0.81	22	
Soil	South of Capenhurst	1[E]		<3.0	16	<0.64	18	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		<4.0	20	1.1	21	
Soil	East of station	1[E]		<3.2	21	0.76	21	

** Not detected by the method used*

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

[b] *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 value is the most appropriate for dose assessments*

[c] *In distillate fraction of sample*

[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 3.1(b). Monitoring of radiation dose rates near Capenhurst, 2005

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Concrete	1	0.094
Rivacre Brook Plant outlet	Grass	1	0.094
Rivacre Brook 1.5 km downstream	Grass	2	0.082
Rivacre Brook 3.1 km downstream	Grass	1	0.078
Rivacre Brook 3.1 km downstream	Mud	1	0.080
Rossmore Road West 4.3 km downstream	Grass	2	0.076

Table 3.2. Individual radiation exposures – Capenhurst and Springfields, 2005

Site	Exposed population group[a]	Exposure, mSv				
		Total	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water
Capenhurst	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	Children playing at Rivacre Brook[d]	0.009	-	-	0.009	<0.005
Springfields	Seafood consumers	0.023	0.023	-	-	-
	Houseboat occupants	0.037	-	-	0.035	<0.005
	Fishermen handling nets or pots[c]	0.44	-	-	0.44	-
	Children playing at Lower Penwortham[d]	<0.005	-	-	<0.005	<0.005
	Anglers	0.007	-	-	0.007	-
	Consumers of locally grown food[e]	<0.005	-	<0.005	-	-

[a] *Adults are the most exposed group unless otherwise stated*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *Children aged 10y*
[e] *Includes a component due to natural sources of radionuclides*

Table 3.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{14}C	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples												
Flounder	Ribble Estuary	1		<0.11		<1.2	<0.30	5.5				*
Salmon	Ribble Estuary	1		<0.10		<0.98	<0.24	0.12				*
Sea trout	Ribble Estuary	1		<0.12		<1.2	<0.28	2.2				*
Grey mullet	Ribble Estuary	1		<0.11		<1.3	<0.30	4.2				*
Shrimps[d]	Ribble Estuary	2	58	<0.06	0.96	<0.54	<0.15	2.2	0.0098	0.019	0.0042	<4.6
Cockles	Ribble Estuary	2		0.60		<1.0	<0.30	2.6	0.50	0.42	0.20	19
Mussels	Ribble Estuary	2		0.47		<1.3	0.66	1.7	0.27	0.75	0.14	110
Samphire	Marshside Sands	1		<0.07		<0.82	<0.17	0.73				*
Grass (washed)	Hutton Marsh	1			0.27							
Grass (unwashed)	Hutton Marsh	1			0.27							
Soil	Hutton Marsh	1			24							
Sediment	River Ribble outfall	4[E]		3.3		<10		220	23	140	19	22000
Sediment	Lower Penwortham Park	4[E]		3.4		<12		220	26	150	20	19000
Sediment	Penwortham rail bridge	4[E]		<2.5		<8.8		95	16	79	14	23000
Sediment	Penwortham rail bridge - West bank	2[E]		<1.8		<16		580	50	530	46	990
Sediment	Penwortham position 1	4[E]		<1.1		<8.3		130	24	160	21	<720
Sediment	Penwortham position 2	1[E]		<0.56		<4.0		36	23	36	23	290
Sediment	Lytham Yacht Club	1[E]		4.5		<12		270	21	76	14	3900
Sediment	Becconsall	4[E]		<2.3		<11		240	20	79	17	11000
Sediment	Freckleton	1[E]		4.0		<8.6		240	14	110	11	30000
Sediment	Hutton Marsh	1[E]		<0.86		<7.0		240	67	200	32	330
Sediment	Longton Marsh	1[E]		<1.6		<14		460	43	240	41	<170

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Marine samples												
Flounder	Ribble Estuary	1						<0.45				
Salmon	Ribble Estuary	1						<0.11				
Sea trout	Ribble Estuary	1						<0.12				
Grey mullet	Ribble Estuary	1						<0.48				
Shrimps[d]	Ribble Estuary	2				0.0029	0.016	0.030	*	*		
Cockles	Ribble Estuary	2				0.25	1.4	3.9	*	0.0066		
Mussels	Ribble Estuary	2						2.0				
Samphire	Marshside Sands	1						0.29				
Sediment	River Ribble outfall	4[E]	24	<0.96	22			160			920	9200
Sediment	Lower Penwortham Park	4[E]	32	1.3	29			140			1100	11000
Sediment	Penwortham rail bridge	4[E]	19	<0.91	18			47			810	18000
Sediment	Penwortham rail bridge - West bank	2[E]	57	2.2	49			210			1600	1700
Sediment	Penwortham position 1	4[E]	25	<1.1	23			75			800	1300
Sediment	Penwortham position 2	1[E]	24	<0.57	25			7.9			350	400
Sediment	Lytham Yacht Club	1[E]	26	0.80	28			200			810	2700
Sediment	Becconsall	4[E]	25	<0.97	24			130			810	5400
Sediment	Freckleton	1[E]	38	0.95	31			230			1100	11000
Sediment	Hutton Marsh	1[E]	21	0.88	21			120			1500	1100
Sediment	Longton Marsh	1[E]	34	2.4	34			230			1400	2000

Table 3.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{106}Ru	^{129}I	^{137}Cs	Total Cs
Terrestrial samples										
Milk		1								
Apples		1	9.0	12	<0.30	0.027	<2.7	<0.025		0.046
Beetroot		1	<5.0	5.0	<0.40	0.076	<3.3	<0.021		0.036
Blackberries		1	<4.0	15	<0.30	0.21	<2.1	<0.055		0.064
Cabbage		1	<5.0	6.0	<0.30	0.36	<1.2	<0.024		<0.013
Duck		1	<5.0	28	<0.40	<0.010	<2.7		1.2	1.1
Potatoes		1	<5.0	<4.0	<0.20	0.022	<2.1	<0.027		0.056
Runner beans		1	<5.0	<3.0	<0.40	0.055	<1.6	<0.018		0.060
Sediment	Deepdale Brook	2[E]			<1.2		<7.5		<0.88	
Grass		1			<0.60		<1.3		1.7	

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples									
Milk		1							<0.0061
Apples		1	0.0039	<0.00080		0.0079	<0.00070	0.0057	<0.029
Beetroot		1	0.0046	<0.00050					<0.031
Blackberries		1	0.0044	0.0015					0.094
Cabbage		1	0.0029	<0.00090					<0.033
Duck		1	0.0093	0.0016					
Potatoes		1	0.0029	0.00090					<0.033
Runner beans		1	0.0036	<0.00080					<0.033
Sediment	Deepdale Brook	2[E]			<470	49	1.8	51	
Grass	Site fence	1[E]				0.31	<0.090	0.20	
Grass	Opposite site entrance	1[E]				0.63	<0.16	0.40	
Grass	Opposite windmill	1[E]				1.0	<0.14	1.1	
Grass	Deepdale Brook	1[E]				0.88	<0.090	0.70	
Grass	Lea Town	1[E]				0.37	<0.070	0.35	
Grass	N of Lea Town	1[E]				0.91	<0.10	0.90	
Silage		1				0.29	0.011	0.27	0.69
Soil		1				20	0.71	19	80
Soil	Site fence	1[E]				110	4.5	94	
Soil	Opposite site entrance	1[E]				150	6.3	140	
Soil	Opposite windmill	1[E]				180	6.7	170	
Soil	Deepdale Brook	1[E]				120	4.5	110	
Soil	Lea Town	1[E]				34	1.4	35	
Soil	N of Lea Town	1[E]				62	1.9	61	
Freshwater	Deepdale Brook	4[E]				0.52	0.021	0.50	

Table 3.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}					
			^{238}Pu	$^{239}Pu+$ ^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples								
Milk		1						
Apples		1	<0.00030	<0.00020	<0.055	<0.00020		
Beetroot		1	<0.00020	0.00010	<0.065	<0.00030		
Blackberries		1	<0.00030	0.00040	<0.041	0.00060		
Cabbage		1	<0.00030	0.00050	<0.045	0.00090		
Duck		1	0.00060	0.0032	<0.072	0.0046		
Potatoes		1	<0.00030	<0.00030	<0.054	0.00060		
Runner beans		1	<0.00030	0.00060	<0.042	0.00050		
Sediment	Deepdale Brook	2[E]					590	1100
Grass		1				0.80		
Freshwater	Deepdale Brook	4[E]					0.58	0.56

** Not detected by the method used*

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

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

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *The concentration of ^{237}Np was 0.000035 Bq kg^{-1}*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency*

Table 3.3(b). Monitoring of radiation dose rates near Springfields, 2005

Location	Material or ground type	No. of sampling observa-tions	µGy h⁻¹
Mean gamma dose rates at 1 m over substrate			
Lytham Yacht Club	Mud	1	0.061
Warton Marsh	Mud[a]	4[F]	0.12
Warton Mud Marsh	Mud	2	0.11
Warton Salt Marsh	Salt marsh	2	0.11
Naze Point	Salt marsh	2	0.12
Banks Marsh	Mud[a]	4[F]	0.12
Banks Marsh	Salt marsh	4[F]	0.13
Banks Marsh	Salt marsh	2	0.11
Hesketh Bank	Salt marsh	2	0.11
Freckleton	Mud	1	0.12
Becconsall	Grass and mud	4	0.083
Becconsall (vicinity of houseboats)	Grass and mud	2	0.083
Longton Marsh	Salt marsh	1	0.14
Hutton Marsh	Grass and salt marsh	1	0.14
River Ribble outfall	Mud	3	0.11
River Ribble outfall	Grass and mud	1	0.10
Savick Brook, confluence with Ribble	Mud	1	0.097
Savick Brook, confluence with Ribble	Grass and mud	1	0.13
South bank opposite outfall	Salt marsh	1	0.11
Penworthham Bridge cadet hut	Grass and mud	2	0.078
Lower Penwortham Park	Grass and mud	3	0.073
Lower Penwortham Park	Grass	1	0.080
Lower Penwortham Railway Bridge	Mud	2	0.089
Lower Penwortham Railway Bridge	Sand	1	0.080
Lower Penwortham Railway Bridge	Grass and mud	1	0.077
River Darwen	Grass and mud	3	0.076
River Darwen	Grass	1	0.076
Riverbank Angler location 1	Grass and mud	4	0.069
Riverbank Angler location 2	Grass and mud	1	0.071
Ulnes Walton, BNFL area survey	Grass	3	0.078
Mean beta dose rates			
Lytham - Granny's Bay	Mud and sand	1[F]	0.35
Ribble Estuary	Gill net	2[F]	0.68
Ribble Estuary	Shrimp net	2[F]	0.34
Banks Marsh	Mud	4[F]	3.9
Banks Marsh	Salt marsh	4[F]	0.67
Warton Marsh	Mud	4[F]	5.0
Warton Marsh	Salt marsh	4[F]	0.87

[a] 15cm above substrate

[F] Measurements are made on behalf of the Environment Agency unless labelled "F". In that case they are made on behalf of the Food Standards Agency

Table 3.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2005

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		17	<4.7	<5.0	16	<0.31	0.072	<0.0050	<2.2	<0.61	<0.014
Milk[d]	max		<5.8	<6.0	20	<0.40	0.18		<2.5	<0.68	<0.017
Milk[e]		1				<0.20			<1.7	<0.70	
Milk[e]		1				<0.30			<2.6	<0.90	
Apples		2	<4.0	7.5	24	<0.30	0.13	<0.033	<0.90	<0.55	<0.063
Apples	max		<6.0	9.0	36		0.20		<1.0	<0.60	0.095
Barley		1		<7.0	92	<0.20	1.2		<2.6	<0.60	0.041
Blackberries		3	<5.3	<6.3	11	<0.33	0.62		<2.6	<0.73	<0.032
Blackberries	max		<7.0	8.0	13	<0.40	0.97		<3.1	<0.80	<0.041
Beef kidney		1	<8.0	<8.0	19	<0.40	0.56	<0.039	<2.9	<1.2	<0.020
Beef liver		1	<8.0	<8.0	<11	<0.50	0.039	<0.027	<2.1	<0.80	<0.036
Beef muscle		1	<4.0	<4.0	30	<0.40	0.026	<0.036	<3.1	<0.70	<0.019
Broccoli		1	<5.0	<5.0	4.0	<0.50	0.18		<3.2	<0.80	0.042
Cabbage		1	4.0	7.0	<3.0	<0.20	0.54		<2.0	<0.40	0.031
Carrots		1	<4.0	<4.0	<3.0	<0.30	0.27	<0.034	<3.0	<0.80	0.032
Cauliflower		1	<4.0	<4.0	6.0	<0.30	0.13		<2.6	<0.40	<0.020
Deer muscle		1	<6.0	<6.0	13	<0.30	<0.0060	<0.034	<2.7	<0.60	<0.026
Eggs		1	<5.0	<5.0	67	<0.30	0.020		<2.4	<0.80	0.049
Elderberries		1	<6.0	<4.0	13	<0.30	0.38		<2.4	<0.90	<0.028
Field beans		1		9.0	67	<0.50	0.48		<3.3	<0.80	<0.046
Honey		1		<7.0	56	<0.30	0.039		<1.4	<0.70	<0.013
Mushrooms		1	<6.0	<6.0	<4.0	<0.30	0.055		<1.6	<0.50	<0.022
Onions		1	<5.0	<5.0	5.0	<0.40	0.19		<3.1	<0.70	0.076
Pheasants		1	<9.0	9.0	16	<0.30	0.020	<0.030	<1.8	<0.60	<0.033
Potatoes		1	<5.0	<5.0	20	<0.40	0.011		<1.1	<0.70	<0.019
Rabbit		1	<6.0	<6.0	12	<0.10	0.13	0.048	<2.4	<1.0	<0.025
Runner beans		1	6.0	8.0	4.0	<0.40	0.31		<3.1	<1.1	0.077
Sheep muscle		2	<8.5	8.5	21	<0.30	0.017	<0.050	<2.4	<0.55	<0.028
Sheep muscle	max		<9.0	9.0	26		0.018	0.070		<0.60	<0.035
Sheep offal		2	<6.5	<8.5	<15	<0.40	1.1	<0.028	<2.1	<0.40	<0.023
Sheep offal	max		<8.0	9.0	21		1.4	<0.029	<2.6		<0.024
Swede		1	3.0	6.0	8.0	<0.30	0.45		<2.6	<0.80	<0.027
Turnips[f]		1	<5.0	<5.0	8.0	<0.30	0.34		<2.1	<0.80	<0.022
Wheat		1		<8.0	76	<0.40	0.38		<3.0	<0.80	<0.019
Wood pigeon muscle		2	<6.0	<6.0	18	<0.45	0.024		<3.1	<0.45	<0.037
Wood pigeon muscle	max				22	<0.50	0.027		<3.2	<0.50	0.053
Grass		5				<0.47		<0.078	<2.5	<0.67	
Grass	max					<0.60		0.13	<3.0	<0.70	
Soil[g]		3				<0.57			<2.9	<1.3	
Soil[h]	max					0.70			<3.5	<1.5	

Table 3.4. continued

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	Total Cs	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		17	<0.26	<0.34	0.20		<0.00015	<0.00014	<0.031	<0.00017
Milk[d]	max		<0.30	<0.46	0.42		<0.00018	<0.00015	<0.036	<0.00020
Milk[e]		1	<0.20	0.50						
Milk[e]		1	<0.30	<0.40						
Apples		2			0.61		<0.00030	0.00090	<0.052	0.0014
Apples	max				0.92		0.00030	0.0010		0.0015
Barley		1			0.59		<0.00040	0.0018	<0.074	0.0039
Blackberries		3			0.22		<0.00027	0.0012	<0.059	0.0023
Blackberries	max				0.36		<0.00030	0.0015	<0.076	0.0026
Beef kidney		1			1.2		<0.00020	0.00080	<0.081	0.00060
Beef liver		1			0.85		<0.0010	<0.0011	<0.15	<0.00080
Beef muscle		1			1.3		<0.00020	<0.00020	<0.046	<0.00020
Broccoli		1			0.070		<0.00030	0.0024	<0.064	0.00020
Cabbage		1			0.052		<0.00030	<0.00030	<0.063	<0.00020
Carrots		1			0.15		<0.00020	0.00050	<0.052	0.00060
Cauliflower		1			0.059	<0.034	<0.00020	<0.00020	<0.049	0.00030
Deer muscle		1			8.6		<0.00030	<0.00020	<0.096	<0.00020
Eggs		1			0.088		<0.00020	<0.00020	<0.051	0.00080
Elderberries		1			0.51		0.0011	0.0045	<0.053	0.0085
Field beans		1			0.28		<0.00030	0.00020	0.12	<0.00030
Honey		1			0.094		<0.00010	<0.00020	<0.047	<0.00020
Mushrooms		1			0.084		0.00060	0.0044	0.12	0.00030
Onions		1			0.048		<0.00030	0.00060	<0.053	0.00020
Pheasants		1			0.61		<0.00020	0.00030	<0.038	0.00020
Potatoes		1			0.11		<0.00030	<0.00020	<0.053	0.00040
Rabbit		1			4.3		<0.00030	0.0012	<0.046	0.0034
Runner beans		1			0.23		<0.00030	0.0011	<0.045	0.0019
Sheep muscle		2			1.2		<0.00025	0.00080	<0.040	0.0018
Sheep muscle	max				1.7		<0.00030	0.0014	<0.041	0.0034
Sheep offal		2			0.59		0.00045	0.0024	<0.057	0.0034
Sheep offal	max				0.67		0.00050	0.0030	<0.067	0.0036
Swede		1			0.19		<0.00010	0.00010	0.13	0.00020
Turnips[f]		1			0.25	<0.034	<0.00020	0.00060	0.063	0.0011
Wheat		1			0.15		<0.00040	0.0019	<0.068	0.0032
Wood pigeon muscle		2			5.9		<0.00035	<0.00040	<0.077	<0.00055
Wood pigeon muscle	max				11		<0.00040	<0.00050	<0.091	<0.00090
Grass		5	<0.30	1.6						
Grass	max			3.0						
Soil[g]		3	<0.37	87		70				7.8
Soil[h]	max		<0.40	110						9.4

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[b] *Except for milk where units are Bq l^{-1}*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The mean concentration of ^{131}I was <0.012 Bq l^{-1} and the maximum was <0.014 Bq l^{-1}*
[e] *Additional milk sampling week commencing 29th August 2005*
[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0084, 0.00090 and 0.0082 Bq kg^{-1} respectively*
[g] *The Total U analysis was carried out on a separate sample*
[h] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 13, 0.46 and 13 Bq kg^{-1} respectively*

Table 3.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb
Cumbria									
Maryport	Plaice	4				<0.10		<0.36	<0.56
River Derwent	Sea trout	1				<0.10		<0.51	<0.94
Parton	Cod	4				<0.10		<0.35	<0.52
Whitehaven	Cod	4			72	<0.09	0.039	<0.32	<0.40
Whitehaven	Plaice	4				<0.10	0.078	<0.41	<0.76
Whitehaven	Skates/rays	4				<0.17		<1.0	<1.4
Whitehaven	Sole	4				<0.12		<0.58	<0.93
River Ehen	Salmon	1				<0.11		<3.9	*
Sellafield coastal area	Cod	8				<0.28		<0.69	<1.1
Sellafield coastal area	Plaice	5	97	96		<0.11		<0.40	<0.67
Sellafield coastal area	Bass	1				<0.26		<0.98	<1.3
Sellafield coastal area	Mullet	1				<0.11		<0.48	<0.69
Sellafield offshore area	Cod	1				<0.35		<1.4	<1.8
Sellafield offshore area	Plaice[a]	2			300	0.12	0.053	<0.32	<0.56
Sellafield offshore area	Dab	2				<0.27		<0.61	<0.85
Sellafield offshore area	Red gurnard	1			150	<0.09	<0.064	<0.47	<0.79
Sellafield offshore area	Lesser spotted dogfish	2				<0.08		<0.34	<0.52
Sellafield offshore area	Skates/rays	1				<0.10		<0.49	<0.70
Ravenglass	Cod	6				<0.14		<0.35	<0.66
Ravenglass	Plaice	4	210	230		<0.11		<0.41	<0.73
Morecambe Bay (Flookburgh)	Flounder	3			100	<0.10		<0.63	<1.4
Morecambe Bay (Flookburgh)	Plaice	1				<0.40		<2.0	<4.1
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Plaice	4	<25	36		<0.12	0.034	<1.1	<0.77
Morecambe Bay (Morecambe)	Bass	2				<0.17		<1.6	<2.2
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.08	0.28	<0.28	<0.42
Fleetwood	Cod	4			95	<0.08	0.052	<0.51	<1.3
Fleetwood	Plaice	4				<0.16		<1.4	<0.40
Ribble Estuary	Flounder	1				<0.11		<1.1	*
Ribble Estuary	Mullet	1				<0.11		<0.97	<2.6
Ribble Estuary	Salmon	1				<0.10		<0.67	<1.3
Ribble Estuary	Sea trout	1				<0.12		<0.56	<0.89
Liverpool Bay	Flounder	2		<30					
Mersey Estuary	Flounder	2		<25					
Scotland									
Shetland	Fish meal	3				<0.22	0.13	<0.59	<0.58
Shetland	Fish oil	3				<0.12		<0.62	<1.1
Minch	Herring	2				<0.11		<1.8	*
Minch	Mackerel	2			68	<0.09	<0.030	<0.86	<1.0
West of Scotland	Mackerel	2				<0.09		<0.59	<1.2
West of Scotland	Farmed salmon	1				<0.09		<0.73	<1.6
Kirkcudbright	Lemon sole	1				<0.10		<0.22	<0.20
North Solway	Cod[b]	2	<25	<25	57	<0.07	0.043	<0.29	<0.45
Inner Solway	Plaice[c]	1			20	<0.14		<0.66	<0.97
Inner Solway	Flounder[d]	1			90	<0.17	<0.10	<0.96	<1.7
Inner Solway	Lemon sole	1				<0.11		<0.53	<0.78
Inner Solway	Salmon	1		<5.0		<0.10		<0.62	<1.5
Inner Solway	Sea trout	1		<5.0		<0.10		<0.34	<0.85

Table 3.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Cumbria								
Maryport	Plaice	4	<0.85	<0.22	<0.10	4.4	<0.45	
River Derwent	Sea trout	1	<0.92	<0.22	<0.10	4.3	<0.40	
Parton	Cod	4	<0.87	<0.23	<0.10	7.0	<0.42	
Whitehaven	Cod	4	<0.79	<0.20	<0.09	3.9	<0.37	
Whitehaven	Plaice	4	<0.88	<0.25	<0.10	4.4	<0.59	
Whitehaven	Skates/rays	4	<1.9	<0.42	<0.18	5.2	<0.95	
Whitehaven	Sole	4	<1.3	<0.28	<0.12	3.5	<0.53	
River Ehen	Salmon	1	<1.4	<0.27	<0.13	0.27	<0.77	
Sellafield coastal area	Cod	8	<1.5	<0.37	<0.20	9.7	<0.61	190
Sellafield coastal area	Plaice	5	<1.0	<0.26	<0.11	4.8	<0.59	140
Sellafield coastal area	Bass	1	<2.4	<0.59	<0.27	13	<1.0	
Sellafield coastal area	Mullet	1	<1.3	<0.31	<0.12	8.0	<0.71	
Sellafield offshore area	Cod	1	<3.4	<0.83	<0.33	4.7	<1.7	
Sellafield offshore area	Plaice[a]	2	<0.61	<0.19	<0.06	5.5	<0.30	
Sellafield offshore area	Dab	2	<1.5	<0.37	<0.16	7.4	<0.62	
Sellafield offshore area	Red gurnard	1	<0.83	<0.21	<0.09	5.6	<0.43	
Sellafield offshore area	Lesser spotted dogfish	2	<0.85	<0.23	<0.09	10	<0.48	
Sellafield offshore area	Skates/rays	1	<1.2	<0.32	<0.12	7.1	<0.77	
Ravenglass	Cod	6	<0.74	<0.21	<0.10	9.3	<0.44	
Ravenglass	Plaice	4	<0.85	<0.25	<0.10	5.7	<0.45	
Morecambe Bay (Flookburgh)	Flounder	3	<1.0	<0.29	<0.10	12	<0.63	
Morecambe Bay (Flookburgh)	Plaice	1	<3.7	<0.73	<0.36	6.3	<1.3	
Lancashire and Merseyside								
Morecambe Bay (Morecambe)	Plaice	4	<1.3	<0.31	<0.13	4.9	<0.80	
Morecambe Bay (Morecambe)	Bass	2	<1.8	<0.38	<0.18	11	<0.72	
Morecambe Bay (Sunderland Point)	Whitebait	1	<0.63	<0.17	<0.07	5.4	<0.32	
Fleetwood	Cod	4	<0.75	<0.19	<0.09	4.7	<0.45	
Fleetwood	Plaice	4	<1.7	<0.34	<0.15	4.2	<0.69	
Ribble Estuary	Flounder	1	<1.2	<0.30	<0.13	5.5	<0.82	
Ribble Estuary	Mullet	1	<1.3	<0.30	<0.12	4.2	<0.86	
Ribble Estuary	Salmon	1	<0.98	<0.24	<0.11	0.12	<0.53	
Ribble Estuary	Sea trout	1	<1.2	<0.28	<0.12	2.2	<0.55	
Liverpool Bay	Flounder	2						
Mersey Estuary	Flounder	2						
Scotland								
Shetland	Fish meal	3	<2.0	<0.51	<0.23	0.49	<1.1	
Shetland	Fish oil	3	<1.2	<0.32	<0.13	<0.11	<0.69	
Minch	Herring	2	<1.4	<0.30	<0.13	<0.13	<0.96	
Minch	Mackerel	2	<1.0	<0.24	<0.10	<0.12	<0.69	
West of Scotland	Mackerel	2	<0.91	<0.20	<0.10	<0.11	<0.42	
West of Scotland	Farmed salmon	1	<0.99	<0.24	<0.10	0.24	<0.67	
Kirkcudbright	Lemon sole	1	<0.71	<0.20	<0.10	0.51	<0.50	
North Solway	Cod	2	<0.66	<0.16	<0.08	2.3	<0.35	
Inner Solway	Plaice	1	<1.4	<0.37	<0.13	4.0	<0.91	
Inner Solway	Flounder	1	<1.7	<0.45	<0.17	15	<1.2	
Inner Solway	Lemon sole	1	<1.1	<0.28	<0.11	2.7	<0.68	
Inner Solway	Salmon	1	<0.81	<0.20	<0.10	0.19	<0.57	
Inner Solway	Sea trout	1	<0.42	<0.11	<0.10	0.81	<0.33	

Table 3.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb
Isle of Man									
Isle of Man	Cod	4				<0.12		<0.80	<1.3
Isle of Man	Herring	3				<0.15		<1.2	<2.9
Wales									
North Anglesey	Skates/rays	4				<0.14		<0.91	<0.55
North Anglesey	Plaice	2	<25	<25	71	<0.05		<0.35	<0.78
Northern Ireland									
North coast	Cod	2				<0.05		<0.28	<0.52
North coast	Spurdog	4				<0.13		<0.87	<1.2
Portavogie	Cod	1				<0.05		<0.35	<0.76
Portavogie	Haddock	4				<0.13		<1.0	<0.69
Portavogie	Spurdog	4				<0.15		<0.79	<1.0
Ardglass	Herring	2				<0.27		<2.3	<3.4
Kilkeel	Cod	4			26	<0.10		<0.85	<0.47
Kilkeel	Whiting	4				<0.12		<0.83	<1.4
Further afield									
Baltic Sea	Cod	4				<0.19		<1.9	<0.80
Baltic Sea	Herring	4				<0.26		<2.3	<1.1
Barents Sea	Cod	2				<0.27		*	*
Barents Sea	Haddock	1				<0.19		<1.2	<2.3
Barents Sea	Herring	1				<0.20		<1.3	<2.5
Norwegian Sea	Herring	1				<0.18		<1.1	<2.3
Norwegian Sea	Saithe	1				<0.15		<0.86	<1.6
Norwegian processed	Cod	2			30	<0.05		<0.17	<0.21
Iceland area	Cod	2				<0.13		<0.89	<2.1
Skagerrak	Cod	4				<0.12		<1.0	<1.7
Skagerrak	Herring	4				<0.07		<0.54	<1.1
Northern North Sea	Cod	4				<0.10	<0.020	<0.70	<0.25
Northern North Sea	Plaice	4				<0.15		<0.99	<1.5
Northern North Sea	Haddock	4			14	<0.09		<0.48	<0.47
Northern North Sea	Herring	2				<0.25		<2.7	*
Mid North Sea	Cod	4			25	<0.08	<0.027	<0.54	<1.2
Mid North Sea	Plaice	4			17	<0.10	0.018	<0.67	<1.5
Gt Yarmouth (retail shop)	Cod	4				<0.06		<0.42	<0.89
Gt Yarmouth (retail shop)	Plaice	4				<0.05		<0.38	<0.40
Southern North Sea	Bass	2				<0.07		<0.28	<0.43
Southern North Sea	Cod	2				<0.07	0.025	<0.32	<0.56
Southern North Sea	Sole	4				<0.07	<0.029	<0.39	<0.74
Southern North Sea	Herring	2				<0.09		<0.53	<1.2
English Channel-East	Cod	3				<0.10		<0.49	<0.85
English Channel-East	Plaice	4				<0.11		<0.56	<1.0
English Channel-East	Whiting	1				<0.06		<0.24	<0.35
English Channel-West	Mackerel	4				<0.09		<0.43	<0.70
English Channel-West	Plaice	4			27	<0.14		<0.79	<1.6
English Channel-West	Whiting	4				<0.15		<0.97	<2.3
Celtic Sea	Cod	4			29	<0.12	<0.025	<0.61	<1.1
Celtic Sea	Megrim	1				<0.13		<0.89	<1.8
Celtic Sea	Plaice	1				<0.06		<0.34	<0.59
Celtic Sea	Whiting	2				<0.18		<0.89	<2.0
Northern Irish Sea	Dab	1				<0.14		<1.1	<2.7
Northern Irish Sea	Lesser spotted dogfish	1				<0.20		<1.8	<4.9
Northern Irish Sea	Skates/rays	1				<0.18		<1.7	<4.3

Table 3.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man							
Isle of Man	Cod	4	<1.4	<0.30	<0.13	2.2	<0.75
Isle of Man	Herring	3	<1.7	<0.37	<0.17	0.99	<0.89
Wales							
North Anglesey	Skates / rays	4	<1.6	<0.33	<0.14	1.3	<0.72
North Anglesey	Plaice	2	<0.56	<0.13	<0.06	1.3	<0.36
Northern Ireland							
North coast	Cod	2	<0.56	<0.14	<0.06	1.8	<0.36
North coast	Spurdog	4	<1.5	<0.34	<0.15	1.6	<0.78
Portavogie	Cod	1	<0.55	<0.14	<0.06	1.9	<0.36
Portavogie	Haddock	4	<1.4	<0.29	<0.13	1.1	<0.60
Portavogie	Spurdog	4	<1.6	<0.36	<0.16	1.1	<0.82
Ardglass	Herring	2	<3.1	<0.60	<0.28	0.50	<1.5
Kilkeel	Cod	4	<1.2	<0.24	<0.11	1.5	<0.50
Kilkeel	Whiting	4	<1.4	<0.31	<0.14	0.42	<0.78
Further afield							
Baltic Sea	Cod	4	<2.2	<0.45	<0.20	8.9	<0.92
Baltic Sea	Herring	4	<2.9	<0.60	<0.26	6.0	<1.4
Barents Sea	Cod	2	<4.2	<0.61	<0.31	<0.28	<1.9
Barents Sea	Haddock	1	<2.3	<0.50	<0.20	<0.19	<1.2
Barents Sea	Herring	1	<2.0	<0.39	<0.20	0.48	<0.71
Norwegian Sea	Herring	1	<2.0	<0.40	<0.18	0.26	<0.75
Norwegian Sea	Saithe	1	<1.6	<0.33	<0.15	0.24	<0.60
Norwegian processed	Cod	2	<0.47	<0.11	<0.05	0.32	<0.24
Iceland area	Cod	2	<1.4	<0.32	<0.14	<0.18	<0.82
Skagerrak	Cod	4	<1.3	<0.25	<0.13	0.25	<0.58
Skagerrak	Herring	4	<0.72	<0.16	<0.07	0.37	<0.35
Northern North Sea	Cod	4	<1.2	<0.24	<0.11	<0.19	<0.58
Northern North Sea	Plaice	4	<1.7	<0.34	<0.16	<0.17	<0.71
Northern North Sea	Haddock	4	<0.95	<0.21	<0.10	<0.15	<0.52
Northern North Sea	Herring	2	<3.0	<0.53	<0.28	<0.27	<1.1
Mid North Sea	Cod	4	<0.88	<0.18	<0.09	0.34	<0.39
Mid North Sea	Plaice	4	<1.1	<0.23	<0.11	<0.18	<0.57
Gt Yarmouth (retail shop)	Cod	4	<0.67	<0.14	<0.07	0.21	<0.33
Gt Yarmouth (retail shop)	Plaice	4	<0.56	<0.13	<0.06	0.11	<0.32
Southern North Sea	Bass	2	<0.60	<0.14	<0.07	0.62	<0.29
Southern North Sea	Cod	2	<0.63	<0.15	<0.07	0.39	<0.33
Southern North Sea	Sole	4	<0.78	<0.17	<0.10	0.32	<0.38
Southern North Sea	Herring	2	<0.94	<0.22	<0.10	0.27	<0.59
English Channel-East	Cod	3	<1.0	<0.24	<0.11	<0.21	<0.60
English Channel-East	Plaice	4	<1.2	<0.25	<0.11	<0.14	<0.51
English Channel-East	Whiting	1	<0.57	<0.13	<0.06	0.38	<0.24
English Channel-West	Mackerel	4	<0.90	<0.21	<0.09	<0.16	<0.46
English Channel-West	Plaice	4	<1.5	<0.30	<0.15	<0.12	<0.72
English Channel-West	Whiting	4	<1.6	<0.35	<0.15	0.24	<0.83
Celtic Sea	Cod	4	<1.2	<0.26	<0.13	<0.32	<0.50
Celtic Sea	Megrim	1	<1.4	<0.27	<0.12	0.21	<0.54
Celtic Sea	Plaice	1	<0.62	<0.16	<0.07	0.14	<0.42
Celtic Sea	Whiting	2	<1.7	<0.33	<0.17	0.50	<0.67
Northern Irish Sea	Dab	1	<1.7	<0.36	<0.15	2.5	<0.90
Northern Irish Sea	Lesser spotted dogfish	1	<2.4	<0.48	<0.22	1.7	<0.93
Northern Irish Sea	Skates/rays	1	<2.2	<0.42	<0.20	0.47	<0.87

* *Not detected by the method used*

[a] *The concentrations of ^{129}I and ^{147}Pm were <0.91 and <0.048 Bq kg^{-1} respectively*

[b] *The concentrations of ^{99}Tc was 0.28 Bq kg^{-1}*

[c] *The concentrations of ^{99}Tc was 0.32 Bq kg^{-1}*

[d] *The concentrations of ^{99}Tc was 6.5 Bq kg^{-1}*

Table 3.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria											
Silloth	Mussels	4		<31		0.75		<0.28	<0.40		<1.4
Silloth	Shrimps	4				<0.09		<0.25	<0.29		<0.79
Parton	Crabs	4				0.98		<1.1	<0.75		<1.7
Parton	Lobsters	4				0.86		<0.32	<0.56		<0.81
Parton	Winkles	4				5.6		<0.33	<0.39		7.0
Whitehaven	*Nephrops*	4			93	<0.14	0.19	<0.64	<1.1	160	<1.4
Whitehaven	Cockles	2				<0.12		<0.48	<0.83		<1.2
Whitehaven	Mussels	2				<0.06	<0.019	<0.25	<0.42		<0.58
Whitehaven outer harbour	Mussels	2				1.4		<0.29	<0.33		3.2
Saltom Bay	Winkles	4				7.0		<0.64	<0.95		<6.9
St Bees	Winkles[a]	4			190	9.2	1.8	<0.26	<0.42	120	14
St Bees	Mussels	4				5.5		<0.33	<0.42		13
St Bees	Limpets	4				3.6		<0.39	<0.53		<9.7
Nethertown	Winkles	12	<32	37	240	15	7.6	<0.47	<0.63	210	21
Nethertown	Mussels	4	190	230	310	8.4		<0.26	<0.29	540	19
Sellafield coastal area	Crabs[b]	8			210	2.5	0.74	<0.29	<0.55	19	<1.3
Sellafield coastal area	Lobsters	8			420	2.4	0.25	<0.50	<1.2	1800	<1.1
Sellafield coastal area	*Nephrops*	1				0.63		<0.46	<0.63	370	<1.4
Sellafield coastal area[c]	Winkles	8			320	17	1.3	<0.49	<0.65	430	25
Sellafield coastal area[c]	Mussels	4				6.4	1.4	<0.41	<0.56		11
Sellafield coastal area[c]	Limpets	4			150	3.2	2.5	<0.54	<0.86	520	11
Whitriggs	Shrimps	1				<0.26		<2.1	*		<2.7
Drigg	Winkles	4			290	16		<0.57	<0.82	200	24
Ravenglass	Crabs	4				1.0	0.39	<0.41	<0.84	13	<0.94
Ravenglass	Lobsters	6				1.3	0.20	<0.56	<1.2	890	<1.1
Ravenglass	Winkles	2				5.7		<0.50	<0.77		11
Ravenglass	Cockles	4			270	16	1.4	<0.41	<0.59	31	8.6
Ravenglass	Mussels	4		100		6.0		<0.29	<0.35	1300	11
Tarn Bay	Winkles	4				8.5		<0.54	<0.81		12
Haverigg	Cockles	4				5.5		<0.30	<0.35		5.1
Millom	Mussels	2				1.4		<0.49	<1.2		5.6
Barrow	Crabs	4				0.46		<0.34	<0.51		<0.81
Barrow	Lobsters	4				0.27		<0.32	<0.62	660	<0.73
Roosebeck	Pacific oysters	2				0.31		<0.19	<0.30		<0.84
Morecambe Bay (Flookburgh)	Shrimps	4			130	<0.09		<0.27	<0.34	2.6	<0.79
Morecambe Bay (Flookburgh)	Cockles	3			120	1.7	0.43	<0.61	<1.1	9.3	<2.4
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Mussels	4	67	67	140	<1.0		<0.31	<0.39	200	<2.4
Red Nab Point	Winkles	4				0.99		<0.19	<0.22		<1.7
Morecambe Bay (Middleton Sands)	Cockles	2				1.6		<0.15	<0.18		1.0
Knott End	Cockles	2				2.1		<0.88	<1.6		<2.9
Fleetwood	Squid	1				<0.18		<1.6	*		<2.1
Ribble Estuary	Shrimps	2			58	<0.06		<0.16	<0.17	0.96	<0.54
Ribble Estuary	Cockles	2				0.60		<0.36	<0.48		<1.0
Ribble Estuary	Mussels	2				0.47		<0.16	<0.19		<1.3
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<28							
Dee Estuary	Cockles	4				0.21		<0.16	<0.19	9.9	<0.48
Wirral	Shrimps	2		<25		<0.05		<0.17	<0.22	2.7	<0.48

Table 3.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Total beta
Cumbria											
Silloth	Mussels	4	<0.14	0.97	<0.08	3.4	<0.43		<0.21	<0.20	
Silloth	Shrimps	4	<0.15	<0.22	<0.09	3.2	<0.40		<0.24	<0.18	
Parton	Crabs	4	<0.45	<0.57	<0.15	1.8	<0.68		<0.41	<0.25	
Parton	Lobsters	4	0.65	<0.42	<0.07	2.9	<0.33		<0.21	<0.13	
Parton	Winkles	4	0.61	3.0	<0.11	7.6	<0.67		<0.28	<0.32	
Whitehaven	*Nephrops*	4	<0.27	<0.32	<0.14	2.6	<0.62		<0.40	<0.27	210
Whitehaven	Cockles	2	<0.22	<0.29	<0.13	<0.14	<0.68		<0.29	<0.31	
Whitehaven	Mussels	2	<0.11	<0.15	<0.06	<0.05	<0.40		<0.15	<0.19	
Whitehaven outer harbour	Mussels	2	<0.17	2.0	<0.09	2.3	<0.57		<0.23	<0.27	
Saltom Bay	Winkles	4	<1.5	6.0	<0.18	7.1	<0.75		<0.43	<0.31	
St Bees	Winkles[a]	4	2.6	3.8	<0.07	7.5	<0.44	1.1	<0.19	<0.14	
St Bees	Mussels	4	<0.20	4.2	<0.10	3.8	<0.85		<0.27	<0.28	
St Bees	Limpets	4	2.1	7.1	<0.12	4.8	<0.67		<0.31	<0.31	
Nethertown	Winkles	12	3.9	4.4	<0.16	10	<1.2	6.2	<0.45	<0.34	380
Nethertown	Mussels	4	<0.18	6.1	<0.09	2.8	<0.96		<0.30	<0.22	470
Sellafield coastal area	Crabs[b]	8	1.2	0.75	<0.06	1.8	<0.29	0.40	<0.17	<0.12	140
Sellafield coastal area	Lobsters	8	2.7	<0.70	<0.11	3.1	<0.46	0.54	<0.27	<0.18	1300
Sellafield coastal area	*Nephrops*	1	<0.23	<0.33	<0.12	4.9	<0.67		<0.35	<0.27	
Sellafield coastal area[c]	Winkles	8	3.5	4.4	<0.16	8.1	<1.1	1.1	<0.41	<0.29	
Sellafield coastal area[c]	Mussels	4	<0.22	3.9	<0.11	3.1	<0.64		<0.27	<0.29	
Sellafield coastal area[c]	Limpets	4	1.5	10	<0.15	5.5	<0.94		<0.37	<0.43	
Whitriggs	Shrimps	1	<0.53	<0.52	<0.23	3.3	<0.92		<0.65	<0.30	
Drigg	Winkles	4	3.2	4.5	<0.17	9.6	<1.6	2.5	<0.40	<0.35	360
Ravenglass	Crabs	4	<0.43	<0.45	<0.07	1.5	<0.43		<0.20	<0.17	93
Ravenglass	Lobsters	6	1.6	<0.46	<0.10	2.2	<0.52		<0.27	<0.21	790
Ravenglass	Winkles	2	2.3	3.4	<0.12	6.6	<0.74		<0.30	<0.22	
Ravenglass	Cockles	4	<0.30	1.9	<0.11	4.2	<0.77		<0.30	<0.20	170
Ravenglass	Mussels	4	<0.22	3.9	<0.09	1.9	<0.54		<0.23	<0.24	
Tarn Bay	Winkles	4	2.1	2.9	<0.15	5.6	<0.71		<0.37	<0.31	
Haverigg	Cockles	4	<0.18	1.2	<0.10	4.3	<0.49		<0.25	<0.18	
Millom	Mussels	2	<0.15	1.5	<0.08	1.3	<0.99		<0.18	<0.22	
Barrow	Crabs	4	<0.24	<0.31	<0.09	1.3	<0.42		<0.24	<0.18	
Barrow	Lobsters	4	0.37	<0.22	<0.08	2.1	<0.39		<0.21	<0.16	500
Roosebeck	Pacific oysters	2	1.4	0.52	<0.05	1.8	<0.25		<0.15	<0.11	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.15	<0.23	<0.08	4.8	<0.42		<0.23	<0.19	
Morecambe Bay (Flookburgh)	Cockles	3	<0.22	<1.0	<0.12	4.6	<0.64		<0.29	<0.25	
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Mussels	4	<0.17	1.3	<0.09	4.0	<0.43		<0.25	<0.19	
Red Nab Point	Winkles	4	<0.16	1.4	<0.07	5.0	<0.37		<0.18	<0.17	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.08	0.71	<0.05	3.4	<0.25		<0.12	<0.11	
Knott End	Cockles	2	<0.33	<1.1	<0.16	5.4	<0.66		<0.46	<0.26	
Fleetwood	Squid	1	<0.39	<0.38	<0.20	0.73	<0.72		<0.51	<0.24	
Ribble Estuary	Shrimps	2	<0.10	<0.15	<0.06	2.2	<0.29		<0.17	<0.14	
Ribble Estuary	Cockles	2	<0.17	<0.30	<0.10	2.6	<0.47		<0.27	<0.19	
Ribble Estuary	Mussels	2	<0.10	0.66	<0.06	1.7	<0.36		<0.14	<0.16	
Liverpool Bay	Mussels	2									
Mersey Estuary	Mussels	2									
Dee Estuary	Cockles	4	<0.08	0.37	<0.05	1.9	<0.28		<0.13	<0.13	
Wirral	Shrimps	2	<0.10	<0.13	<0.05	2.0	<0.24		<0.16	<0.10	

Table 3.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland										
Lewis	Mussels	1			<0.10		<0.27	<0.30		<0.77
Skye	Lobsters	1			0.12		<0.10	<0.10	<1.5	<0.17
Skye	Mussels	1			<0.10		<0.22	<0.23		<0.70
Islay	Crabs	1			<0.10		<0.17	<0.12		<0.85
Islay	Scallops	1			<0.10		<0.12	<0.10		<0.46
Kirkcudbright	Scallops	7[F,S]			<0.06		<0.13	<0.19	1.1	<0.31
Kirkcudbright	Queens	8[F,S]			<0.09		<0.16	<0.22	3.3	<0.38
Southerness	Winkles	4	<5.0		1.0	0.21	<0.38	<0.43	150	<1.3
North Solway coast	Crabs	8[F,S]		110	0.39	0.65	<0.42	<0.62	16	<0.99
North Solway coast	Lobsters	8[F,S]		130	<0.33	0.12	<0.37	<0.60	590	<0.86
North Solway coast	Winkles	8[F,S]			2.5	0.43	<0.32	<0.40	290	<2.2
North Solway coast	Cockles	6[F,S]	5.3	99	1.7	0.60	<0.19	<0.29	12	<0.73
North Solway coast	Mussels	8[F,S]	<5.0	120	0.59	0.88	<0.23	<0.40	100	<0.79
Inner Solway	Shrimps	3	<6.1		<0.10	0.18	<0.17	<0.40	1.2	<0.40
Isle of Man										
Isle of Man	Lobsters	4			<0.06		<0.28	<0.45	130	<0.62
Isle of Man	Scallops	4			<0.05		<0.20	<0.31		<0.46
Wales										
Conwy	Mussels	2		64	<0.05		<0.15	<0.15		<0.52
Menai Straits	Lobsters	1							190	
Menai Straits	Cockles	1							7.2	
Menai Straits	Mussels	1							23	
North Anglesey	Crabs	2			<0.15		<0.84	<1.6	4.3	<1.6
North Anglesey	Lobsters	2			<0.06		<0.28	<0.53	150	<0.56
Northern Ireland										
Ballycastle	Lobsters	2			<0.15		<0.95	<2.0	53	<1.7
County Down	Scallops	2			<0.05		<0.35	<0.84		<0.50
Ards Peninsula	Winkles	4			<0.16		<0.96	<0.65		<1.8
Portavogie	*Nephrops*	3			<0.12		<0.87	<0.80	31	<1.3
Kilkeel	Crabs	4			<0.16		<1.3	<1.4		<1.8
Kilkeel	Lobsters	4			<0.14		<0.90	<1.9	150	<1.6
Kilkeel	*Nephrops*	4			<0.17		<1.3	<1.7		<2.0
Carlingford Lough	Mussels	2			<0.13		<0.78	<1.7	18	<1.4
Further afield										
Northern North Sea	*Nephrops*	4			<0.07		<0.33	<0.56	4.9	<0.68
Cromer	Crabs	1			<0.07		<0.35	<0.59		<0.68
The Wash	Mussels	2								
Southern North Sea	Cockles	2			<0.13		<0.59	<1.3		<1.1
Southern North Sea	Mussels	4			<0.10		<0.68	<0.67	2.9	<1.1
Southern North Sea	Cockles[d]	2			<0.04		<0.16	<0.21	<0.34	<0.42
Southern North Sea	Mussels[d]	2			<0.09		<0.24	<0.22		<0.94
English Channel-East	Scallops	4		31	<0.06		<0.32	<0.64		<0.57
English Channel-West	Crabs	4		33	<0.15		<0.77	<1.4		<1.5
English Channel-West	Lobsters	4			<0.08		<0.48	<0.85	0.33	<0.96
English Channel-West	Scallops	4		24	<0.13		<0.85	<1.7		<1.5
Northern Irish Sea	Crabs	1			1.2		<0.62	<1.5		<0.96
Northern Irish Sea	Cuttlefish	1			<0.07		<0.85	*		<0.85

Table 3.6. continued

Location	Material	No. of sampling observ- ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Total beta
Scotland										
Lewis	Mussels	1	<0.10	<0.21	<0.10	<0.10	<0.49	<0.11	0.18	
Skye	Lobsters	1	<0.10	<0.10	<0.13	0.25	<0.13	<0.10	<0.10	
Skye	Mussels	1	<0.10	<0.20	<0.10	<0.10	<0.45	<0.11	<0.19	
Islay	Crabs	1	<0.10	<0.25	<0.10	0.14	<0.58	<0.15	<0.27	
Islay	Scallops	1	<0.10	<0.13	<0.29	0.14	<0.29	<0.10	<0.15	
Kirkcudbright	Scallops	7[F,S]	<0.08	<0.09	<0.06	<0.23	<0.22	<0.09	<0.11	
Kirkcudbright	Queens	8[F,S]	<0.09	<0.10	<0.07	0.34	<0.22	<0.12	<0.10	
Southerness	Winkles	4	<0.21	<0.82	<0.14	1.2	<0.76	<0.17	<0.32	
North Solway coast	Crabs	8[F,S]	<0.17	<0.36	<0.11	1.2	<0.61	<0.20	<0.25	
North Solway coast	Lobsters	8[F,S]	<0.16	<0.24	<0.10	1.7	<0.56	<0.18	<0.24	
North Solway coast	Winkles	8[F,S]	<0.54	1.6	<0.12	1.5	<0.53	<0.22	<0.24	
North Solway coast	Cockles	6[F,S]	<0.11	0.67	<0.08	3.7	<0.30	<0.14	<0.14	
North Solway coast	Mussels	8[F,S]	<0.12	0.75	<0.09	2.6	<0.33	<0.15	<0.15	
Inner Solway	Shrimps	3	<0.11	<0.15	<0.10	3.3	<0.26	<0.10	<0.13	
Isle of Man										
Isle of Man	Lobsters	4	<0.13	<0.15	<0.07	0.49	<0.32	<0.20	<0.13	160
Isle of Man	Scallops	4	<0.09	<0.11	<0.05	0.27	<0.23	<0.15	<0.10	
Wales										
Conwy	Mussels	2	<0.09	<0.14	<0.05	0.30	<0.33	<0.14	<0.15	
Menai Straits	Lobsters	1								
Menai Straits	Cockles	1								
Menai Straits	Mussels	1								
North Anglesey	Crabs	2	<0.31	<0.32	<0.15	0.68	<0.63	<0.41	<0.22	
North Anglesey	Lobsters	2	<0.13	<0.12	<0.06	0.74	<0.25	<0.16	<0.10	170
Northern Ireland										
Ballycastle	Lobsters	2	<0.31	<0.33	<0.15	<0.24	<0.64	<0.41	<0.21	
County Down	Scallops	2	<0.11	<0.11	<0.05	0.34	<0.28	<0.15	<0.11	
Ards Peninsula	Winkles	4	<0.31	<0.38	<0.17	<0.34	<0.78	<0.46	<0.29	
Portavogie	*Nephrops*	3	<0.25	<0.29	<0.12	1.1	<0.61	<0.35	<0.24	
Kilkeel	Crabs	4	<0.33	<0.37	<0.16	<0.29	<0.88	<0.42	<0.33	
Kilkeel	Lobsters	4	<0.29	<0.31	<0.15	<0.33	<0.69	<0.38	<0.27	
Kilkeel	*Nephrops*	4	<0.37	<0.40	<0.18	0.91	<0.84	<0.50	<0.30	
Carlingford Lough	Mussels	2	<0.26	<0.29	<0.14	0.46	<0.64	<0.36	<0.24	
Further afield										
Northern North Sea	*Nephrops*	4	<0.13	<0.15	<0.07	<0.09	<0.30	<0.20	<0.12	
Cromer	Crabs	1	<0.14	<0.15	<0.07	<0.06	<0.31	<0.20	<0.12	
The Wash	Mussels	2								
Southern North Sea	Cockles	2	<0.19	<0.22	<0.10	0.21	<0.55	<0.27	<0.21	
Southern North Sea	Mussels	4	<0.21	<0.23	<0.10	0.16	<0.46	<0.28	<0.16	
Southern North Sea	Cockles[d]	2	<0.08	<0.11	<0.05	0.09	<0.29	<0.11	<0.14	
Southern North Sea	Mussels[d]	2	<0.15	<0.22	<0.10	<0.09	<0.46	<0.25	<0.23	17
English Channel-East	Scallops	4	<0.13	<0.13	<0.06	<0.05	<0.32	<0.19	<0.13	
English Channel-West	Crabs	4	<0.29	<0.32	<0.16	<0.13	<0.61	<0.43	<0.24	
English Channel-West	Lobsters	4	<0.17	<0.22	<0.09	<0.08	<0.55	<0.24	<0.22	
English Channel-West	Scallops	4	<0.27	<0.31	<0.14	<0.11	<0.72	<0.38	<0.28	
Northern Irish Sea	Crabs	1	0.42	0.38	<0.08	1.5	<0.43	<0.23	<0.15	
Northern Irish Sea	Cuttlefish	1	<0.19	<0.19	<0.08	<0.07	<0.59	<0.24	<0.23	

[a] *The concentration of ^{129}I was <0.59 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <0.30 Bq kg^{-1}*
[c] *Samples collected by Consumer 971*
[d] *Landed in Holland or Denmark*
[F,S] *Samples collected on behalf of the Food Standards Agency and SEPA*

Table 3.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Cumbria									
Silloth	Mussels	1		0.70	3.8		7.0	*	*
Silloth	Shrimps	1		0.0056	0.030	0.23	0.059	*	0.000050
Maryport	Plaice	4					<0.22		
River Derwent	Sea trout	1					<0.09		
Parton	Cod	4					<0.13		
Parton	Crabs	4					1.1		
Parton	Lobsters	4					2.1		
Parton	Winkles	1		1.5	7.1	66	13	*	0.010
Whitehaven	Cod	1		0.00081	0.0044		0.0075	0.000055	0.000028
Whitehaven	Plaice	1		0.0027	0.014		0.029	*	0.000048
Whitehaven	Skates/rays	1		0.00036	0.0019		0.0034	*	0.000013
Whitehaven	Sole	1		0.00040	0.0020		0.0031	*	*
Whitehaven	*Nephrops*	1		0.039	0.22		0.64	*	0.00079
Whitehaven	Cockles	1		0.00072	0.0052		0.0041	*	0.00010
Whitehaven	Mussels	1		0.00033	0.0029	0.086	0.0029	*	0.000011
Whitehaven outer harbour	Mussels	2					6.6		
Saltom Bay	Winkles	4					14		
St Bees	Winkles	1	0.019	1.6	8.2	71	17	0.020	0.040
St Bees	Mussels	2		1.6	7.2	78	14	<0.020	0.031
St Bees	Limpets	1		1.5	7.4		15	*	0.031
Nethertown	Winkles	4	0.074	4.0	20	190	36	0.051	0.076
Nethertown	Mussels	4		1.8	7.6		17	<0.0097	0.035
River Ehen	Salmon	1					<0.10		
Sellafield coastal area	Cod	2		0.00067	0.0033		0.0065	<0.0000087	0.000022
Sellafield coastal area	Plaice	1		0.0022	0.010		0.020	0.000072	0.000050
Sellafield coastal area	Bass	1					<0.19		
Sellafield coastal area	Mullet	1					<0.30		
Sellafield coastal area	Crabs	2	0.0024	0.074	0.33	2.5	1.5	<0.0016	0.0059
Sellafield coastal area	Lobsters	2	0.012	0.073	0.29	4.6	4.7	*	0.0099
Sellafield coastal area	*Nephrops*	1		0.078	0.42		2.9	0.0023	0.0031
Sellafield coastal area[a]	Winkles	2	0.013	2.3	12	120	23	0.046	0.038
Sellafield coastal area[a]	Mussels	1		1.9	9.1	96	18	*	0.032
Sellafield coastal area[a]	Limpets	1		2.0	9.3	93	19	0.035	0.049
Sellafield offshore area	Cod	1					<1.2		
Sellafield offshore area	Plaice	1	0.00014	0.0011	0.0048		0.011	0.000089	*
Sellafield offshore area	Dab	2					<0.15		
Sellafield offshore area	Red gurnard	1		0.0019	0.0093		0.017	*	*
Sellafield offshore area	Lesser spotted dogfish	2					<0.24		
Sellafield offshore area	Skates/rays	1					<0.31		
Whitriggs	Shrimps	1					<0.16		
Drigg	Winkles	1	0.022	2.7	12	130	25	0.028	0.074
Ravenglass	Cod	1		0.0014	0.0065		0.012	*	0.000022
Ravenglass	Plaice	1		0.0038	0.017		0.031	0.00014	0.000074
Ravenglass	Crabs	1		0.047	0.23	2.4	1.3	*	0.0014
Ravenglass	Lobsters	1		0.055	0.26	2.9	3.9	*	0.0063
Ravenglass	Winkles	2					20		
Ravenglass	Cockles	1		2.0	9.0	89	27	*	0.037
Ravenglass	Mussels	1		1.3	6.5	70	15	0.018	0.023
Tarn Bay	Winkles	1		1.6	7.9	76	16	*	0.029
Haverigg	Cockles	1		1.4	6.6		19	0.032	0.046
Millom	Mussels	2					4.6		
Barrow	Crabs	1		0.025	0.12		0.55	*	0.00055
Barrow	Lobsters	4					0.66		
Roosebeck	Pacific oysters	1		0.13	0.61		0.58	*	0.00047
Morecambe Bay (Flookburgh)	Flounder	1		0.00054	0.0026		0.0049	*	0.000017
Morecambe Bay (Flookburgh)	Plaice	1					<0.25		
Morecambe Bay (Flookburgh)	Shrimps	1		0.0040	0.022	0.18	0.036	*	*
Morecambe Bay (Flookburgh)	Cockles	1		0.48	2.4	20	6.5	0.020	0.0085

Table 3.7 continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Plaice	4					<0.43		
Morecambe Bay (Morecambe)	Bass	2					<0.13		
Morecambe Bay (Sunderland Point)	Whitebait	1		0.092	0.49	4.1	0.84	0.0037	0.0011
Morecambe Bay (Morecambe)	Mussels	1		0.44	2.3		4.3	*	0.0069
Red Nab Point	Winkles	1		0.35	1.9		3.5	0.0046	0.0056
Morecambe Bay (Middleton Sands)	Cockles	1		0.31	1.8		4.8	*	0.0075
Knott End	Cockles	1		0.87	4.9		11	0.010	0.017
Fleetwood	Cod	1		0.00015	0.0011		0.0022	*	*
Fleetwood	Plaice	1		0.00013	0.00077		0.0013	*	*
Fleetwood	Squid	1					<0.12		
Ribble Estuary	Flounder	1					<0.45		
Ribble Estuary	Mullet	1					<0.48		
Ribble Estuary	Salmon	1					<0.11		
Ribble Estuary	Sea trout	1					<0.12		
Ribble Estuary	Shrimps	1	0.00035	0.0029	0.016		0.030	*	*
Ribble Estuary	Cockles	1		0.25	1.4		3.9	*	0.0066
Ribble Estuary	Mussels	2					2.0		
Dee Estuary	Cockles	1		0.17	1.1		2.7	*	0.0031
Wirral	Shrimps	2					<0.06		
Scotland									
Shetland	Fish meal	1		0.00011	0.0012		0.00035	*	*
Shetland	Fish oil	3					<0.14		
Minch	Herring	2					<0.48		
Minch	Mackerel	1		0.000029	0.000090		0.000072	*	*
West of Scotland	Mackerel	2					<0.08		
West of Scotland	Farmed salmon	1					<0.39		
Lewis	Mussels	1					<0.13		
Skye	Lobster	1					<0.10		
Skye	Mussels	1					<0.12		
Islay	Crabs	1					<0.15		
Islay	Scallops	1					<0.15		
Kirkcudbright	Plaice	1		<0.00091	0.0051		<0.12		
Kirkcudbright	Lemon sole	1					<0.12		
Kirkcudbright	Scallops	2^{F,S}		0.037	0.21		0.11	*	0.000059
Kirkcudbright	Queens	2^{F,S}		0.012	0.060		0.11	*	0.00017
Southerness	Winkles	4		0.18	1.4		2.5		
North Solway coast	Cod	1		0.00083	0.0046		0.0088	*	0.000011
North Solway coast	Crabs	2^{F,S}		0.038	0.22		0.82	0.00086	0.0011
North Solway coast	Lobsters	2^{F,S}		0.021	0.10	1.2	0.59	*	0.0012
North Solway coast	Winkles	2^{F,S}		0.28	1.4	14	3.3	0.0064	0.0058
North Solway coast	Cockles	5^{F,S}		0.76	4.2	30	10	*	0.015
North Solway coast	Mussels	2^{F,S}		0.56	3.0	29	7.0	0.0083	0.0058
Inner Solway	Plaice	1					<0.17		
Inner Solway	Flounder	1		0.0011	0.0024		0.0046		
Inner Solway	Lemon sole	1					<0.15		
Inner Solway	Salmon	1					<0.22		
Inner Solway	Sea trout	1					<0.12		
Inner Solway	Shrimps	1		0.0022	0.011		0.024		
Isle of Man									
Isle of Man	Cod	1		0.00020	0.0012		0.0015	*	*
Isle of Man	Herring	1		0.00021	0.0014		0.0012	*	*
Isle of Man	Lobsters	4					<0.10		
Isle of Man	Scallops	1		0.016	0.088		0.044	*	0.000085
Wales									
Conwy	Mussels	1		0.023	0.13		0.22	0.00027	0.00035
North Anglesey	Skates/rays	1		<0.000035	0.00017		0.00022	*	*
North Anglesey	Plaice	2					<0.18		
North Anglesey	Crabs	1		0.0040	0.023		0.077	0.000035	0.00014
North Anglesey	Lobsters	2					0.14		

Table 3.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Northern Ireland							
North coast	Cod	2			<0.19		
North coast	Spurdog	4			<0.34		
Ballycastle	Lobsters	2			<0.11		
County Down	Scallops	2			<0.18		
Ards Peninsula	Winkles	1	0.030	0.17	0.19	*	0.00027
Portavogie	Cod	1			<0.23		
Portavogie	Haddock	4			<0.14		
Portavogie	Spurdog	4			<0.36		
Portavogie	*Nephrops*	1	0.013	0.076	0.27	*	0.00020
Ardglass	Herring	2			<0.65		
Kilkeel	Cod	4			<0.09		
Kilkeel	Whiting	4			<0.35		
Kilkeel	Crabs	4			<0.37		
Kilkeel	Lobsters	4			<0.24		
Kilkeel	Nephrops	4			<0.21		
Carlingford Lough	Mussels	2			<0.18		
Further afield							
Baltic Sea	Cod	3			<0.23		
Baltic Sea	Herring	4			<0.53		
Barents Sea	Cod	2			<0.31		
Barents Sea	Haddock	1			<0.41		
Barents Sea	Herring	1			<0.13		
Norwegian Sea	Herring	1			<0.13		
Norwegian Sea	Saithe	1			<0.11		
Norwegian processed	Cod	1	0.0000091	0.000017	0.000035	*	*
Iceland area	Cod	2			<0.45		
Skagerrak	Cod	4			<0.13		
Skagerrak	Herring	4			<0.08		
Northern North Sea	Cod	1	0.0000088	0.000050	0.000061	*	0.0000050
Northern North Sea	Plaice	4			<0.20		
Northern North Sea	Haddock	1	<0.000032	0.000076	0.000068	*	*
Northern North Sea	Herring	2			<0.19		
Northern North Sea	*Nephrops*	1	0.00017	0.0019	0.0022	*	*
Mid North Sea	Cod	4			<0.13		
Mid North Sea	Plaice	4			<0.29		
Cromer	Crabs	1			<0.07		
Gt Yarmouth (retail shop)	Cod	4			<0.11		
Gt Yarmouth (retail shop)	Plaice	4			<0.14		
Southern North Sea	Bass	2			<0.07		
Southern North Sea	Cod	2			<0.15		
Southern North Sea	Sole	4			<0.14		
Southern North Sea	Herring	2			<0.39		
Southern North Sea	Cockles	1	0.0014	0.0071	0.0081	*	0.00039
Southern North Sea	Mussels[b]	1	0.0019	0.011	0.016	0.000013	0.000066
Southern North Sea	Cockles[c]	1	0.0030	0.011	0.018	0.000047	0.0013
Southern North Sea	Mussels	1	0.0027	0.018	0.0072	0.000039	0.000034
English Channel-East	Cod	3			<0.26		
English Channel-East	Plaice	4			<0.17		
English Channel-East	Whiting	1			<0.06		
English Channel-East	Scallops	1	0.00063	0.0023	0.00095	*	0.000069
English Channel-West	Mackerel	4			<0.16		
English Channel-West	Plaice	4			<0.35		
English Channel-West	Whiting	4			<0.35		
English Channel-West	Crabs	1	0.00011	0.00084	0.00072	*	*
English Channel-West	Lobsters	4			<0.22		
English Channel-West	Scallops	1	0.00031	0.0042	0.0012	*	0.000018
Celtic Sea	Cod	4			<0.15		
Celtic Sea	Megrim	1			<0.09		
Celtic Sea	Plaice	1			<0.28		
Celtic Sea	Whiting	2			<0.14		
Northern Irish Sea	Dab	1			<0.29		
Northern Irish Sea	Lesser spotted dogfish	1			<0.15		
Northern Irish Sea	Skates/rays	1			<0.14		
Northern Irish Sea	Crabs	1			2.1		
Northern Irish Sea	Cuttlefish	1			<0.33		

** Not detected by the method used*
[a] Samples collected by consumer 971
[b] Landed in Holland or Denmark
[c] Landed in Holland
[F,S] Samples collected on behalf of the Food Standards Agency and SEPA

Table 3.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria												
Newton Arlosh	Sediment	4		<2.2		<2.4	<1.3	<6.5		<7.2	<0.71	210
Maryport Outer Harbour	Sediment	2		<1.3	<1.0	<1.8	<1.2	<4.4		<4.7	<0.56	64
Workington Harbour	Sediment	2		6.9		<3.5	<4.3	<7.5		11	<0.92	160
Harrington Harbour	Sediment	2		7.3		<2.2	<1.5	<12		<12	<0.73	210
Whitehaven Outer Harbour	Sediment	4		<1.6	<3.0	<2.5	<1.7	<5.8		7.1	<0.69	130
St Bees	Sand	3^F	<0.59	2.9		<2.9	<5.4	<6.5	<1.1	<2.4	<0.66	70
St Bees	Sediment	4		3.3		<2.4	<1.8	<5.6		<5.6	<0.68	74
Sellafield	Sand	4^F	<0.71	4.5		<4.3	<9.8	<7.2	<1.3	<2.4	<0.72	60
Ehen Spit	Sediment	2		3.4		<1.6	<0.88	<4.8		<4.7	<0.56	71
River Calder - downstream	Sediment	2		<0.92		<3.2	<2.4	<6.1		<6.3	<0.75	140
River Calder - upstream	Sediment	2		<1.1		<2.7	<1.5	<6.3		<6.1	<0.84	67
Seascale beach	Sediment	4		2.2		<1.7	<1.1	<3.8		<3.5	<0.46	50
Ravenglass - Carleton Marsh	Mud	3^F	<1.3	27		<7.0	<11	<88	<2.4	<24	<1.6	2000
Ravenglass - Carleton Marsh	Sediment	4		20		<5.2	<2.9	<50		<28	<1.8	2200
River Mite Estuary	Sediment	4		<7.8	290	<4.9	<2.1	<19		<25	<2.0	4600
Ravenglass - Raven Villa	Mud and sand	3^F	<1.1	23		<4.9	<6.9	<51	<1.9	25	<1.3	610
Ravenglass - Raven Villa	Sediment	4		22		<4.5	<3.0	<40		<24	<1.5	550
Newbiggin (Eskmeals)	Sediment	4		28	100	<3.7	<2.1	58		27	<1.3	650
Haverigg	Sediment	2		<2.0		<1.6	<0.90	<4.0		<4.6	<0.53	30
Millom	Sediment	2		8.9		<2.2	<1.3	25		16	<0.75	170
Low Shaw	Sediment	2		<0.97		<2.4	<1.5	<6.4		<6.0	<0.76	83
Walney Channel - west	Sediment	2		7.0		<2.3	<1.4	19		12	<0.77	150
Walney Channel - east	Sediment	2		6.2		<3.4	<2.2	<16		11	<0.80	110
Sand Gate Marsh	Turf	4^F	<0.76	<1.3		<3.5	<6.1	<8.2	<1.3	<2.6	<0.91	120
Sand Gate Marsh	Sediment	4		<1.7		<3.6	<3.1	<7.3		<7.9	<0.76	210
Flookburgh	Sediment	2		<0.69		<2.9	<2.1	<6.6		<7.7	<0.69	320
Kents Bank 1	Sediment	1		<1.2								260
Kents Bank 2	Sediment	1		<0.99								160
Lancashire												
Morecambe	Sediment	2		<2.1								110
Half Moon Bay	Sediment	2		<0.87								23
Half Moon Bay	Mud and sand	1^F										
Heysham pipelines	Sediment	2		<0.74								24
Potts Corner	Sediment	2		<0.75								34
Sunderland Point	Sediment	4		2.3		<2.3	<1.5	<4.9		<5.3	<0.62	68
Conder Green	Turf	4^F	<1.1	3.8		<4.9	<8.2	<12	<1.9	<8.2	<1.2	260
Conder Green	Sediment	4		2.5		<2.6	<1.4	<6.8		<7.4	<0.79	160
Hambleton	Sediment	4		4.0		<3.4	<1.9	<9.1		<12	<1.1	490
Skippool Creek	Sediment	4		4.5		<3.8	<2.6	<11		<12	<0.99	460
Fleetwood	Sediment	4		<0.70		<2.1	<1.3	<4.5		<3.9	<0.61	20
Blackpool	Sediment	4		<0.57		<1.4	<0.83	<3.7		<3.0	<0.49	4.5
Crossens Marsh	Sediment	4		<1.3		<4.9	<3.4	<9.4		<9.0	<1.2	88
Ainsdale	Sediment	4		<0.57		<1.5	<0.95	<3.6		<3.0	<0.48	6.9
Rock Ferry	Sediment	4		<1.1		<2.4	<1.4	<5.7		<6.3	<0.70	120
New Brighton	Sediment	4		<0.45		<1.3	<0.90	<2.9		<2.4	<0.39	4.4
Scotland												
Campbeltown	Sediment	1	<0.10	<0.10		<0.30	<0.38	<0.74	<0.12	0.19	<0.10	8.6
Garlieston	Sediment	2	<0.10	0.60		<0.43	<0.22	<1.0	<0.12	2.2	<0.10	42
Innerwell	Mud	2^F	<0.87	4.0		<3.8	<6.4	<9.1	<1.5	3.6	<0.98	110
Innerwell	Sediment	2	<0.11	2.0		<0.49	<0.71	3.2	<0.11	2.4	<0.10	86
Bladnoch	Sediment	1	<0.12	5.3		<1.9	<0.83	12	<0.16	5.4	<0.12	360
Carsluith	Sediment	2	<0.10	4.2		<0.32	<0.63	9.5	<0.10	6.0	<0.14	170
Skyreburn	Sediment	1	<0.10	<0.10		<0.19	<0.14	<0.81	<0.12	<0.30	<0.11	52
Cutter's Pool	Sediment	1	<0.11	3.8		<0.83	<0.88	<1.7	<0.21	7.7	<0.10	160
Rascarrel Bay		1	<0.10	2.3		<0.41	0.87	4.7	<0.10	3.3	<0.10	91
Palnackie Harbour	Sediment	2	<0.10	3.2		<0.43	<0.69	7.2	<0.15	4.4	<0.13	160
Gardenburn	Sediment	1	<0.10	3.4		<0.61	1.5	6.1	<0.12	4.1	0.18	150
Kippford Slipway	Sediment	2	<0.13	3.8		<0.44	<0.59	7.7	<0.11	5.0	<0.10	140
Kippford Merse	Turf	1	<0.10	2.8		<0.54	<0.61	3.5	<0.11	2.4	<0.10	180
Kippford Merse	Sediment	1	<0.11	2.8		<0.61	<0.76	2.6	<0.11	2.1	<0.10	190
Southerness	Sediment	1	<0.10	0.41		<0.21	<0.11	<0.71	<0.11	1.1	<0.10	23
Kirkconnel Merse	Sediment	2	<0.13	1.2		<0.87	<1.4	<1.7	<0.17	3.0	<013	750
Dornoch Brow	Sediment	1	<0.10	2.8		<0.29	0.37	6.9	0.17	4.4	0.19	210

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}										
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Cumbria													
Newton Arlosh	Sediment	4	<3.5	<3.7	<2.0				190			580	810
Maryport Outer Harbour	Sediment	2	<2.4	<3.0	<1.3	9.2	53	450	73			380	460
Workington Harbour	Sediment	2	<3.8	<4.2	<2.1				240			1200	1300
Harrington Harbour	Sediment	2	<3.5	<3.8	<2.0				290			750	850
Whitehaven Outer Harbour	Sediment	4	<3.1	<3.5	<1.7	8.9	49	410	78			430	590
St Bees	Sand	3[F]	<4.5	<1.6	<2.1				170				
St Bees	Sediment	4	<2.9	<3.6	<1.5				200			460	370
Sellafield	Sand	4[F]	<4.7	<2.0	<2.0				160				
Ehen Spit	Sediment	2	<2.4	<3.1	<1.4				150			400	460
River Calder - downstream	Sediment	2	<3.7	<3.8	<2.0				24			410	950
River Calder - upstream	Sediment	2	<3.3	<4.3	<2.0							450	1200
Seascale beach	Sediment	4	<2.1	<2.5	<1.2				140			470	430
Ravenglass - Carleton Marsh	Mud	3[F]	<17	23	<7.7				3600				
Ravenglass - Carleton Marsh	Sediment	4	<14	21	<6.2				4500			6400	2300
River Mite Estuary	Sediment	4	<9.8	<30	<8.9	490	2600	24000	4500			9000	4400
Ravenglass - Raven Villa	Mud and sand	3[F]	<8.4	10	<3.9				1300				
Ravenglass - Raven Villa	Sediment	4	<5.9	<8.7	<3.1				1600			3100	1500
Newbiggin (Eskmeals)	Sediment	4	<9.0	10	<4.4	150	770	6500	1300			3000	2300
Haverigg	Sediment	2	<2.0	<2.7	<1.1				81			320	400
Millom	Sediment	2	<3.4	<3.8	<1.9				380			930	850
Low Shaw	Sediment	2	<3.2	<4.0	<1.8				110			320	500
Walney Channel - west	Sediment	2	<3.6	<3.8	<2.0				300			1000	860
Walney Channel - east	Sediment	2	<3.3	<3.9	<1.8				200			700	760
Sand Gate Marsh	Turf	4[F]	<5.1	<2.2	<2.3				72				
Sand Gate Marsh	Sediment	4	<3.7	<3.7	<1.9				130			550	710
Flookburgh	Sediment	2	<3.6	<3.0	<2.0				190			740	740
Kents Bank 1	Sediment	1				17	100		170				
Kents Bank 2	Sediment	1				12	69		110				
Lancashire													
Morecambe	Sediment	2							110				
Half Moon Bay	Sediment	2							21				
Half Moon Bay	Mud and sand	1[F]				8.8	50		86	*	0.089		
Heysham pipelines	Sediment	2							20				
Potts Corner	Sediment	2							15				
Sunderland Point	Sediment	4	<3.0	<3.1	<1.7				64			310	470
Conder Green	Turf	4[F]	<7.4	<2.8	<3.4				180				
Conder Green	Sediment	4	<3.4	<4.0	<2.0				130			490	730
Hambleton	Sediment	4	<5.2	<4.4	<2.9				360			1000	1300
Skippool Creek	Sediment	4	<5.2	<4.3	<2.7				350			1000	1300
Fleetwood	Sediment	4	<2.5	<3.1	<1.4				22			220	440
Blackpool	Sediment	4	<1.9	<2.5	<1.1				5.1			<120	240
Crossens Marsh	Sediment	4	<4.5	<5.7	<2.5				76			400	720
Ainsdale	Sediment	4	<1.8	<2.5	<1.0				4.3			<100	<200
Rock Ferry	Sediment	4	<3.0	<3.6	<1.7				70			400	860
New Brighton	Sediment	4	<1.7	<2.1	<0.93				2.9			<110	230
Scotland													
Campbeltown	Sediment	1	<0.72	<0.16	<0.63				1.6				
Garlieston	Sediment	2	<0.81	<0.31	<0.48	5.1	29		51				
Innerwell	Mud	2[F]	<5.7	<2.3	<2.9				150				
Innerwell	Sediment	2	<0.77	<0.48	1.2				96				
Bladnoch	Sediment	1	<1.2	2.0	1.8				360				
Carsluith	Sediment	2	<0.66	1.5	1.2	35	190		320			420	920
Skyreburn	Sediment	1	<0.80	<0.21	<0.32				8.1				
Cutter's Pool	Sediment	1	<1.6	1.7	2.1				240				
Rascarrel Bay		1	<0.72	0.67	1.3				110				
Palnackie Harbour	Sediment	2	<1.2	1.0	<0.77	15	61		140				
Gardenburn	Sediment	1	<0.86	1.3	<0.86	24	130		220				
Kippford Slipway	Sediment	2	<1.0	1.3	1.0	17	91		190				
Kippford Merse	Turf	1	<0.85	1.5	<0.91				220				
Kippford Merse	Sediment	1	<0.87	1.3	<0.92	28	140		270				
Southerness	Sediment	1	<0.70	<0.17	0.92	2.8	16		25				
Kirkconnel Merse	Sediment	2	<1.5	1.6	<1.5	22	120		250			130	150
Dornoch Brow	Sediment	1	<0.67	0.93	1.5				150				

Table 3.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs
Isle of Man											
Ramsey	Sediment	1		<0.33	<0.77	<0.34	<1.9		<1.7	<0.28	7.0
Wales											
Rhyl	Sediment	2		<0.76	<3.2	<3.0	<5.6		<6.1	<0.70	80
Llandudno	Sediment	2		<0.57	<2.2	<1.7	<3.7		<3.2	<0.51	4.3
Caerhun	Sediment	2		<2.3	<7.9	<6.3	<18		<17	<2.1	220
Llanfairfechan	Sediment	2		<1.2	<3.8	<2.1	<8.3		<8.1	<1.1	79
Northern Ireland											
Carrichue	Mud, sand and stones	2[F]	<0.37	<0.30	<1.5	<2.4	<3.5	<0.63	<0.84	<0.36	2.4
Portrush	Sand	2[F]	<0.53	<0.40	<5.1	<3.4	<4.7	<1.1	<1.1	<0.52	0.70
Oldmill Bay	Mud	2[F]	<0.72	<0.63	<2.9	<4.2	<6.8	<1.2	<2.6	<0.83	43
Ballymacormick	Mud	2[F]	<0.49	<0.43	<1.7	<2.2	<4.5	<0.84	<1.4	<0.58	20
Strangford Lough - Nicky's Point	Mud	2[F]	<0.70	<0.52	<3.5	<6.2	<6.1	<1.3	<1.9	<0.79	34
Dundrum Bay	Mud	2[F]	<0.56	<0.46	<3.2	<6.7	<5.3	<1.1	<1.4	<0.63	6.3
Carlingford Lough	Mud	2[F]	<1.0	<0.81	<5.2	<10	<9.5	<1.8	<3.7	<1.2	64

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Isle of Man												
Ramsey	Sediment	1	<1.1	<1.5	<0.70			2.1			250	400
Wales												
Rhyl	Sediment	2	<3.2	<3.4	<1.8			47			540	810
Llandudno	Sediment	2	<2.1	<2.5	<1.1						<160	340
Caerhun	Sediment	2	<8.3	<11	<4.7			54			400	820
Llanfairfechan	Sediment	2	<4.1	<5.4	<2.6			46			440	790
Northern Ireland												
Carrichue	Mud, sand and stones	2[F]	<2.4	<0.86	<1.0	0.020	0.17	0.19	*	*		
Portrush	Sand	2[F]	<3.3	<1.1	<1.3			<2.1				
Oldmill Bay	Mud	2[F]	<4.8	<1.9	<2.2	2.7	15	24	*	0.050		
Ballymacormick	Mud	2[F]	<3.1	<1.3	<1.5	1.5	8.5	13	*	*		
Strangford Lough - Nicky's Point	Mud	2[F]	<4.7	<1.6	<2.2	1.9	11	12	*	*		
Dundrum Bay	Mud	2[F]	<3.8	<1.5	<1.6			<2.4				
Carlingford Lough	Mud	2[F]	<6.0	<2.4	<2.6	2.2	13	8.7	*	0.0067		

** Not detected by the method used*

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Table 3.9. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2005

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Salt marsh	2	0.079
Burgh Marsh	Salt marsh	1	0.076
Burgh Marsh	Grass and salt marsh	1	0.12
Port Carlisle 1	Mud	1	0.086
Port Carlisle 1	Grass and mud	2	0.092
Port Carlisle 1	Sand	1	0.089
Port Carlisle 2	Grass and mud	3	0.10
Port Carlisle 2	Grass and salt marsh	1	0.099
Greenend 1	Mud	1	0.094
Greenend 1	Salt marsh and mud	2	0.093
Greenend 1	Grass and salt marsh	1	0.087
Greenend 2	Mud	1	0.097
Greenend 2	Salt marsh and mud	1	0.082
Greenend 2	Salt marsh	1	0.089
Greenend 2	Sand	1	0.093
Greenend 3	Mud	1	0.089
Greenend 3	Salt marsh and mud	1	0.091
Greenend 3	Salt marsh	1	0.086
Greenend 3	Grass and sand	1	0.088
Cardurnock Marsh	Salt marsh	1	0.076
Cardurnock Marsh	Grass and salt marsh	3	0.077
Newton Arlosh	Grass and mud	3	0.092
Newton Arlosh	Salt marsh and mud	1	0.094
Silloth harbour	Mud and pebbles	2	0.10
Silloth harbour	Pebbles and sand	1	0.099
Silloth harbour	Sand	1	0.082
Silloth silt pond	Grass	1	0.075
Silloth silt pond	Grass and sand	3	0.079
Allonby	Pebbles and sand	4	0.10
Maryport harbour	Sand	2	0.089
Parton	Winkle bed	4^F	0.087
Workington harbour	Mud	1	0.10
Workington harbour	Mud and sand	1	0.10
Harrington harbour	Mud and pebbles	1	0.099
Harrington harbour	Sand	1	0.10
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	1	0.11
Whitehaven - outer harbour	Pebbles and sand	2	0.10
Whitehaven - outer harbour	Sand and shingle	1	0.11
Saltom Bay	Winkle bed	4^F	0.091
St Bees	Sand	2	0.080
St Bees	Pebbles and sand	2	0.10
Nethertown beach	Pebbles and rock	1	0.081
Nethertown beach	Rock	1	0.077
Braystones	Pebbles and sand	1	0.10
Braystones	Pebbles	1	0.10
Sellafield beach	Sand	2	0.083
Sellafield beach	Grass and sand	2	0.090
Pipeline on foreshore	Sand	1	0.088
Pipeline on foreshore	Pebbles and sand	1	0.098
Ehen Spit seashore	Sand	2	0.082
River Calder downstream of factory sewer	Pebbles and sand	1	0.14
River Calder downstream of factory sewer	Rock	1	0.11
River Calder upstream of factory sewer	Grass and mud	1	0.092
River Calder upstream of factory sewer	Grass and sand	1	0.093
Seascale	Sand	2	0.076
Seascale	Grass	4	0.081
Seascale	Pebbles and sand	2	0.10
Drigg Barn Scar	Mussel bed	4^F	0.085

Table 3.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Salt marsh and mud	2	0.16
Ravenglass - Carleton Marsh	Grass and mud	1	0.16
Ravenglass - Carleton Marsh	Salt marsh	1	0.16
Ravenglass - River Mite estuary	Grass and mud	4	0.15
Ravenglass - Raven Villa	Salt marsh and mud	2	0.14
Ravenglass - Raven Villa	Grass and mud	2	0.17
Ravenglass - boat area	Mud and pebbles	2	0.10
Ravenglass - boat area	Pebbles and sand	2	0.10
Ravenglass - ford	Mud	3	0.11
Ravenglass - ford	Mud and sand	1	0.11
Muncaster Bridge	Salt marsh and mud	1	0.12
Muncaster Bridge	Grass and mud	2	0.13
Muncaster Bridge	Grass	1	0.13
Ravenglass - salmon garth	Mud and pebbles	4	0.11
Ravenglass - Eskmeals Nature Reserve	Mud	1	0.098
Ravenglass - Eskmeals Nature Reserve	Salt marsh and mud	3	0.15
Newbiggin/Eskmeals viaduct	Mud	1	0.13
Newbiggin/Eskmeals viaduct	Salt marsh and mud	2	0.15
Newbiggin/Eskmeals viaduct	Salt marsh	1	0.17
Newbiggin/Eskmeals bridge	Salt marsh and mud	3	0.18
Newbiggin/Eskmeals bridge	Grass and mud	1	0.18
Tarn Bay	Winkle bed	2[F]	0.083
Tarn Bay	Pebbles	1	0.11
Silecroft	Pebbles	1	0.10
Silecroft	Pebbles and sand	1	0.099
Haverigg	Mud and sand	1	0.086
Haverigg	Sand	1	0.073
Millom	Mud	1	0.11
Millom	Salt marsh and mud	1	0.10
Low Shaw	Salt marsh and mud	1	0.085
Low Shaw	Grass and mud	1	0.085
Askam	Sand	2	0.077
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	1	0.094
Walney Channel, N of discharge point	Mud and pebbles	1	0.096
Walney Channel, S of discharge point	Mud	2	0.093
Tummer Hill Marsh	Salt marsh	2	0.13
Roa Island	Pebbles and rock	1	0.077
Roa Island	Rock	1	0.096
Greenodd	Grass and mud	2	0.075
Sand Gate Marsh	Salt marsh	2	0.088
Sand Gate Marsh	Grass and mud	2	0.095
Flookburgh	Salt marsh and mud	1	0.094
Flookburgh	Salt marsh	1	0.088
High Foulshaw	Salt marsh and mud	1	0.079
High Foulshaw	Grass and mud	2	0.079
High Foulshaw	Salt marsh	1	0.079
Arnside 1	Mud and sand	3	0.074
Arnside 1	Sand	1	0.081
Arnside 2	Salt marsh	4	0.096
Lancashire and Merseyside			
Morecambe Central Pier	Mud and pebbles	1	0.082
Morecambe Central Pier	Pebbles and sand	1	0.077
Half Moon Bay	Rock and sand	1	0.071
Half Moon Bay	Pebbles and sand	1	0.072
Middleton Sands	Sand	2	0.074
Sunderland Point	Mud	3	0.090
Sunderland Point	Mud and sand	1	0.086
Sunderland	Mud	3	0.089
Sunderland	Grass and mud	1	0.076
Colloway Marsh	Mud and salt marsh	1	0.083
Colloway Marsh	Salt marsh	3	0.090
Lancaster	Grass and mud	3	0.078
Lancaster	Grass	1	0.079
Aldcliffe Marsh	Grass and mud	1	0.091
Aldcliffe Marsh	Salt marsh	3	0.10
Conder Green	Mud	1	0.093
Conder Green	Grass and mud	3	0.084

Table 3.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Lancashire and Merseyside			
Knott End	Mud and sand	2[F]	0.073
Heads - River Wyre	Grass and mud	3	0.11
Heads - River Wyre	Salt marsh and mud	1	0.10
Height o' th' hill - River Wyre	Grass and salt marsh	1	0.10
Height o' th' hill - River Wyre	Grass	3	0.11
Hambleton	Grass and mud	3	0.12
Hambleton	Grass and salt marsh	1	0.095
Skippool Creek 1	Grass and mud	4	0.12
Skippool Creek 2	Mud	1	0.096
Skippool Creek 2	Grass and mud	3	0.099
Skippool Creek 3	Wood	3	0.11
Skippool Creek boat 2	Wood	4	0.094
Skippool Creek boat 2 (in vicinity of boats)	Mud	3	0.092
Skippool Creek boat 2 (in vicinity of boats)	Grass and mud	1	0.097
Fleetwood shore 1	Sand	4	0.072
Fleetwood shore 2	Salt marsh	4	0.14
Blackpool	Sand	4	0.062
Crossens Marsh	Salt marsh	2	0.089
Crossens Marsh	Grass and salt marsh	1	0.091
Crossens Marsh	Salt marsh and sand	1	0.077
Ainsdale	Sand	4	0.063
Rock Ferry	Mud and sand	3	0.086
Rock Ferry	Sand	1	0.081
New Brighton	Sand	4	0.062
West Kirby	Mud and stones	1	0.066
West Kirby	Sand	3	0.067
Little Neston Marsh 1	Mud	1	0.078
Little Neston Marsh 1	Grass and mud	1	0.090
Little Neston Marsh 2	Salt marsh and mud	1	0.081
Little Neston Marsh 2	Salt marsh	1	0.10
Flint 1	Mud	1	0.077
Flint 1	Grass and mud	1	0.093
Flint 2	Salt marsh and mud	1	0.077
Flint 2	Salt marsh	1	0.091
Scotland			
Piltanton Burn	Salt marsh	4	0.059
Garlieston	Mud	4	0.068
Innerwell	Mud	4[F]	0.075
Innerwell	Mud	4	0.081
Bladnoch	Mud	4	0.082
Creetown	Salt marsh	1	0.066
Carsluith	Mud	4	0.080
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.074
Cumstoun	Salt marsh	1	0.077
Kirkcudbright	Salt marsh	4	0.072
Cutters Pool	Winkle bed	4[F]	0.082
Cutters Pool	Winkle bed	4	0.084
Rascarrel Bay	Winkle bed	4[F]	0.11
Rascarrel Bay	Winkle bed	4	0.11
Gardenburn	Salt marsh	1	0.089
Palnackie Harbour	Mud	2	0.074
Kippford - Slipway	Mud	4	0.095
Kippford - Merse	Salt marsh	2	0.094
Southerness	Winkle bed	4	0.059
Carsethorn	Mud	1	0.073
Kirkconnell Marsh	Salt marsh	1	0.10
Glencaple Harbour	Mud and sand	4	0.086
Isle of Man			
Ramsey	Mud and pebbles	1	0.081

Table 3.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, µGy h^{-1}
Wales			
Prestatyn	Sand	1	0.059
Prestatyn	Pebbles and rock	1	0.087
Rhyl	Mud	2	0.082
Llandudno	Pebbles and sand	1	0.099
Llandudno	Pebbles	1	0.083
Caerhun	Grass and mud	1	0.086
Caerhun	Salt marsh	1	0.10
Llanfairfechan	Mud and shingle	1	0.085
Llanfairfechan	Pebbles and sand	1	0.077
Northern Ireland			
Lishally	Mud	1	0.066
Eglington	Shingle	1	0.055
Bellerena	Mud	2	0.061
Carrichue House	Mud	1	0.058
Benone	Sand	2	0.063
Castlerock	Sand	2	0.063
Portstewart	Sand	2	0.060
Portrush, Blue Pool	Sand	1	0.065
Portrush, White Rocks	Sand	1	0.059
Port-Ballintrae	Sand	1	0.061
Giant's Causeway	Sand	1	0.061
Ballycastle	Sand	2	0.061
Cushendun	Sand	1	0.069
Cushendall	Sand and stones	1	0.077
Red Bay	Sand	1	0.074
Carnlough	Sand	1	0.063
Glenarm	Sand	1	0.065
Half Way House	Sand	1	0.063
Ballygally	Sand	1	0.060
Drains Bay	Sand	1	0.060
Larne	Sand	1	0.066
Whitehead	Sand	1	0.070
Carrickfergus	Sand	1	0.068
Belfast Lough	Sand	1	0.067
Helen's Bay	Sand	1	0.071
Groomsport	Sand	1	0.075
Millisle	Sand	1	0.085
Ballywalter	Sand	1	0.070
Ballyhalbert	Sand	1	0.069
Cloughy	Sand	1	0.075
Portaferry	Shingle and stones	1	0.10
Kircubbin	Sand	1	0.090
Greyabbey	Sand	1	0.081
Ards Maltings	Mud	1	0.087
Island Hill	Mud	1	0.085
Nicky's Point	Mud	1	0.088
Strangford	Shingle and stones	1	0.11
Kilclief	Sand	1	0.078
Ardglass	Mud	1	0.091
Killough	Mud	1	0.091
Rocky Beach	Sand	1	0.085
Tyrella	Sand	1	0.085
Dundrum	Mud	1	0.092
Newcastle	Sand	1	0.13
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.096
Greencastle	Sand	1	0.098
Mill Bay	Mud	1	0.11
Rostrevor	Sand	1	0.14
Narrow Water	Mud	1	0.11

[F] *Measurements labelled "F" are those in which the Food Standards Agency has also participated for quality control purposes, all other measurements are made on behalf of the Environment Agency*

Table 3.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2005

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, $\mu Sv\ h^{-1}$
M	Nets	4	0.082
	Ropes	4	0.047
S	Nets	2	0.069
	Pots	4	0.12
T	Gill nets	3	0.067
	Pots	3	0.14
W	Gill nets	2	0.081
	Pots	2	0.14
X	Gill nets	3	0.073
	Pots	3	0.088
Z	Nets	4	0.095

Table 3.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2005

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, $\mu Sv\ h^{-1}$
Whitehaven - outer harbour	Mud and sand	2	0.19
St Bees	Sand	2	0.21
Nethertown	Winkle bed	2	0.44
Sellafield pipeline	Sand	2	0.16
Drigg Barn Scar	Mussel bed	2	0.21
Ravenglass - Raven Villa	Salt marsh	2	0.72
Ravenglass - salmon garth	Mussel bed	2	0.46
Tarn Bay	Sand	2	0.18

Table 3.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Cumbria									
Silloth	Seaweed	2		<2.8			<4.7	<2.4	2600
Harrington Harbour	Seaweed	2		<3.5			<3.5	<1.8	2300
St Bees	*Fucus vesiculosus*[a]	4[F]		4.9	<0.19	2.1	<0.29	<0.48	3800
St Bees	*Porphyra*	4[F]	46	0.70	<0.21	0.28	<0.27	<0.38	3.5
St Bees	Seaweed	2		18			<4.1	<2.2	2300
Braystones South	*Porphyra*	4[F]		<1.2	<0.28		<0.38	<0.52	
Sellafield	*Fucus vesiculosus*	1[F]				3.3			
Sellafield	Seaweed	2		29			<4.1	<2.3	6900
Seascale	*Porphyra*[b]	52[F]		<1.4	<0.66		<0.46	<0.27	
Rabbit Cat How	Samphire	1[F]		0.27	<0.18		<0.48	<1.1	1.5
Ravenglass	Seaweed	2		21			<5.3	<2.9	650
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]		0.71	<0.69		<1.7	<0.77	1200
Half Moon Bay	Seaweed	2		<2.0			<3.9	<2.2	570
Marshside Sands	Samphire	1[F]		<0.07	<0.22		<0.53	<1.3	
Cockerham Marsh	Samphire	1[F]		<0.04	<0.11		<0.21	<0.35	
Scotland									
Aberdeen	Seaweed	1		<0.10	<0.12		<0.10	<0.10	<0.78
Wick	*Fucus vesiculosus*	1[F]		<0.05	<0.18		<0.36	<0.83	
Lerwick	Seaweed	1		<0.10	<0.13		<0.38	<1.5	
Cape Wrath	*Fucus vesiculosus*	1[F]		<0.05	<0.16		<0.16	<0.17	110
Lewis	Seaweed	1		<0.10	<0.11		<0.27	<0.82	4.4
Islay	Seaweed	1		<0.10	<0.10		<0.10	<0.10	
Campbeltown	Seaweed	1		0.15	<0.10		<0.10	<0.10	
Knock Bay	*Porphyra*	4[F]		<0.07	<0.20		<0.27	<0.38	
Knock Bay	*Porphyra*	1		<0.10	<0.33		<0.54	<0.91	
Port William	*Fucus vesiculosus*	4[F]		<0.18	<0.25		<0.27	<0.30	580
Port William	Seaweed	4		0.38	<0.20		<0.28	<0.47	910
Garlieston	*Fucus vesiculosus*	4[F]		0.77	<0.31		<0.36	<0.46	860
Garlieston	Seaweed	4		1.2	<0.20		<0.33	<0.26	980
Auchencairn	*Fucus vesiculosus*	4[F]		0.77	<0.26		<0.32	<0.40	1200
Auchencairn	Seaweed	4		0.86	<0.11		<0.12	<0.16	1400
Isle of Man	*Fucus vesiculosus*	4[F]		<0.15	<0.17		<0.27	<0.51	650
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]		<0.09	<0.26		<0.35	<0.54	280
Cemaes Bay	Seaweed	2		<2.4			<4.8	<2.9	730
Porthmadog	Seaweed	2		<2.0			<4.5	<2.5	48
Lavernock Point	*Fucus serratus*	2[F]		<0.06	<0.20		<0.30	<0.44	17
Fishguard	*Fucus vesiculosus*	1[F]		<0.11	<0.29		<0.34	<0.35	110
Fishguard	Seaweed	2		<3.0			<5.4	<2.7	130
South Wales, manufacturer A	Laverbread	4[F]		<0.07	<0.19		<0.28	<0.43	
South Wales, manufacturer C	Laverbread	4[F]		<0.11	<0.30		<0.53	<0.91	
South Wales, manufacturer D	Laverbread	4[F]		<0.08	<0.21		<0.33	<0.51	
South Wales, manufacturer E	Laverbread	1[F]		<0.11	<0.29		<0.50	<0.91	
Northern Ireland									
Portrush	*Fucus* spp.	4		<0.07	<0.20		<0.34	<0.57	
Strangford Lough	*Rhodymenia* spp.	3		<0.12	<0.38		<0.59	<1.0	24
Ardglass	*Ascophyllum nodosum*	1		<0.21	<0.54		<0.83	<1.3	
Ardglass	*Fucus vesiculosus*	3		<0.20	<0.54		<1.1	<1.5	310
Carlingford Lough	*Ascophyllum nodosum*	1		<0.07	<0.20		<0.26	<0.31	
Carlingford Lough	*Fucus* spp.	3		<0.13	<0.37		<0.63	<0.98	330
Isles of Scilly	*Fucus vesiculosus*	1[F]		<0.04	<0.12		<0.16	<0.24	1.6

Table 3.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu
Cumbria										
Silloth	Seaweed	2	<17	<2.8	<13	<2.2	8.4	<7.0		
Harrington Harbour	Seaweed	2	<12	<2.0	<9.7	<1.6	8.0	<5.5		
St Bees	*Fucus vesiculosus*[a]	4[F]	<1.4	<0.81	3.5	<0.07	4.9	<0.29	<0.19	<0.13
St Bees	*Porphyra*	4[F]	3.8	<0.15	1.2	<0.07	1.7	<0.35	<0.24	<0.15
St Bees	Seaweed	2	<14	<2.5	<11	<1.9	<4.1	<5.6		
Braystones South	*Porphyra*	4[F]	8.2	<0.20	1.6	<0.10	1.4	<0.41	<0.31	<0.17
Sellafield	*Fucus vesiculosus*	1[F]								
Sellafield	Seaweed	2	<15	<2.6	<12	<2.1	16	<6.6		
Seascale	*Porphyra*[b]	52[F]	<10	<0.51	<3.2	<0.30	1.4	<1.3	<0.89	<0.65
Rabbit Cat How	Samphire	1[F]	<0.78	<0.14	<0.17	<0.07	1.4	<0.41	<0.18	<0.15
Ravenglass	Seaweed	2	<22	<3.5	<20	<2.7	120	<8.1		
Lancashire										
Half Moon Bay	*Fucus vesiculosus*	4[F]	<2.0	<0.45	1.5	<0.17	5.3	<0.98	<0.42	<0.28
Half Moon Bay	Seaweed	2	<13	<2.3	<10	<1.9	7.2	<5.6		
Marshside Sands	Samphire	1[F]	<0.82	<0.16	<0.17	<0.07	0.73	<0.32	<0.21	<0.10
Cockerham Marsh	Samphire	1[F]	<0.42	<0.08	<0.10	<0.04	1.1	<0.20	<0.11	<0.08
Scotland										
Aberdeen	Seaweed	1	<0.29	<0.10	<0.10	<0.10	0.16	<0.20	<0.10	<0.10
Wick	*Fucus vesiculosus*	1[F]	<0.49	<0.12	<0.10	<0.05	0.13	<0.21	<0.17	<0.08
Lerwick	Seaweed	1	<0.29	<0.10	<0.10	<0.10	0.13	<0.22	<0.10	<0.10
Cape Wrath	*Fucus vesiculosus*	1[F]	<0.52	<0.11	<0.14	<0.07	0.75	<0.36	<0.19	<0.18
Lewis	Seaweed	1	<0.26	<0.10	<0.10	<0.10	0.33	<0.20	<0.10	<0.10
Islay	Seaweed	1	<0.24	<0.10	1.1	<0.10	0.19	<0.17	<0.10	<0.10
Campbeltown	Seaweed	1	<0.23	<0.10	0.47	<0.10	0.84	<0.17	<0.10	<0.13
Knock Bay	*Porphyra*	4[F]	<0.70	<0.14	<0.15	<0.07	0.27	<0.35	<0.23	<0.16
Knock Bay	*Porphyra*	1	<0.96	<0.13	<0.25	<0.10	0.48	<0.57	<0.12	<0.22
Port William	*Fucus vesiculosus*	4[F]	<0.79	<0.17	0.52	<0.10	1.6	<0.43	<0.29	<0.22
Port William	Seaweed	4	<0.51	<0.12	<0.79	<0.10	1.5	<0.35	<0.11	<0.19
Garlieston	*Fucus vesiculosus*	4[F]	<0.91	<0.20	0.79	<0.11	3.2	<0.46	<0.34	<0.22
Garlieston	Seaweed	4	<0.68	<0.13	2.2	<0.11	8.1	<0.36	<0.12	<0.31
Auchencairn	*Fucus vesiculosus*	4[F]	<0.80	<0.18	1.2	<0.10	4.3	<0.42	<0.28	<0.20
Auchencairn	Seaweed	4	<0.28	<0.10	1.7	<0.10	3.3	<0.19	<0.10	<0.11
Isle of Man	*Fucus vesiculosus*	4[F]	<0.56	<0.12	<0.30	<0.07	0.80	<0.33	<0.19	<0.16
Wales										
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.75	<0.17	<0.30	<0.09	1.1	<0.36	<0.28	<0.15
Cemaes Bay	Seaweed	2	<15	<2.6	<12	<2.0	<1.9	<6.5		
Porthmadog	Seaweed	2	<14	<2.4	<11	<1.8	<1.8	<6.3		
Lavernock Point	*Fucus serratus*	2[F]	<0.59	<0.13	<0.13	<0.07	0.42	<0.33	<0.22	<0.15
Fishguard	*Fucus vesiculosus*	1[F]	<1.1	<0.19	<0.25	<0.12	0.11	<0.56	<0.32	<0.25
Fishguard	Seaweed	2	<19	<3.3	<15	<2.5	<2.4	<8.0		
South Wales, manufacturer A	Laverbread	4[F]	<0.69	<0.12	<0.14	<0.06	0.11	<0.25	<0.19	<0.09
South Wales, manufacturer C	Laverbread	4[F]	<1.1	<0.21	<0.24	<0.11	<0.16	<0.48	<0.32	<0.19
South Wales, manufacturer D	Laverbread	4[F]	<0.77	<0.14	<0.16	<0.07	<0.07	<0.31	<0.22	<0.11
South Wales, manufacturer E	Laverbread	1[F]	<1.0	<0.19	<0.21	<0.11	0.34	<0.35	<0.31	<0.14
Northern Ireland										
Portrush	*Fucus* spp.	4	<0.65	<0.14	<0.16	<0.07	<0.08	<0.40	<0.21	<0.17
Strangford Lough	*Rhodymenia* spp.	3	<1.2	<0.24	<0.25	<0.12	0.70	<0.53	<0.40	<0.23
Ardglass	*Ascophyllum nodosum*	1	<2.1	<0.37	<0.44	<0.22	0.62	<0.71	<0.61	<0.28
Ardglass	*Fucus vesiculosus*	3	<1.9	<0.38	<0.39	<0.19	0.49	<0.76	<0.55	<0.27
Carlingford Lough	*Ascophyllum nodosum*	1	<0.71	<0.14	0.40	<0.08	0.49	<0.46	<0.23	<0.21
Carlingford Lough	*Fucus* spp.	3	<1.2	<0.25	<0.29	<0.15	0.98	<0.57	<0.40	<0.30
Isles of Scilly	*Fucus vesiculosus*	1[F]	<0.35	<0.08	<0.09	<0.04	0.07	<0.22	<0.13	<0.11

Table 3.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{238}Pu	$^{239}Pu+$ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+$ ^{244}Cm	Total beta
Cumbria									
Silloth	Seaweed	2				<3.1			
Harrington Harbour	Seaweed	2				7.6			
St Bees	*Fucus vesiculosus*[a]	4[F]	1.6	7.2		4.5	*	0.0089	
St Bees	*Porphyra*	4[F]	0.43	2.2	20	4.8	*	0.0054	180
St Bees	Seaweed	2				9.9			
Braystones South	*Porphyra*	4[F]	0.31	1.6	16	3.6	*	0.0078	
Sellafield	*Fucus vesiculosus*	1[F]	2.7	11		4.2	*	0.015	
Sellafield	Seaweed	2				31			
Seascale	*Porphyra*[b]	52[F]				4.4			
Rabbit Cat How	Samphire	1[F]				4.1			
Ravenglass	Seaweed	2				410			
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]				0.79			
Half Moon Bay	Seaweed	2				<2.4			
Marshside Sands	Samphire	1[F]				0.29			
Cockerham Marsh	Samphire	1[F]				0.65			25
Scotland									
Aberdeen	Seaweed	1				<0.11			
Wick	*Fucus vesiculosus*	1[F]				<0.05			
Lerwick	Seaweed	1				<0.10			
Cape Wrath	*Fucus vesiculosus*	1[F]				<0.18			
Lewis	Seaweed	1				<0.10			
Islay	Seaweed	1				0.11			
Campbeltown	Seaweed	1				0.23			
Knock Bay	*Porphyra*	4[F]				<0.28			
Knock Bay	*Porphyra*	1				0.88			
Port William	*Fucus vesiculosus*	4[F]				<0.54			
Port William	Seaweed	4				0.91			
Garlieston	*Fucus vesiculosus*	4[F]				2.6			
Garlieston	Seaweed	4				10			
Auchencairn	*Fucus vesiculosus*	4[F]				2.2			
Auchencairn	Seaweed	4				2.7			
Isle of Man	*Fucus vesiculosus*	4[F]				<0.25			
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]				0.16			
Cemaes Bay	Seaweed	2				<2.7			
Porthmadog	Seaweed	2				<2.6			
Lavernock Point	*Fucus serratus*	2[F]				<0.16			
Fishguard	*Fucus vesiculosus*	1[F]				<0.23			
Fishguard	Seaweed	2				<3.4			
South Wales, manufacturer A	Laverbread	4[F]				<0.09			
South Wales, manufacturer C	Laverbread	4[F]				<0.17			
South Wales, manufacturer D	Laverbread	4[F]				<0.08			79
South Wales, manufacturer E	Laverbread	1[F]				0.24			
Northern Ireland									
Portrush	*Fucus* spp.	4				<0.16			
Strangford Lough	*Rhodymenia* spp.	3	0.046	0.28		0.44	*	0.00093	
Ardglass	*Ascophyllum nodosum*	1				0.37			
Ardglass	*Fucus vesiculosus*	3				<0.15			
Carlingford Lough	*Ascophyllum nodosum*	1				<0.21			
Carlingford Lough	*Fucus* spp.	3				<0.26			
Isles of Scilly	*Fucus vesiculosus*	1[F]				<0.16			

* *Not detected by the method used*
[a] *The concentration of ^{129}I was 6.4 Bq kg^{-1}*
[b] *Counted wet*
[F] *Measurements are made on behalf of the environment agencies unless labelled "F". In that case they are made on behalf of the Food Standards Agency*

Table 3.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}											
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				0.82								
Newton Arlosh	Washed grass	1				0.31								
Newton Arlosh	Soil	1				18								
Sellafield 14[b]	Onions	1	<0.04	<0.19	<0.34	2.2	<0.41	<0.09	<0.04	<0.03	<0.22	<0.11	<0.08	<0.07
Sellafield 14[b]	Potatoes	1	<0.03	<0.14	<0.20	17	<0.31	<0.08	<0.03	0.21	<0.21	<0.10	<0.09	<0.09
Sellafield 14[b]	Runner Beans	1	<0.10	<0.81	<2.1	33	<1.1	<0.22	<0.11	<0.08	<0.58	<0.29	<0.22	<0.19
Sellafield 14[b]	Soil	1	34	<2.9	<3.2	5500	30	20	<0.86	82	<4.7	<2.0	<2.3	110
Sellafield 1674[b]	Beetroot	1	<0.06	<0.45	<1.0	73	<0.71	<0.15	<0.06	0.06	<0.36	<0.19	<0.13	<0.12
Sellafield 1674[b]	Spinach Beet	1	<0.13	<0.83	<1.8	1200	<1.4	<0.30	<0.13	0.30	<0.73	<0.37	<0.27	<0.26
Sellafield 1674[b]	Soil	1	<1.0	<3.8	<6.0	1300	<9.0	<2.4	<1.1	54	<4.8	<2.7	<2.1	4.7
Sellafield 1710[b]	Onions	1	<0.08	<0.56	<1.2	2.0	<0.93	<0.20	<0.09	0.11	<0.50	<0.22	<0.18	<0.16
Sellafield 1710[b]	Soil	1	1.6	<1.0	<0.83	1500	<4.4	<1.4	<0.60	53	<3.1	<1.4	<1.7	5.3
Hutton Marsh	Grass	1				0.27								
Hutton Marsh	Washed grass	1				0.27								
Hutton Marsh	Soil	1				24								

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

Table 3.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2005

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		3	<4.8	16	<0.29	0.043	<0.58	<0.44	<0.0051	<2.0	<0.58	<0.014
Milk	max		<5.0	17		0.055	<0.64	<0.46	<0.0053	<2.1	<0.63	<0.015
Apples		1	<5.0	16	<0.20	0.078	<0.50	<0.40	<0.027	<2.9	<0.70	<0.023
Barley		1	<7.0	83	<0.40	0.49	<0.50	<0.40	<0.024	<1.1	<0.80	<0.018
Blackberries		1	<4.0	14	<0.30	0.40	<0.50	<0.30	<0.023	<2.1	<0.50	<0.032
Beef kidney		1	18	23	<0.50	1.4	<0.90	<0.60	<0.064	<3.4	<1.3	<0.017
Beef liver		1	12	23	<0.30	0.076	<0.50	<0.30	<0.024	<2.3	<0.50	<0.023
Beef muscle		1	6.0	24	<0.30	0.0060	<0.30	<0.20	0.050	<1.4	<0.40	<0.035
Broad beans		1							<0.023			
Carrots		1	8.0	<3.0	<0.30	0.16	<0.40	<0.30	<0.025	<1.7	<0.60	<0.023
Cauliflower		1	<5.0	<3.0	<0.50	0.031	<0.50	<0.40	<0.026	<2.1	<0.60	<0.023
Honey		1	21	98	<0.20	0.023	<0.30	<0.30	<0.027	<1.5	<0.60	<0.014
Lettuce[e]		1							<0.032			
Pheasants		1	11	17	<0.30	0.010	<0.60	<0.40	<0.030	<2.0	<0.50	<0.042
Potatoes		1	<5.0	22	<0.30	0.026	<0.40	<0.30	<0.026	<1.8	<0.40	<0.033
Runner beans		1	<4.0	9.0	<0.40	0.065	<0.40	<0.30	<0.025	<2.3	<0.60	<0.025
Sheep muscle		2	<10	29	<0.35	0.017	<0.50	<0.30	<0.078	<2.1	<0.60	<0.023
Sheep muscle	max		15	33	<0.40	0.021			<0.11	<2.2	<0.70	<0.025
Sheep offal		2	<7.5	<19	<0.35	0.10	<0.70	<0.55	<0.026	<3.2	<0.80	<0.031
Sheep offal	max		<8.0	24	<0.40	0.14	<0.80	<0.60	<0.028	<3.5	<1.0	<0.043
Grass		2							<0.032			
Grass	max								0.037			

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}						
			Total Cs	^{144}Ce	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		3	0.16	<1.0		<0.00016	<0.00014	<0.031	<0.00019
Milk	max		0.23	<1.1		<0.00018	<0.00015		<0.00020
Apples		1	0.13	<1.0		<0.00030	0.00050	<0.056	0.00090
Barley		1	0.19	<0.90		0.00050	0.0034	<0.075	0.0043
Blackberries		1	0.18	<1.0		0.00040	0.0014	<0.057	0.0021
Beef kidney		1	4.2	<1.8		<0.00040	0.0026	<0.11	0.010
Beef liver		1	1.9	<1.0		0.012	0.071	0.51	0.089
Beef muscle		1	5.5	<0.60		<0.00030	0.00010	<0.058	<0.00020
Broad beans		1			<0.032				
Carrots		1	0.15	<0.80		<0.00020	0.00020	<0.059	<0.00020
Cauliflower		1	0.23	<1.2		0.00020	<0.00020	<0.061	<0.00020
Honey		1	0.22	<1.3		<0.00020	0.00030	<0.062	0.00050
Lettuce[e]		1			<0.033				
Pheasants		1	0.47	<0.80		<0.00020	0.00040	<0.046	0.00030
Potatoes		1	0.23	<1.0		<0.00030	<0.00020	<0.051	0.00040
Runner beans		1	0.16	<1.0		<0.00020	0.00030	<0.052	0.00070
Sheep muscle		2	4.4	<1.1		<0.00030	<0.00035	<0.083	<0.00025
Sheep muscle	max		8.1			<0.00040	<0.00040	<0.088	<0.00030
Sheep offal		2	1.2	<1.5		<0.00035	0.0014	<0.070	0.0033
Sheep offal	max		2.0			0.00040	0.0022	<0.079	0.0059
Soil[f]		1			48				

[a] Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given, the mean is also the maximum
[b] Except for milk where units are Bq l^{-1}
[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime
[d] The mean concentrations of ^{134}Cs and ^{137}Cs were <0.24 and <0.30 (max <0.31) Bq l^{-1}
[e] The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.015, <0.0010 and 0.017 Bq kg^{-1} respectively
[f] The concentrations of ^{234}U, ^{235}U and ^{238}U were 8.6, 0.33 and 8.3 Bq kg^{-1} respectively

Table 3.15. Concentrations of radionuclides in surface waters from West Cumbria, 2005

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
		^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	Total alpha	Total beta
Ehen Spit issue	4	430	<0.24	<0.11		<0.24	<0.52	<0.0093	<0.0075	<2.0	11
Seaburn sewer outfall	3	<4.7	<0.13	<0.033		<0.12	<0.11	<0.0087	<0.0050	<0.057	0.39
River Calder (downstream)	4	<4.4	<0.21	<0.048		<0.20	<0.18	<0.010	<0.0055	<0.038	<0.16
River Calder (upstream)	4	<4.0	<0.26	<0.032		<0.25	<0.21	<0.011	<0.0050	<0.043	<0.11
Braystones culvert	1	<4.0		<0.030	<4.0		<4.0	<0.0090	<0.0050		
Braystones pipe	1	4.1		<0.030	<4.0		<4.0	<0.010	<0.0050		
Wast Water	1	<4.0	<0.11				<0.10			0.030	0.25
Ennerdale Water	1	<4.0	<0.10				<0.08			<0.030	0.52
Devoke Water	1	<4.0	<0.13				<0.12			<0.020	0.25
Thirlmere	1	<4.0	<0.10				<0.10			<0.030	0.17

Table 3.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2005

Location	No. of sampling observations	Radioactivity concentration (dry), Bq kg^{-1}						
		^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Seascale SS 204	1	<0.98	<2.0	<1.0	400	1.1	6.2	8.8
Seascale SS 233	1	<0.98	6.8	<1.0	440	2.5	23	20
Seascale SS 209	1	<0.51	<2.0	<0.45	40	2.8	13	20
Seascale SS 232	1	<1.1	<2.0	<0.98	75	1.6	10	14
Seascale SS 231	1	<0.50	<2.0	<0.54	20	2.2	11	16
Whitehaven SS 201	1	<2.1	<2.0	<2.0	37	<0.63	1.5	2.8

Table 3.17. Individual radiation exposures, Sellafield, 2005

Exposed population group[a]	Exposure, mSv						
	Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Seafood consumers							
Local seafood consumers (habits averaged 2001-5)	0.46[d]	0.19	0.23	-	0.030	-	-
Local seafood consumers (habits for 2005)	0.44[e]	0.20	0.21	-	0.025	-	-
Whitehaven seafood consumers	0.008	0.008	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.031	0.014	-	-	0.017	-	-
Morecambe Bay seafood consumers	0.063	0.047	-	-	0.016	-	-
Fleetwood seafood consumers	0.019	0.019	-	-	-	-	-
Isle of Man seafood consumers	0.008	0.008	-	-	-	-	-
Northern Ireland seafood consumers	0.020	0.016	-	-	<0.005	-	-
North wales seafood consumers	0.015	0.009	-	-	0.006	-	-
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Other groups							
Ravenglass estuary, recreational use	0.036	-	-	-	0.023	0.013	-
Ravenglass estuary, nature warden	0.033	-	-	-	0.028	0.005	-
Fishermen handling nets or pots[c]	0.066	-	-	-	0.066	-	-
Bait diggers and shellfish[c] collectors	0.26	-	-	-	0.26	-	-
Ribble estuary houseboats	0.037	-	-	-	0.035	<0.005	-
Average beach occupancy in Cumbria	<0.005	-	-	-	<0.005	-	-
Local consumers at Ravenglass[b]	0.018	-	-	0.018	-	-	-
Local consumers of vegetables grown on land with seaweed added[b]	0.069	-	-	0.069	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.034	-	-	0.033	-	-	<0.005
Average consumer of locally grown food	0.011	-	-	0.011	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *The total dose due to nuclear industry discharges was 0.22 mSv*
[e] *The total dose due to nuclear industry discharges was 0.23 mSv*

4. RESEARCH ESTABLISHMENTS

This section considers the effects of discharges from research establishments that hold nuclear site licences.

The UKAEA operates the majority of such sites, with licensed nuclear sites at Harwell, Winfrith and Windscale in England, and at Dounreay in Scotland. Ownership of the sites at Dounreay, Harwell, Winfrith and Windscale were transferred from UKAEA to the NDA in April 2005 and the non-nuclear site at Culham will transfer to the NDA when operations cease. UKAEA currently operates the nuclear sites at Harwell, Winfrith and Windscale in England and Dounreay in Scotland on behalf of the NDA and at Culham on behalf of the European Fusion Development Agreement. All of the nuclear sites have reactors that are at different stages of decommissioning. Discharges of radioactive waste are largely related to decommissioning and decontamination operations and the nuclear related research that is undertaken. Tenants, or contractors, such as RWE NUKEM Limited carry out some of this work.

Regular monitoring of the environment was undertaken in relation to all UKAEA sites, which included the effects of discharges from neighbouring sites and tenants where appropriate, i.e. the Vulcan Naval Reactor Test Establishment (NRTE) adjacent to the Dounreay site, and GE Healthcare at Harwell. Windscale is adjacent to the BNG Sellafield site, therefore its discharges, which are negligible compared with Sellafield, are monitored and considered as part of the Sellafield monitoring programme.

Other research sites considered in this section are the Imperial College Reactor Centre, Imperial Chemical Industries plc, the Scottish Universities' Environmental Research Centre and Culham.

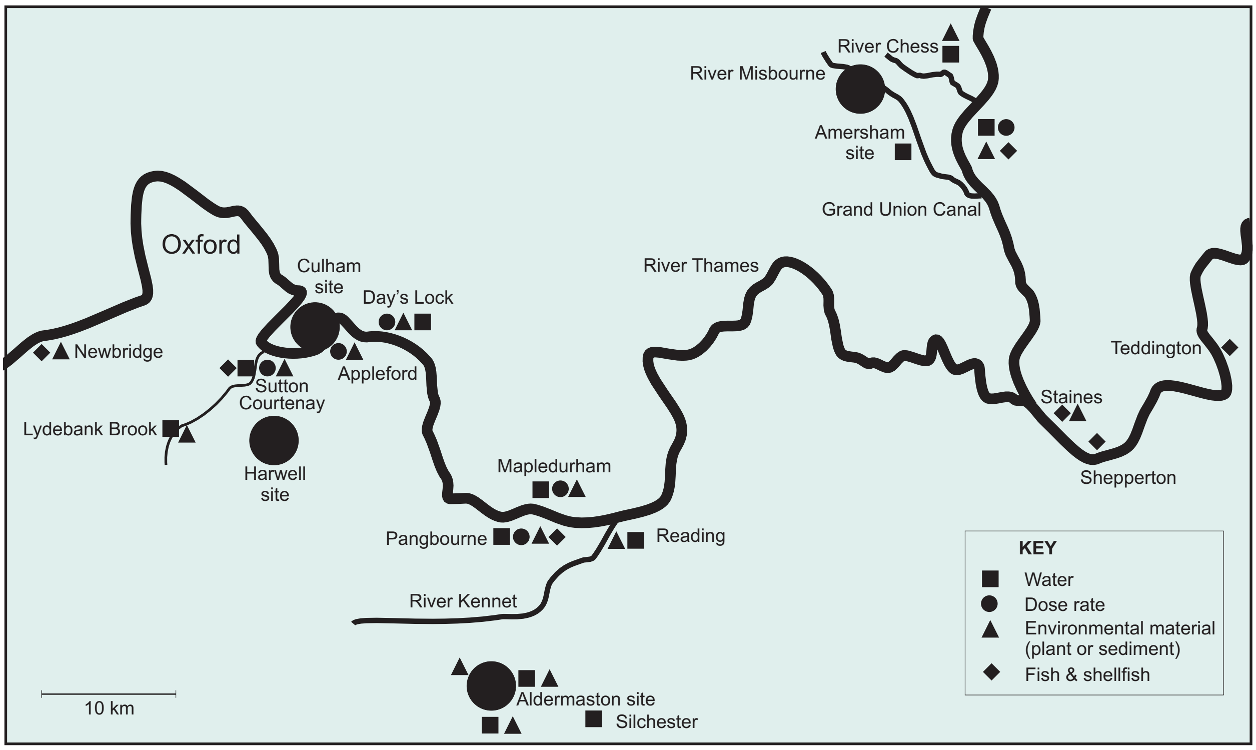


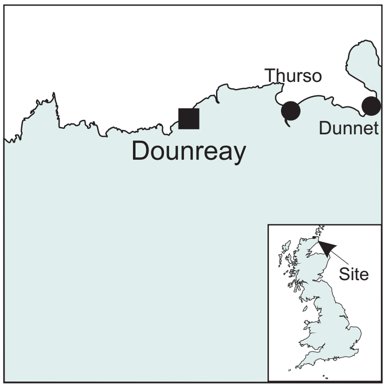
Figure 4.1 Monitoring locations at Thames sites (excluding farms)

4.1 Culham, Oxfordshire

Culham is home to an experimental fusion reactor, the Joint European Torus. Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2005. Locations and data are shown in Figure 4.1 and Table 4.1 respectively. The main effect of the site's operation was increased tritium found in grass collected near the site perimeter. Although the value found in 2005 was relatively high (180 Bq kg^{-1}), the concentration would be likely to have been transient due to the nature of the discharges. The Environment Agency will continue to monitor the situation in 2006. In the extreme, if all terrestrial foods were contaminated at the same concentration, the exposure of high-rate consumers would still have been less than 0.005 mSv.

The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but are due to discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986. The dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2005 was estimated to be much less than 0.005 mSv (Table 4.2).

4.2 Dounreay, Highland



Radioactive waste discharges from Dounreay are made by UKAEA under authorisations granted by the Scottish Environment Protection Agency. The quantities discharged in 2005 were generally similar to those in 2004 (Appendix 1). Radioactive waste discharges from the site also include a minor contribution from the adjoining reactor site (Vulcan NRTE), which the Defence Procurement Agency operates.

From April 2005, the NDA was formed which became responsible for the UK's civil nuclear liabilities that included those at UKAEA Dounreay. Following the formation of the NDA, UKAEA became a contractor to the NDA.

In common with other NDA sites, UKAEA has prepared a long term decommissioning plan known as the Lifecycle Baseline (LCBL). The LCBL is expanded into much greater detail for the first three years in to what is known as the Near Term Work Plan.

In 2005, SEPA consulted Scottish Ministers on the determination of an application by UKAEA to dispose of low level solid radioactive waste by transfer to the LLWR at Drigg. The Scottish Ministers directed SEPA to refuse this application. SEPA varied Dounreay's extant solid waste authorisation into a modern multi-media format which included improvement conditions such as the preparation of a plan for the carrying out of a Post Closure Safety Case for the low level waste pits.

In late 2005, UKAEA applied for authorisations for gaseous and liquid discharges for decommissioning however, this was withdrawn in early 2006.

In 2005, UKAEA reported to SEPA that inappropriate calibration of instrumentation used to measure gaseous radioactive discharges had resulted in the under-reporting of discharges for approximately five years. Following a formal investigation of this incident, SEPA issued an Enforcement Notice requiring corrective action and submitted a report to the Procurator Fiscals' Service. There is no evidence that any authorised discharge limits were broken as a result of this under reporting.

Following a number of notifications relating to gaseous discharges from the site, SEPA carried out a detailed inspection of the maintenance of gaseous discharge systems on the Dounreay site. As a result of this, an Enforcement Notice was issued containing 17 improvement items.

Operations in the Dounreay Cementation Plant continued to immobilise radioactive liquors resulting from historic re-processing of reactor fuels at Dounreay. This process results in cemented waste that is grouted into 500 litre steel containers. An incident in the Cementation plant during 2005 resulted in the spillage of a significant quantity of this liquor that was retained within a shielded cell. Although there was no release to the environment, the plant remained shut down for the remainder of the year whilst recovery plans were developed.

Work to construct the associated Dounreay Cementation Plant Import/Export facility, progressed. This plant will facilitate the handling of the containers of cemented liquors produced by the Dounreay Cementation Plant as well as allow the eventual repatriation of cemented wastes resulting from the reprocessing of fuels from overseas reactors.

The sodium disposal plant, which opened in 2002, was fully operational in 2005 and is progressing with the treatment of 1500 tons of sodium that was used as a coolant in the Prototype Fast Reactor. This work is expected to be complete by the end of 2006.

In addition to the planning and design work associated with implementing the LCBL, physical enabling works were carried out.

Monitoring conducted in 2005, included sampling of grass and soil and terrestrial foods including meat, vegetables and cereals. As there are no dairy herds in the Dounreay area no milk samples were collected. Routine marine monitoring included sampling of seafood around the Dounreay outfall in the North Atlantic and other materials from further afield. Beta and gamma dose rate measurements were also taken. Seafood samples from within the zone covered by a FEPA* order are collected under consent granted in 1998 by the Scottish Office. The results of the Scottish Environment Protection Agency's monitoring are presented in Tables 4.3(a) and (b).

During 2005, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by the Scottish Environment Protection Agency. In 2005 this requirement included the monitoring of Dunnet Beach for the first time.

At one of the beaches, monitoring for radioactive fragments is undertaken via an agreement between UKAEA Dounreay and the landowner. In 2005 access was withdrawn from April to June, and as a result no monitoring was undertaken in this period.

In 2005, five fragments were recovered from Sandside Bay and seven from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 11 kBq and 47 kBq. Surveys undertaken by divers during 2005 identified 83 fragments on the offshore seabed, all of which were recovered.

In 2005, in accordance with the authorisation issued by the Scottish Environment Protection Agency, UKAEA monitored the beach at Dunnet for the presence of radioactive particles. During this survey UKAEA detected and recovered a piece of contaminated plastic and a single radioactive fragment with activities of 20 kBq and 8.9 kBq caesium-137, respectively.

In 2005, UKAEA deployed a remotely operated survey vehicle to assist with demarcation of the extent of contamination of the marine environment. In 2006 further monitoring will occur to provide more information on the extent of the contamination of the environment.

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* *The FEPA order was made in 1997 following the discovery of 34 fragments of irradiated nuclear fuel on the seabed near Dounreay, by UKAEA, and prohibits the harvesting of seafoods within a 2 km radius of the discharge pipeline.*

The offshore work provided data on repopulation rates of particles to areas of the seabed previously cleared of particles. This work has improved the understanding of particle movements in the marine environment. The current state of knowledge is described in the Dounreay Particles Advisory Group's (DPAG)* Third Interim Report, which will be available on the Scottish Environment Protection Agency's website (Dounreay Particles Advisory Group, 2006).

The Scottish Environment Protection Agency commissioned the National Radiological Protection Board (NRPB) (now the Radiation Protection Division of HPA) to undertake a re-assessment of potential health effects of particles. The scientific work assessing the probability of encountering a particle and the potential hazard was completed in summer 2005 and is available on the Scottish Environment Protection Agency's website (http://www.sepa.org.uk/radioactivity/dounreay/particles.htm).

The marine monitoring programme relates to the existence of four potential exposure pathways at Dounreay. Details are given in Appendix 4. The characteristics of the pathways were revised in 2003, with the results from a local habits survey.

The first potential pathway involves the internal exposure of consumers of locally collected fish and shellfish. Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. Concentrations of radionuclides in 2005 were generally similar to those for 2004. Technetium-99 in seaweed remained at the expected levels for this distance from Sellafield. The estimated dose from consumption of fish and shellfish by high-rate consumers was less than 0.005 mSv or less than 0.5% of the annual dose limit for members of the public of 1 mSv (Table 4.2).

The second potential pathway relates to external exposure over local beaches. Gamma dose rates measured over intertidal areas were close to or less than those measured in previous years. The radiation dose due to occupancy in such areas was 0.007 mSv, which was less than 1% of the annual dose limit for members of the public of 1 mSv.

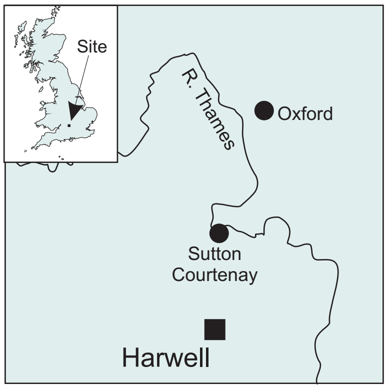
The third potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore. Monitoring of spume at Oigin's Geo and measurements of gamma dose rates above areas of the foreshore remained similar to those for 2004. The radiation dose to the public from these rocky areas was less than 0.005 mSv, which was less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The fourth potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a radiation dose to the skin of the hands and forearms of fishermen, mainly from beta radiation. The critical group is represented by a small number of people who operate a fishery close to Dounreay. The measurements in 2005 gave results less than the LoD, so the estimate of dose based on these LoDs was of no radiological significance.

The results for terrestrial samples and radioactivity in air are given in Table 4.3(a) and (c) and generally show low levels of radioactivity. Low levels of strontium-90, caesium-137, europium-155, uranium, plutonium and americium-241 were reported in samples. The dose to the critical group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.04 mSv, which was less than 4% of the annual dose limit for members of the public of 1 mSv. The estimated dose in 2004 was 0.008 mSv. The increase in dose was largely attributable to increases in the LoD for iodine-129 analysis. The contribution from this analysis accounted for approximately 75% of the dose. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

** DPAG was set up in 2000 to provide independent advice to Scottish Environment Protection Agency and UKAEA on issues relating to the Dounreay fragments.*

4.3 Harwell, Oxfordshire



Discharges of radioactive wastes from Harwell continued in 2005 under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere. The Environment Agency launched a public consultation in February 2004 to consider an application by one of the tenants on the site, Amersham plc, to vary its authorisations for disposal of radioactive waste. Further details are provided in Section 7.

The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish, water and indicator materials together with measurements of gamma dose rates close to the liquid discharge point. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 4.1. Monitoring of the aquatic environment at Newbridge (upstream of the site) is undertaken as a control site to indicate background levels remote from nuclear establishments.

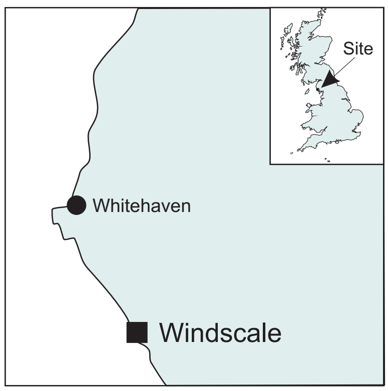
The results of measurements of radioactivity concentrations and dose rates are shown in Tables 4.4(a) and (b).

Concentrations of caesium-137 were enhanced close to the outfall for liquid discharges at Sutton Courtenay but the levels were small in terms of any radiological effect. The concentrations of most radionuclides in local pike were below the LoD; only caesium-137 was positively detected. The concentration of caesium-137 in pike (0.37 Bq kg^{-1}) at Sutton Courtenay was similar to that in 2004, following a continuing decline in recent years (1999: 7.4 Bq kg^{-1}; 2000: 3.0 Bq kg^{-1}; 2001: 1.7 Bq kg^{-1}, 2002 and 2003: 0.53 Bq kg^{-1} and 2004: 0.21 Bq kg^{-1}). Concentrations of transuranic elements were similar to those in 2004.

Habits surveys have identified anglers as the critical group affected by direct discharges into the river. Their occupancy of the riverbank has been assessed to estimate their external exposures. Consumption of indigenous freshwater fish was not found to occur, but it is considered prudent to include a component in the assessment of the angler's exposure. A consumption rate of 1 kg $year^{-1}$ was selected. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 2005 was 0.012 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv (Table 4.2). Thames river water is used as a source of drinking water. The annual dose from drinking River Thames water downstream of the discharge point was much less than 0.005 mSv.

The results of tritium and gamma-ray spectrometry analyses of terrestrial food samples were all below detection limits. The dose to the critical group of terrestrial food consumers was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

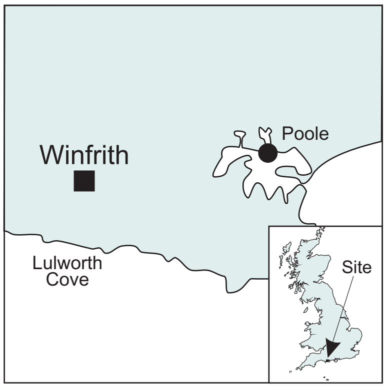
4.4 Windscale, Cumbria



This site, which is operated by the UKAEA, adjoins the north part of the BNGSL Sellafield site. Most of the radioactive wastes derive from decontamination and decommissioning operations, some of which are of the early Windscale reactor buildings. Gaseous wastes are authorised from specific stacks on the Windscale site; liquid radioactive wastes are disposed by authorised transfer to the BNGSL Sellafield site, whence they are discharged after appropriate treatment to the Irish Sea via the Sellafield pipelines. The liquid discharges are included as part of the authorised Sellafield discharges (Table A1.1). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from BNGSL Sellafield. Disposals of radioactive wastes from Windscale were subject to ongoing review and consultation by the Environment Agency in 2005 (Environment Agency, 2002b; Environment Agency, 2005d).

Regular monitoring of the environment by the Environment Agency and the Food Standards Agency is carried out as part of the overall programme for the Sellafield site. The results of this monitoring and the implications in terms of dose to critical groups are described in Section 3.3.

4.5 Winfrith, Dorset



Discharges of radioactive wastes from this site continued in 2005, at the low rates typical of recent years. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. Gaseous wastes are disposed of from various stacks on site.

Public consultations were held by the Environment Agency, between 4 July and 30 September 2005, to consider applications by the UKAEA and Waste Management Technology Ltd (WMTL) for authorisations to dispose of radioactive waste (Environment Agency, 2005e). The UKAEA application included a requirement to discharge radioactive aqueous liquid and gaseous waste from its facilities on the Winfrith site. It also included the transfer of radioactive intermediate level solid waste to UKAEA, Harwell, radioactive organic liquid waste to Shanks Chemical Services in Hampshire, low level radioactive solid waste to the LLWR at Drigg in Cumbria and also very low level radioactive waste to landfill. The WMTL application included a requirement to discharge radioactive gaseous waste from its facilities on the Winfrith Nuclear site, Dorset. It also included the transfer of low level radioactive solid and radioactive aqueous liquid waste to UKAEA at Winfrith, radioactive solid waste to UKAEA, Windscale in Cumbria, low level radioactive solid and radioactive organic liquid waste to Shanks Chemical Services in Hampshire and radioactive low level solid waste to the LLWR at Drigg in Cumbria. The Environment Agency decided to grant revised variations to UKAEA and WMTL and these came into effect on 23 March 2006 (Environment Agency, 2006a and b).

The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and environmental materials.

Data are presented in Tables 4.5(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. Low levels of tritium were found in surface water to the north of the site, similar to previous years. In all cases the gross alpha and gross beta activities were below the WHO's screening values for drinking water. The critical group for gaseous discharges was terrestrial food consumers who were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 4.2). Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Concentrations of radionuclides in the marine environment largely continued at the low levels found in recent years. Gamma dose rates were difficult to distinguish from natural background. The radiation dose to the critical group of fish and shellfish consumers, including a contribution from external exposure, remained low in 2005 at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public.

4.6 Minor sites

Three minor sites with very low levels of discharge are monitored using a small sampling programme of environmental materials. The results, given in the following sections, show that there was no detected impact on the environment in 2005 due to operation of these sites.

4.6.1 Imperial College Reactor Centre, Ascot, Berkshire

The Environment Agency issued a revised authorisation which took effect on 1st December 2004 (Environment Agency, 2004b). This followed public consultation on an application received from the Imperial College of Science, Technology and Medicine principally to reduce the aqueous and gaseous discharge limits (Environment Agency, 2004c). The reductions as implemented now minimise the headroom between limits and actual discharges from the site.

The discharges are very low and the environmental monitoring of their effects comprises sampling of grass. Two grass samples were analysed by gamma-ray spectrometry. Both sets of results in 2005 were less than the limits of detection.

4.6.2 Imperial Chemical Industries plc, Billingham, Cleveland

The reactor at this site ceased operation on 28 June 1996. The demolition of the facility and the ancillary buildings was completed in June 2003. HSE signed the revocation of the licence for the reactor on 25 November 2005 (Health and Safety Executive, 2005a). The Environment Agency revoked the authorisations under the Radioactive Substances Act 1993 for the nuclear site in December 2005.

In previous years, analysis of grass samples, by gamma-ray spectrometry, indicated levels below the limits of detection.

4.6.3 Scottish Universities' Environmental Research Centre, South Lanarkshire

The small research reactor at this site has been decommissioned and the waste disposed of under the authorisations granted by the Scottish Environment Protection Agency in 2001 for decommissioning. The site continues to hold a nuclear site licence. Routine laboratory work continues at the site, resulting in the authorised disposal of small quantities of radioactive substances. The Scottish Environment Protection Agency has received applications to amend the operational authorisations in line with current work.

Table 4.1. Concentrations of radionuclides in the environment near Culham, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Total alpha	Total beta
Freshwater	River Thames (upstream)	2	<4.0				<0.17	<0.095	<0.19
Freshwater	River Thames (downstream)	2	<4.0				<0.26	<0.037	0.33
Grass	1 km west of site perimeter	1	180	<25	<1.0	<0.50	<1.3		180
Sediment	River Thames (upstream)	2					5.2		
Sediment	River Thames (downstream)	2					36		
Soil	1 km west of site perimeter	1	<25	<25	21	<2.0	5.5		510

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

Table 4.2. Individual radiation exposures – research sites, 2005

Site	Exposed population group[a]	Exposure, mSv				
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water
Culham	Drinkers of river water	<0.005	-	-	-	<0.005
Dounreay	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.007	-	-	0.007	-
	Geo occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food[c]	0.040	-	0.040	-	-
Harwell	Anglers	0.012	<0.005	-	0.012	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Winfrith	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Children aged 10y*

Table 4.3(a). Concentrations of radionuclides in food and the environment near Dounreay, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			^{3}H	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb	^{137}Cs
Marine samples													
Crabs	Pipeline	4		<0.12	<0.37	0.42	<1.2	<5.3	2.5	<1.3	<0.16	<0.31	<0.12
Crabs	Pipeline inner zone	4		<0.12	<0.41		<1.3	<5.4		<1.3	<0.16	<0.30	<0.11
Crabs	Strathy	4		<0.10	<0.25		<0.31	<0.39		<0.81	<0.10	<0.22	<0.10
Crabs	Kinlochbervie	4		<0.10	<0.19		<0.25	<0.28	1.2	<0.76	<0.10	<0.21	<0.11
Crabs	Melvich Bay	4		<0.11	<0.29		<0.38	<0.46	0.86	<0.94	<0.11	<0.26	<0.11
Winkles	Brims Ness	4		<0.20	<0.29	<0.10	<0.40	<0.54		<1.0	<0.12	<0.26	<0.11
Winkles	Sandside Bay	4		<0.11	<0.30	<0.10	<0.43	<0.54	6.3	<1.0	<0.12	<0.28	<0.18
Mussels	Echnaloch Bay	3		<0.10	<0.22		<0.30	<0.43	14	<0.71	<0.10	<0.19	<0.10
Fucus vesiculosus	Kinlochbervie	2		<0.10	<0.22		<0.24	<0.28	130	<0.60	<0.10	<0.29	0.34
Fucus vesiculosus	Brims Ness	4		<0.10	<0.16		<0.18	<0.19		<0.41	<0.10	<0.14	<0.11
Seaweed	Sandside Bay	4		<0.10	<0.14		<0.14	<0.19	250	<0.35	<0.10	<0.12	<0.17
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.15		<0.17	<0.23	43	<0.34	<0.10	<0.12	<0.13
Sediment	Oigins Geo	3		<0.40	<0.99		<1.5	<3.5		<2.9	<0.47	<0.84	20
Sediment	Brims Ness	1		<0.10	<0.22		<0.15	<0.14		<0.54	<0.10	<0.17	1.6
Sediment	Sandside Bay	2		<0.10	<0.23		<0.14	<0.14		<0.59	<0.10	<0.18	3.3
Sediment	Rennibister	2		<0.10	<0.27		<0.34	<0.50		<0.69	<0.10	<0.21	12
Seawater	Brims Ness	3	<1.0	<0.10	<0.13		<0.15	<0.20		<0.35	<0.10	<0.12	<0.10
Seawater	Sandside Bay	4	<1.0	<0.10	<0.11		<0.13	<0.18		<0.28	<0.10	<0.10	<0.10
Spume	Oigins Geo	1		<0.10	<0.22		<0.84	<0.36		<0.63	<0.10	<0.19	4.9

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Marine samples										
Crabs	Pipeline	4	<0.85	<0.16	<0.30	0.0053	0.021	<0.17	2.9	86
Crabs	Pipeline inner zone	4	<0.79	<0.15	<0.27			<0.15		
Crabs	Strathy	4	<0.53	<0.12	<0.22	<0.0015	0.012	<0.12		
Crabs	Kinlochbervie	4	<0.49	<0.12	<0.21	<0.0012	0.0072	<0.0071		
Crabs	Melvich Bay	4	<0.57	<0.13	<0.24	<0.0015	0.0029	0.0033		
Winkles	Brims Ness	4	<0.63	<0.14	<0.26	0.035	0.16	0.25		
Winkles	Sandside Bay	4	<0.70	<0.15	<0.28	0.030	0.14	0.22		
Mussels	Echnaloch Bay	3	<0.46	<0.11	<0.20	0.0042	0.021	0.013		
Seaweed	Kinlochbervie	2	<0.37	<0.11	<0.16			<0.12		
Fucus vesiculosus	Brims Ness	4	<0.28	<0.11	<0.15			<0.12	<2.1	190
Seaweed	Sandside Bay	4	<0.23	<0.10	<0.13			<0.22	<1.9	330
Fucus vesiculosus	Burwick Pier	4	<0.24	<0.11	<0.14			<0.13		
Sediment	Oigins Geo	3	<2.2	<0.77	<1.1	2.5	9.8	4.8		
Sediment	Brims Ness	1	<0.51	0.27	<0.21	2.1	8.8	8.6		
Sediment	Sandside Bay	2	<0.54	<0.24	<0.24	1.3	5.4	5.6		
Sediment	Rennibister	2	<0.65	<0.15	0.91	0.092	0.63	0.27		
Seawater	Brims Ness	3	<0.24	<0.10	<0.13			<0.10		
Seawater	Sandside Bay	4	<0.18	<0.10	<0.10			<0.10		
Spume	Oigins Geo	1	<0.64	<0.15	0.99	2.7	11	42		

Table 4.3(a). continued

Material	Location or Selection[b]	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs
Terrestrial samples											
Barley		1	<5.0	<0.05	1.1		<0.06	<0.40	<0.91	<0.05	0.05
Beef muscle		1	<5.0	<0.05	<0.10	<0.26	<0.29	<0.46	<1.1	<0.05	0.08
Beef offal		1	<5.0	<0.05	<0.10	<0.22	<0.34	<0.42	<1.8	<0.05	<0.05
Blackberries		1	8.3	<0.05	<0.10	<0.05	<0.05	<0.24	<0.84	<0.05	0.25
Cabbage		1	<5.0	<0.07	1.1	<0.22	<0.24	<0.65	<0.89	<0.07	0.20
Potatoes		1	<5.0	<0.05	<0.10	<0.07	<0.07	<0.20	<0.88	<0.05	0.53
Rabbit		2	<5.0	<0.12	<0.10	<0.31	<0.33	<1.1	<1.7	<0.11	<0.18
	max			<0.13		<0.36	<0.37	<1.2		<0.12	0.23
Rosehips		2	<5.4	<0.05	<0.15	<0.09	<0.07	<0.29	<0.85	<0.05	1.4
	max		5.7		0.20	<0.12	<0.10	<0.42	<0.86		2.7
Rowan berries		1	<5.0	<0.05	<0.10		<0.07	<0.29	<0.72	<0.05	0.63
Sheep muscle		1	<5.0	<0.05	<0.10	<0.28	<0.50	<0.48	<1.2	<0.05	0.38
Turnips		1	<5.0	<0.05	0.24	<0.14	<0.15	<0.38	<0.74	<0.05	<0.05
Grass		6	<5.0	<0.05	0.66	<0.12	<0.14	<0.31	<0.18	<0.05	<0.13
Grass	max				0.97	<0.17	<0.19	<0.45	<0.20		0.20
Soil		6	<5.8	<0.06	2.3	<0.25	<0.26	<0.54	<0.034	<0.07	21
Soil	max		9.5	<0.08	3.8	<0.29	<0.43	<0.68	<0.048	<0.09	33

Material	Location or Selection[b]	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{144}Ce	^{234}U	^{235}U	^{238}U	^{238}Pu	^{240}Pu	^{239}Pu+ ^{241}Am
Terrestrial samples									
Barley		1	<0.31				<0.050	<0.050	<0.050
Beef muscle		1	<0.30	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Beef offal		1	<0.31	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Blackberries		1	<0.18				<0.050	<0.050	<0.050
Cabbage		1	<0.41				<0.050	<0.050	<0.050
Potatoes		1	<0.14				<0.050	<0.050	<0.050
Rabbit		2	<0.64						<0.17
	max		<0.71						<0.18
Rosehips		2	<0.20				<0.050	<0.050	<0.050
	max		<0.27						
Rowan berries		1	<0.23				<0.050	<0.050	<0.050
Sheep muscle		1	<0.36	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Turnips		1	<0.27				<0.050	<0.050	<0.050
Grass		6	<0.21	0.12	<0.027	0.12	<0.050	<0.050	<0.050
Grass	max		<0.29	0.36	<0.050	0.35			
Soil		6	<0.54	31	1.7	28	<0.053	0.40	0.31
Soil	max		<0.61	48	3.2	43	0.065	0.51	0.63

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

[b] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima*
If no 'max' value is given the mean value is the most appropriate for dose assessments

Table 4.3(b). Monitoring of radiation dose rates near Dounreay, 2005

Location	Material or ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.073
Sandside Bay	Winkle bed	3	0.11
Oigin's Geo	Spume/sludge	4	0.15
Brims Ness	NA	2	0.084
Melvich	Salt Marsh	2	0.059
Melvich	Sand	2	0.055
Strathy	Sand	2	0.055
Thurso	Riverbank	2	0.087
Achreregan Hill	Soil	2	<0.047
Thurso Park	Soil	2	0.072
Borrowston Mains	Soil	2	0.078
East of Dounreay	Soil	2	0.072
Castletown Harbour	NA	2	0.076
Dunnet	NA	2	0.054
Mean beta dose rates			μSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Brims Ness	Surface sediment	1	<1.0
Thurso	Riverbank	2	<1.0
Castletown Harbour	Surface sediment	2	<1.0

NA Not available

Table 4.3(c). Radioactivity in air near Dounreay, 2005

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Shebster	10	<0.010	<0.0048	<0.098
Reay	10	<0.010	<0.0075	<0.12
Balmore	12	<0.010	<0.0071	<0.13

Table 4.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{57}Co	^{60}Co	^{137}Cs	^{238}Pu
Freshwater samples								
Pike	Outfall (Sutton Courtenay)	1	<25	<25	<0.03	<0.04	0.37	
Pike	Newbridge	1	<25	<25	<0.07	<0.11	<0.10	0.000023
Pike	Staines	1	<25	<25	<0.04	<0.06	0.10	
Pike	Shepperton	1	<25	<25	<0.04	<0.05	0.13	
Pike	Teddington	1	<25	<25	<0.03	<0.04	0.14	
Flounder	Beckton	1		<25	<0.06	<0.14	0.37	
Nuphar lutea	Newbridge	1		<25	<0.03	<0.06	0.10	
Nuphar lutea	Staines	1		<25	<0.03	<0.06	<0.05	
Sediment	Appleford	4[E]				<2.1	<11	<0.56
Sediment	Outfall (Sutton Courtenay)	4[E]				<0.46	9.8	<0.64
Sediment	Day's Lock	4[E]				<0.49	3.1	<0.70
Sediment	Lydebank Brook	4[E]				<1.5	8.2	<0.76
Freshwater	Day's Lock	4[E]		<4.0		<0.28	<0.24	
Freshwater	Lydebank Brook	4[E]		<4.1		<0.33	<0.27	
Freshwater	R Thames (above discharge point)	4[E]		<4.0		<0.31	<0.25	
Freshwater	R Thames (below discharge point)	4[E]		<4.0		<0.25	<0.21	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Freshwater samples								
Pike	Outfall (Sutton Courtenay)	1		<0.04				
Pike	Newbridge	1	0.00020	0.00023	*	*		
Pike	Staines	1		<0.07				
Pike	Shepperton	1		<0.06				
Pike	Teddington	1		<0.11				
Flounder	Beckton	1		<0.09				
Nuphar lutea	Newbridge	1		<0.05				
Nuphar lutea	Staines	1		<0.04				
Sediment	Appleford	4[E]	<0.24	1.3			<170	290
Sediment	Outfall (Sutton Courtenay)	4[E]	1.5	2.2			<180	<270
Sediment	Day's Lock	4[E]	0.48	0.88			<180	<130
Sediment	Lydebank Brook	4[E]	0.85	1.2			180	380
Freshwater	Day's Lock	4[E]					<0.045	0.57
Freshwater	Lydebank Brook	4[E]					<0.042	0.48
Freshwater	R Thames (above discharge point)	4[E]					<0.035	0.38
Freshwater	R Thames (below discharge point)	4[E]					<0.035	0.34

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}		
			Organic ^{3}H	^{3}H	^{137}Cs
Terrestrial samples					
Milk		4	<4.5	<4.5	<0.28
Milk	max		<5.0	<5.0	<0.30
Apples		1	<5.0	<5.0	<0.30
Blackberries		1	<5.0	<5.0	<0.40
Cabbage		1	<4.0	<4.0	<0.20
Honey		1		<7.0	<0.30
Parsnips		1	<4.0	<4.0	<0.30
Potatoes		1	<5.0	<5.0	<0.30

* *Not detected by the method used*

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 4.4(b). Monitoring of radiation dose rates near Harwell, 2005

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Mud	1	0.068
Appleford	Grass and mud	1	0.069
Sutton Courtenay	Grass and mud	1	0.078
Sutton Courtenay	Grass	1	0.085
Day's Lock	Grass and mud	1	0.071
Day's Lock	Grass and sand	1	0.065

Table 4.5(a). Concentrations of radionuclides in food and the environment near Winfrith, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples									
Plaice	Weymouth Bay	2		<0.04	<0.12		0.09		
Bass	Weymouth Bay	2		<0.05	<0.19		0.23		
Crabs	Chapman's Pool	1		0.15	<0.13		<0.05	0.000086	0.00042
Crabs	Lulworth Banks	1	32	<0.07	<0.15		<0.05	0.00015	0.00076
Pacific Oysters	Poole	1		<0.12	<0.33		<0.09		
Cockles	Poole	1		0.25	<0.13		<0.04		
Whelks	Poole Bay	1		0.16	<0.12		<0.04	0.00051	0.0026
Whelks	Lyme Regis	1		<0.07	<0.24		<0.06	0.00022	0.0017
Scallops	Lulworth Ledges	1		<0.05	<0.13		<0.05	0.00031	0.0024
Clams	Portland Harbour	1		0.18	<0.28		0.08		
Fucus serratus	Kimmeridge	2		0.33	<0.23	0.33	<0.07		
Fucus serratus	Bognor Rock	2		0.12	<0.20	0.64	<0.06		
Seaweed	Lulworth Cove	2[E]		<2.1		<1.0	<1.7		
Seawater	Lulworth Cove	2[E]		<0.32			<0.25		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples							
Plaice	Weymouth Bay	2	<0.12				
Bass	Weymouth Bay	2	<0.19				
Crabs	Chapman's Pool	1	0.0010	*	0.000017		
Crabs	Lulworth Banks	1	0.0013	*	0.000052		
Pacific Oysters	Poole	1	<0.09				
Cockles	Poole	1	<0.05				
Whelks	Poole Bay	1	0.0029	*	0.000025		
Whelks	Lyme Regis	1	0.0017	*	0.000026		
Scallops	Lulworth Ledges	1	0.00049	*	*		
Clams	Portland Harbour	1	<0.07				
Fucus serratus	Kimmeridge	2	<0.28				
Fucus serratus	Bognor Rock	2	<0.06				
Seaweed	Lulworth Cove	2[E]	<2.5				
Seawater	Lulworth Cove	2[E]	<0.45			<2.8	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		4	<4.8	<4.8	14	<0.28	<0.29		
Milk	max		<6.0	<6.0	15	<0.33	<0.30		
Apples		1	<5.0	<5.0	19	<0.30	<0.30		
Blackberries		1	<4.0	<4.0	14	<0.40	<0.30		
Cabbage		1	<4.0	<4.0	<3.0	<0.40	<0.30		
Carrots		1	<4.0	<4.0	9.0	<0.30	<0.30		
Honey		1		<7.0	120	<0.20	0.30		
Potatoes		1	<5.0	<5.0	23	<0.50	<0.40		
Grass		2	<9.0	<5.5	21	<0.45	<0.45		
Grass	max			<6.0	25	<0.50	<0.60		
Sediment	North of site (Stream A)	2[E]				<0.52	14	<130	<220
Sediment	R Frome (upstream)	2[E]				<0.80	<1.3	<230	<210
Sediment	R Frome (downstream)	2[E]				<0.85	9.1	310	420
Sediment	R Win, East of site	2[E]				<0.69	<1.6	210	<170
Freshwater	North of site (Stream A)	2[E]		13		<0.29	<0.24	0.030	0.16
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.31	<0.25	<0.056	0.16
Freshwater	R Frome (downstream)	2[E]		<4.0		<0.31	<0.25	<0.031	<0.10
Freshwater	R Win, East of site	2[E]		<4.0		<0.30	<0.25	0.049	0.17

** Not detected by the method used*

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 4.5(b). Monitoring of radiation dose rates near Winfrith, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Pebbles and shingle	1	0.060
Red Cliffe Point to Black Head	Pebbles and shingle	1	0.072
St Oswald's Head	Pebbles and shingle	1	0.055
Ringstead Bay	Shingle	1	0.070
Durdle Door	Pebbles	1	0.053
Lulworth Cove	Shingle	1	0.077
Kimmeridge Bay	Pebbles and rock	1	0.087
Swanage Bay 1	Sand	1	0.057
Swanage Bay 2	Sand	1	0.061
Swanage Bay 3	Sand	1	0.061
Poole Harbour	Sand	1	0.058

5. NUCLEAR POWER STATIONS

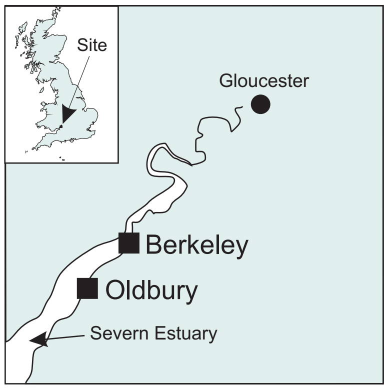
This section considers the effects of discharges from nuclear power stations during 2005. There are a total of 19 nuclear power stations at 14 locations, nine in England (Berkeley, Oldbury, Bradwell, Calder Hall, Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell) two in Wales (Trawsfynydd and Wylfa) and three in Scotland (Chapelcross, Hunterston and Torness). Eleven of the 19 are older Magnox power stations now owned by the NDA. They are operated by Magnox Electric* (a wholly owned subsidiary of BNG) on behalf of the NDA. In 2005, seven of these Magnox stations were in the process of decommissioning, whilst four continued to generate electricity. Discharges from one of the Magnox stations at Calder Hall are considered in Section 3 because it is located at Sellafield. British Energy Generation Ltd and British Energy Generation (UK) Ltd operate a more modern fleet of seven advanced gas-cooled reactor (AGR) power stations and one PWR power station. All of these were generating electricity during 2005. From April 2005, the NDA was formed which became responsible for the UK's civil nuclear liabilities. Following the formation of the NDA, BNG became a contractor to the NDA.

In October 2005, Defra issued a consultation, concerning its draft decision document for applications by BNFL, to dispose of or accumulate radioactive wastes on or from eight Magnox sites and the Environment Agency's decisions and recommendations with regard to the applications (Department for Environment, Food and Rural Affairs, 2005e).

Estimates of dose discussed in this section (and summarised in Table 5.1) do not include a component from direct radiation from the site. The sites are grouped in the section according to whether they are in England, Scotland or Wales.

ENGLAND

5.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station ceased electricity generation in March 1989, but radioactive wastes have been and are still generated by decommissioning operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples. 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.

A habit survey has established that the two potentially critical pathways for public radiation exposure in the aquatic environment were internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of seafood were analysed and gamma dose rates are monitored. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from the GE Healthcare radiopharmaceutical plant in Cardiff (see Section 7). In addition, measurements of external exposure are supported by analyses of intertidal mud. The main focus for terrestrial sampling was on the tritium, carbon-14 and sulphur-35 content of milk, crops and fruit. Local surface water samples were also taken and analysed.

** British Nuclear Group run the Magnox stations under contract to NDA as of 1st April 2005.*

5. Nuclear power stations

Data for 2005 are presented in Tables 5.2(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were generally similar to those in recent years. Most of the artificial radioactivity detected was due to tritium and radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have remained the same for the last decade (Figure 5.1). Relatively high concentrations of tritium were detected in fish and shellfish and these were likely to be mainly due to discharges from GE Healthcare, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. The total dose to the critical group of fish and shellfish consumers was estimated to be 0.010 mSv, which was 1% of the dose limit for members of the public of 1 mSv (Table 5.1). This includes external radiation, a component due to the tritium originating from GE Healthcare, and an increased tritium dose coefficient (see Appendix 5). Recent trends in doses in the area of the Severn Estuary are shown in Figure 7.4.

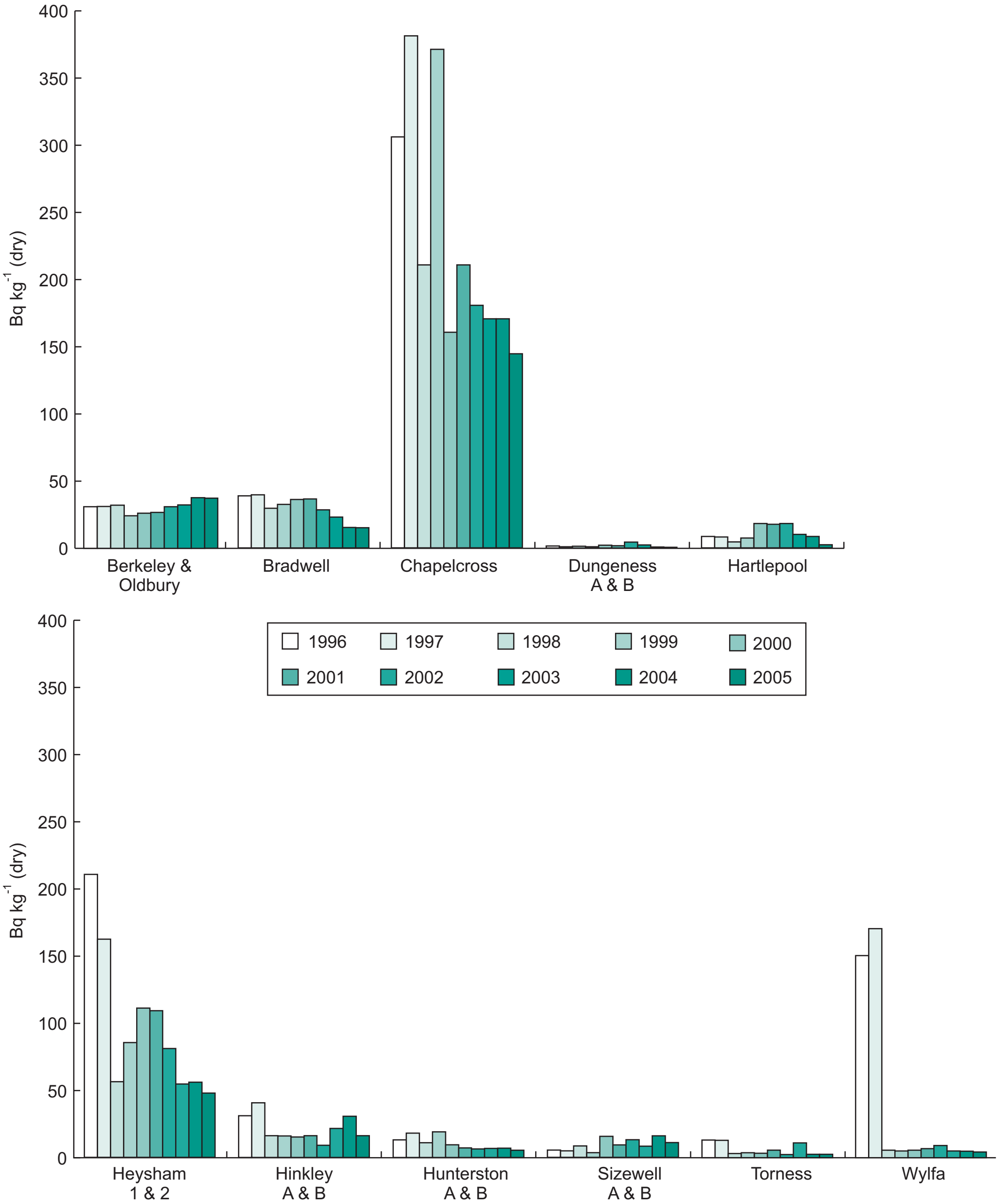
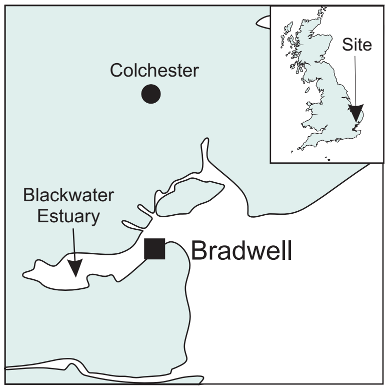


Figure 5.1 Caesium-137 concentration in sediments near nuclear power stations

Sulphur-35 was detected at very low levels in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, at levels slightly above background values. Gross alpha and gross beta concentrations in surface waters were less than the WHO screening levels. An atmospheric dispersion computer model has been used to estimate the concentrations of radionuclides in air due to gaseous releases from the Oldbury site (Appendix 2). The critical group dose from gaseous releases including consumption of foodstuffs was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit.

In June 2005, the Oldbury site operators reported that the weekly advisory levels for carbon-14 had been exceeded. The Food Standards Agency undertook extra analyses of tritium and carbon-14 in samples of local milk but found only minor elevations in the concentrations of these radionuclides, which were of no radiological dose significance.

5.2 Bradwell, Essex



This Magnox power station stopped electricity production in March 2002 after 40 years of operation and is now undergoing defuelling prior to decommissioning. It is authorised to discharge gaseous wastes to the local environment and liquid wastes to the estuary of the River Blackwater.

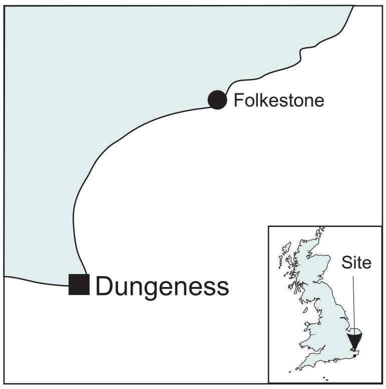
Terrestrial sampling is similar to that for other power stations including analyses of milk, fruit and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch and public supplies. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. Seaweeds were analysed as an environmental indicator material and leaf beet was collected because it is eaten locally and grows in areas that become tidally inundated.

Measurements for 2005 are summarised in Tables 5.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were generally similar to those for 2004, however, there is evidence for a decline in caesium-137 concentrations in sediments (Figure 5.1). The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity, though there may be a small contribution from discharges from the reprocessing plant at Cap de la Hague. The gross beta activity in water from the coastal ditch continued to be enhanced above background levels and was in excess of the WHO screening level of 1 Bq l^{-1} for drinking water. Tritium concentrations in the ditch were similar to values reported in 2004, but were substantially below the EU reference level for tritium of 100 Bq l^{-1}. The ditch is not known to be used as a drinking water source. Gamma dose rates on beaches were difficult to distinguish from natural background. The critical group of seafood consumers received 0.012 mSv, mostly due to the effects of external exposure, which was approximately 1% of the dose limit for members of the public of 1 mSv (Table 5.1).

In September 2005, the failure of a filter in the extract ventilation system for the ponds building resulted in an elevated release of radioactivity to atmosphere. This was most likely due to a defective filter. The impact was very low because the release was less than the authorised discharge limit.

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

5.3 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 AGRs. Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together. The Environment Agency is reviewing the authorisations to dispose of radioactive waste from the nuclear power station at Dungeness B and started a consultation on a proposed authorisation in April 2006 (Environment Agency, 2006c).

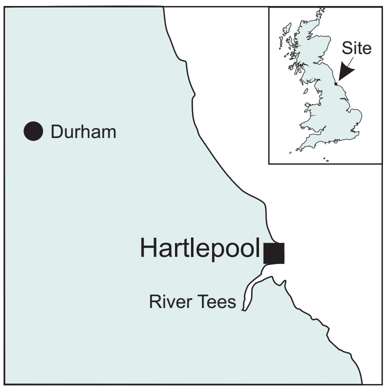
Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments. A habits survey was undertaken in 2005. Small variations in consumption rates have been observed, whilst occupancy rates remain unchanged. The critical group remained as fish and shellfish consumers. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 4.

The results of monitoring for 2005 are given in Tables 5.4(a) and (b). Concentrations of radiocaesium in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield. Apportionment is difficult at these low levels. The small concentrations of transuranics in whelks and sediment were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma dose rates were difficult to distinguish from the natural background; beta dose rates were not detected. The critical group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was low at 0.008 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 5.1). The external radiation dose for houseboat occupants was estimated to be 0.009 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, but some enhancements were observed particularly in peas and honey. Low concentrations of tritium and sulphur-35 were detected in some samples. Concentrations of gross alpha and gross beta activity in freshwater were within WHO screening levels for drinking water. Relatively high concentrations of argon-41 in air were predicted for this site (Appendix 2). The maximum dose due to gaseous disposals was received by prenatal children. Their dose in 2005 was estimated to be 0.11 mSv, which was 11% of the dose limit for members of the public. Most of this was due to argon-41; the contribution from food pathways was less than 0.005 mSv.

In both February and May 2005, the site operators reported that the weekly advisory levels for tritium and carbon-14 had been exceeded. The weekly advisory level for carbon-14 was also exceeded in June 2005. On each occasion, the Food Standards Agency undertook extra analyses of additional samples of local milk but found only minor elevations in the concentrations of these radionuclides, which were of no radiological dose significance.

5.4 Hartlepool, Cleveland



This station is powered by twin AGRs. Authorised discharges of radioactive liquid effluent are made to Hartlepool Bay and the River Tees. Gaseous radioactive waste is discharged via stacks to the local environment. The Environment Agency is reviewing the authorisations to dispose of radioactive waste from the nuclear power station at Hartlepool and started a consultation on a proposed authorisation in April 2006 (Environment Agency, 2006c). A habits survey has examined the potential pathways for radiation exposure due to liquid effluent disposals and this established that exposures could be represented by consumption of local fish and shellfish and external irradiation whilst digging for bait. Technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield. In 2004, the sampling and analytical schedule was extended to include new determinations of polonium-210 and other naturally-occurring radionuclides, to consider the possibility of local enhancement of naturally occurring radionuclides from waste slag historically disposed of from the local iron and steel industries along parts of the River Tees. A selection of terrestrial foods, including milk, was sampled in surveillance of gaseous disposals.

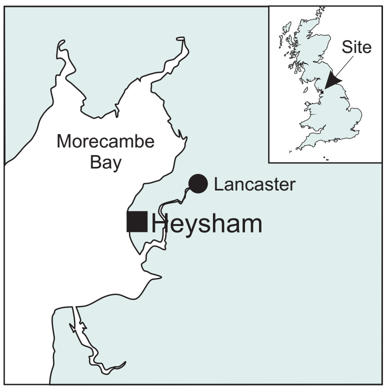
Results of the routine monitoring programme carried out in 2005 are shown in Tables 5.5(a) and (b). These include short-lived nuclides detected by gamma-ray spectrometry from the naturally-occurring decay series. The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though some enhancements of carbon-14 levels in terrestrial samples were apparent. The alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. The critical group dose in 2005 was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1).

Although observed in the past, high levels of tritium in seawater were not observed in 2005. Some bioaccumulation of tritium in seafood was detected but at levels that were much less than those observed in the Cardiff area (Section 7). Concentrations of carbon-14 were enhanced above a background of approximately 25 Bq kg^{-1} expected for seafood (see Appendix 6). This is due to carbon-14 discharges from a non-nuclear site since carbon-14 discharges from the power station are low. Levels of technetium-99 in seaweed (*Fucus vesiculosus*) were reduced and less than the peak observed in 1998 (see also Figure 3.18). They are less than 1% of the equivalent concentrations near Sellafield. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. The enhanced dose rates at Paddy's Hole are believed to be due to a combination of waste slag from local iron and steel industries, used in sea defences, and/or the build up of naturally occurring gamma-ray-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time. The critical occupancy group does not spend time at Paddy's Hole. The radiation dose to local fish and shellfish consumers, including external radiation but excluding naturally occurring radionuclides in seafood, was low, at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

In 2004, the concentrations of lead-210 and polonium-210 found in winkles from Paddy's Hole (2.3 and 25 Bq kg^{-1} respectively) were above those expected due to natural sources. Sampling and analysis undertaken in 2005 gave similar values (2.2 and 19 Bq kg^{-1} respectively). However, data for other naturally occurring radionuclides, locations and species in the Hartlepool area were well within the range of concentrations expected for natural sources (Appendix 6). Paddy's Hole is unlikely to sustain a high rate consumption of winkles as it is a very localised area which contains oil and other wastes. In addition the most recent habits survey undertaken did not identify any consumption of molluscs from Paddy's Hole. However, in the unlikely event that some of these molluscs did enter the diet of the critical group of fish and shellfish consumers, it is estimated that an additional dose from naturally occurring radionuclides of 0.045mSv would be received by this group in addition to that from artificial radionuclides. This estimate assumes that the median concentrations for naturally occurring radionuclides at background (Appendix 6) should be subtracted from the total concentrations as measured in 2005.

5.5 Heysham, Lancashire

This establishment comprises two separate nuclear power stations both powered by AGRs. Disposals of radioactive waste from both stations are made under authorisation via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. The Environment Agency is reviewing the authorisations to dispose of radioactive waste from the nuclear power station at Heysham 1 and 2 and started a consultation on a proposed authorisation in April 2006 (Environment Agency, 2006c and d).

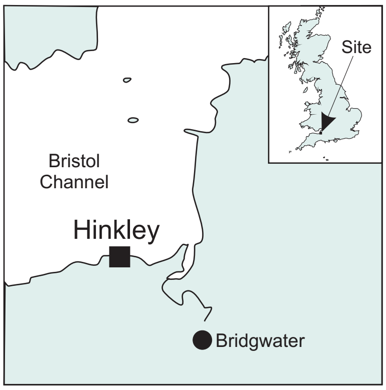


The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. That for liquid disposals was also similar, including sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates, but for completeness the data considered in this section include all of that for Morecambe Bay. A substantial part of the programme is therefore in place in order to monitor the effects of Sellafield disposals.

The results for 2005 are given in Tables 5.6(a) and (b). In general, similar levels to those for 2004 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Levels of tritium in plaice and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at the higher levels typical of recent years. They were caused by discharges from Sellafield. Concentrations of caesium-137 in sediments were also largely due to Sellafield but they are in decline (Figure 5.1). The radiation dose in 2005 to the critical group of fishermen, including a component due to external radiation, was 0.063 mSv, which is well within the dose limit for members of the public of 1 mSv (Table 5.1) and a small decrease compared with 0.068 mSv in 2004.

The effects of gaseous disposals were also difficult to detect in 2005. Small enhancements of concentrations of carbon-14 were apparent in some samples. The critical group dose was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

5.6 Hinkley Point, Somerset



At this establishment, there are two separate ‘A’ and ‘B’ nuclear power stations; the ‘A’ station comprises Magnox reactors and the ‘B’ station AGRs. Magnox Electric announced the closure of Hinkley Point ‘A’ in May 2000 and the station began defuelling in 2002. Defuelling was complete in 2004. Authorised discharges of radioactive liquid effluent from both power stations are made via a common cooling water outlet to the Bristol Channel. Gaseous radioactive wastes are discharged via separate stacks. The Environment Agency is reviewing the authorisations to dispose of radioactive waste from the nuclear power station at Hinkley Point B and started a consultation on a proposed authorisation in April 2006 (Environment Agency, 2006c and e).

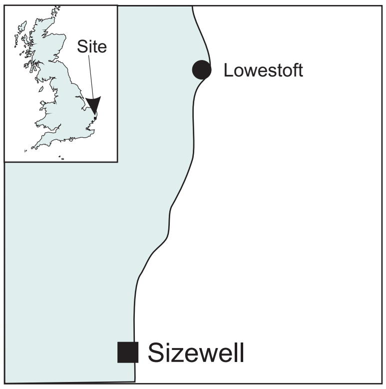
Environmental monitoring covers the effects of the two power stations together. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the GE Healthcare plant at Cardiff.

The environmental results for 2005 are presented in Tables 5.7 (a) and (b). Where results can be compared, the concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in 2004 (see also Figure 5.1). Concentrations of tritium in cod and shrimps were similar their levels in 2004. Further information of tritium levels in seawater from the Bristol Channel is given in Section 9. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl fallout. Apportionment is generally difficult at the low levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from GE Healthcare, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, were similar to those for 2004. The critical group of local fishermen was estimated to receive a dose of 0.018 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv (Table 5.1). This estimate includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 5). Trends in doses in the area of the Severn Estuary are shown in Figure 7.4.

In August 2005, a member of the public reported abnormal radiation readings at nearby Kilve Beach. The Environment Agency carried out monitoring in September 2005, and further monitoring between October 2005 and March 2006. Elevated activity above background was not detected (Environment Agency, 2006d).

Results for 2005 indicate a small enhancement of radioactivity levels due to disposals of gaseous wastes. Activity concentrations of tritium and gamma emitters in terrestrial materials were all below or close to the limits of detection. Concentrations of sulphur-35 showed the effects of the power stations and some of the concentrations of carbon-14 were higher than the default values used to represent background levels (Appendix 6). Freshwater contained alpha and beta activities less than WHO screening levels for drinking water. The estimated critical group dose due to radioactivity in the terrestrial environment was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

5.7 Sizewell, Suffolk



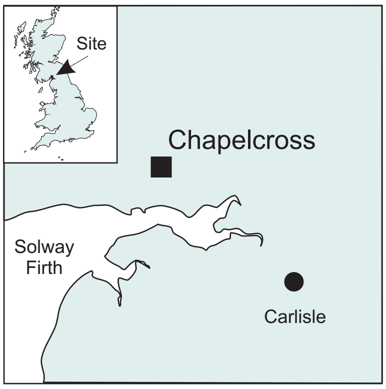
At this establishment there are two stations. The ‘A’ station has two Magnox reactors whilst the ‘B’ station has a Pressurised Water Reactor. The ‘B’ station began operation in 1995. Authorised discharges of radioactive liquid effluent from both power stations are made via adjacent outfalls to the North Sea. Gaseous wastes are discharged via separate stacks to the local environment. The Environment Agency is reviewing the authorisations to dispose of radioactive waste from the nuclear power station at Sizewell ‘B’ and started a consultation on a proposed authorisation in April 2006 (Environment Agency, 2006c and d). Environmental monitoring for the power stations is considered in a single programme covering the area likely to be affected. The results of monitoring in 2005 are shown in Tables 5.8 (a) and (b).

In the aquatic programme, analysis of seafood, sediment, sand and seawater, and measurements of gamma dose rates in intertidal areas were undertaken. Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium levels in seafood were low. A habits survey was undertaken in 2005. For marine pathways, revised consumption and occupancy rates are provided in Appendix 4. In 2005, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). Measured gamma dose rates in intertidal areas were difficult to distinguish from the natural background except at Sizewell Beach where direct radiation is known to have a local effect. The assessment includes a contribution for external exposure based on a calculation using concentrations of radionuclides in sediment.

Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit generally showed very low levels of artificial radionuclides near the power stations in 2005. Concentrations of activity in local freshwater were all low. The estimated dose to the critical group of consumers eating local foods was less than 0.005 mSv. However, making an allowance for concentrations of radionuclides in air using the methods and data in Appendix 2, the critical group dose in 2005 was 0.057 mSv or approximately 6% of the dose limit for members of the public of 1 mSv. The critical group was prenatal children. The increase in dose from 0.040 mSv in 2004 was due to the relatively higher discharges of argon-41 in 2005. Argon-41 discharges from Sizewell ‘A’ were reduced in 2004, due to extended shutdown of one of the reactors.

SCOTLAND

5.8 Chapelcross, Dumfries and Galloway



Chapelcross has a Magnox nuclear power station located near the town of Annan in Dumfries and Galloway. Electricity generation ceased in June 2004 and the station has been preparing for decommissioning.

In April 2005, the ownership of Chapelcross transferred to the newly formed NDA. As of April 2005, operations on the site are carried out by Magnox Electric Limited. SEPA transferred the authorisations held for radioactive waste disposal from Chapelcross to Magnox Electric Limited on 1 April 2005.

Gaseous wastes from the site are discharged to the local environment and liquid waste is discharged to the Solway Firth under authorisation from the Scottish Environment Protection Agency. The end of power generation at Chapelcross also brought an end to the discharge of the radioactive gas, argon-41, which was not discharged during 2005.

Habits surveys have been used to investigate aquatic and terrestrial exposure pathways. A habits survey was conducted during July 2005. This survey confirmed the existence of local fishermen who eat large quantities of local seafood and are also exposed to external radiation whilst tending stake nets. A further group was identified consisting of wildfowlers who were exposed to external radiation whilst on salt marshes. Samples of seawater and *Fucus vesiculosus*, as useful environmental indicators, were collected in addition to seafood, sediments and dose rates. Terrestrial monitoring was expanded in 2004 and a greater number of samples are now collected and analysed. Monitoring of air at three locations was added to the programme in 2001.

The results of routine monitoring in 2005 are presented in Tables 5.9(a), (b) and (c). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides and gamma dose rates in intertidal areas remained at similar levels to those detected in recent years.

The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.018 mSv in 2005, which was less than 2% of the dose limit for members of the public of 1 mSv (Table 5.1). Measurements of the contact beta dose-rate on fishing nets were below the LoD. A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the dose to the local population; the greater proportion of the dose can be attributed to the emissions from Sellafield.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. This area is monitored frequently by Magnox Electric Limited. In 2005, this monitoring resulted in 95 items being detected with radioactivity levels above background. This compares with 3 items in 2004, 21 items in 2003, 3 in 2002, 1 in 2001 and 3 in 2000. The relatively high numbers found in 2005 were due to a series of incidents including a flooding event that was the result of exceptionally heavy rainfall in the area. All contaminated items detected are removed by Magnox Electric Limited and taken back to Chapelcross for analysis and appropriate disposal. SEPA carried out additional monitoring in the vicinity of the pipeline during 2005 and did not find any items above normal background levels. For a number of years there has been a plan to build a new filter house to reduce this problem. However, delays to the construction of this filter house and the nature of some of the incidents during 2005 have resulted in a review of all options for improving the pipeline such that the limescale problem is eliminated in the long term. During 2005, Magnox Electric Limited made several interim improvements to the end of line strainer system both physical and procedural. Additionally, improvements further up the pipeline have been made to reduce the risk of further flooding events.

The activity concentrations of radionuclides in milk and grass were generally similar to those observed in 2004. The maximum concentration of tritium in milk increased from 54 Bq l^{-1} in 2004 to 160 Bq l^{-1} in 2005. However, the effect of this increased concentration on the dose was small. The more extensive dataset now available on terrestrial foods shows that the effects of discharges from Chapelcross can be seen in the levels of tritium and sulphur-35 in a range of foods. The annual dose to the critical group of terrestrial food consumers was estimated to be 0.025 mSv, which was approximately 3% of the dose limit for members of the public of 1 mSv. The dose in 2004 was similar at 0.029 mSv. No argon-41 was discharged in 2005 and the entire dose is due to the consumption of local foodstuffs.

The habits survey in 2005 confirmed consumers of wildfowl and their occupancy over salt marsh. Although samples of wildfowl were not monitored in 2005, an assessment has been undertaken using data from an earlier RIFE report in 2004 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2004). The dose from high-rate consumption of wildfowl based on current consumption data was 0.008 mSv. The doses from consumption of terrestrial foods include contributions due to weapons testing and Chernobyl fallout. Measured concentrations of radioactivity in air at locations near to the site were very low (Table 5.9(c)). The annual dose from inhaling air containing caesium-137 at these concentrations was estimated to be much less than 0.005 mSv.

5.9 Hunterston, North Ayrshire

At this location there are two separate nuclear power stations - Hunterston 'A' and Hunterston 'B'. Hunterston 'B' is owned and operated by British Energy Generation Limited, while Hunterston 'A' has been owned since April 2005, by the NDA and is operated by Magnox Electric Limited (part of BNG). Hunterston 'A' was powered by twin Magnox reactors and Hunterston 'B' is powered by a pair of AGRs. Hunterston 'A' ceased power production at the end of March 1990. Authorised liquid discharges are made to the Firth of Clyde by Hunterston 'B' via the stations' cooling water outfall. Authorised liquid discharges from Hunterston 'A' are also made via the same outfall. Gaseous discharges are made via separate discharge points from the Hunterston 'A' and Hunterston 'B' stations.

Environmental monitoring in the area considers the effects of both sites together. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials. The scope of the terrestrial monitoring programme was enhanced in 2000, and further in 2004, and includes the analysis of a comprehensive range of wild and locally produced foods. In addition, air, grass and soil are sampled to provide background information. The most recent habits survey undertaken in 2001 resulted in three potential critical groups being identified: seafood consumers, terrestrial food consumers and a group of professional shellfish collectors who have a high occupancy time over inter-tidal areas. The results from the monitoring programme are used to quantify the dose to each critical group.

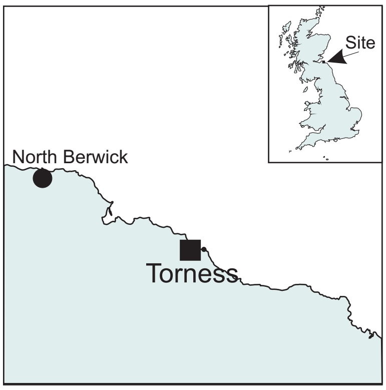
The results of monitoring in 2005 are shown in Tables 5.10(a), (b) and (c). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs and squat lobsters were similar to those in 2004. There was a slight increase in technetium-99 concentrations in the common lobster. Small concentrations of activation products such as manganese-54 that are likely to have originated from the site were also detected but were of negligible radiological significance. In 2005, the dose to the critical group from consumption of fish and shellfish was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). This includes a contribution from the Sellafield - derived technetium-99 in shellfish.

The dose to a separate critical group of shellfish collectors who use local beaches was 0.011 mSv or approximately 1% of the dose limit.

The concentrations of radionuclides in air, milk, vegetables and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. The radiation dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was estimated to be 0.010 mSv which was 1% of the dose limit for members of the public of 1 mSv (Table 5.1). The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

In April 2006, SEPA issued a public consultation on the six applications from British Energy Generation Limited for the authorisation to dispose of radioactive wastes from Hunterston 'B' Power Station (Scottish Environment Protection Agency, 2006a).

5.10 Torness, East Lothian



This station, which is powered by two AGRs, came into operation at the end of 1987. The scope of the monitoring programme at this site was enhanced in 2000, and further in 2004, and includes the analysis of milk, vegetables, fruit, seafood, seawater, seaweed and soil. Various species of plants were monitored as environmental indicator materials and air sampling was introduced in 2001 to investigate the inhalation pathway. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

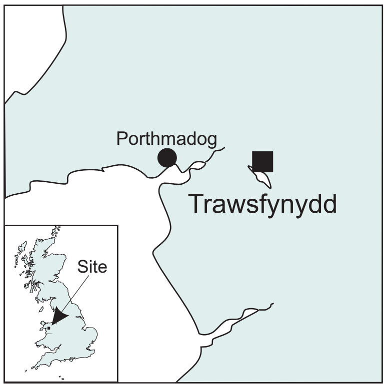
The results of this monitoring in 2005 are shown in Tables 5.11(a), (b) and (c). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace levels of activation products were detected which were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2004, except seaweed where increases in concentrations were measured. . The dose to fish and shellfish consumers (the critical group) was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1).

Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates on beaches were generally indistinguishable from natural background though data for St Abbs and Dunbar were higher. The effects of discharges from the power station were observed in low levels of tritium and sulphur-35 in terrestrial foods and environmental indicator materials. The dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.027 mSv, which was less than 3% of the dose limit for members of the public of 1 mSv. The increase in dose from 0.016 mSv in 2004 was due to the higher LoD for americium-241 in milk in 2005. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

In September 2004, British Energy Generation (UK) Limited and British Energy Generation Limited made a joint application to transfer the authorisations held by Torness Power Station from British Energy Generation (UK) Limited to British Energy Generation Limited. The transfer was granted and effective from 1 July 2005.

In March 2006, SEPA issued a public consultation on the six applications from British Energy Generation Limited for the authorisation to dispose of radioactive wastes from Torness Power Stations (Scottish Environment Protection Agency, 2006b). Changes are being proposed for many of the limits in the certificates of authorisation currently in force at Torness.

WALES



5.11 Trawsfynydd, Gwynedd

This station is being decommissioned but low level discharges continued during 2005 under an authorisation granted by the Environment Agency. Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. Monitoring is carried out on behalf of the Welsh Assembly Government. The aquatic monitoring programme is directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. It is also directed at freshwater and sediment analysis. Habits surveys have established that species of fish regularly consumed are brown trout, rainbow trout and a small amount of perch. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than indigenous fish. The most recent habits survey was undertaken in 2005. For aquatic pathways, the critical group remained as fish consumers, although no consumption of perch was noted and the associated occupancy rates over the lake shore were reduced. Revised consumption and occupancy rates are provided in Appendix 4.

The results of the terrestrial programme, including those for local milk, crops and environmental indicator materials, as well as the aquatics programme, are shown in Tables 5.12 (a) and (b). Concentrations of activity in all terrestrial foods were low. Sulphur-35 was detected in a number of terrestrial foods (vegetables, blackberries and eggs), at levels just above the LoD. The source is unknown but it is very unlikely to be Trawsfynydd as there were no discharges of this radionuclide in recent years. The most likely source of radiocaesium in some terrestrial foods (vegetables, fruit and honey) is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. Detected activities were low and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was no evidence of resuspension of activity in sediment from the lakeshore contributing to increased exposure from transuranic radionuclides in 2005.

The critical group for terrestrial foods at Trawsfynydd in 2005 received doses of 0.005 mSv, which was 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). The contribution from the transuranic activity detailed above was less than 1% of the dose.

In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where anglers fish were difficult to distinguish from background levels and were similar to those in 2004. The predominant radionuclide is caesium-137. The time trend of concentrations of caesium-137 in sediments is shown in Figure 5.2. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. The observed levels now are mainly affected by sample variability.

Concentrations of radiocaesium in fish in 2005 were similar to those in 2004. The activity concentrations in sediments and the activity in the fish that result from discharges from earlier years (and maintained in the water column by processes such as remobilisation) predominate at this stage. Low concentrations of other radionuclides including actinides are also detected, particularly in lake sediments. However, the actinide concentrations in fish are very low and it is the effects of caesium-137, which dominate the fish consumption and external radiation pathways. In 2005, a radiochemical method was used to determine the activity of actinides in a bulk rainbow trout sample, thus enabling a significant reduction in the LoD for americium-241 (in comparison to a LoD value of 0.31 Bq kg^{-1} by gamma-ray spectrometry, reported in 2004). Similar values were observed for the activity of americium-241 in brown and rainbow trout, demonstrating that the activity of americium-241 in rainbow trout is also very low.

Nuclear power

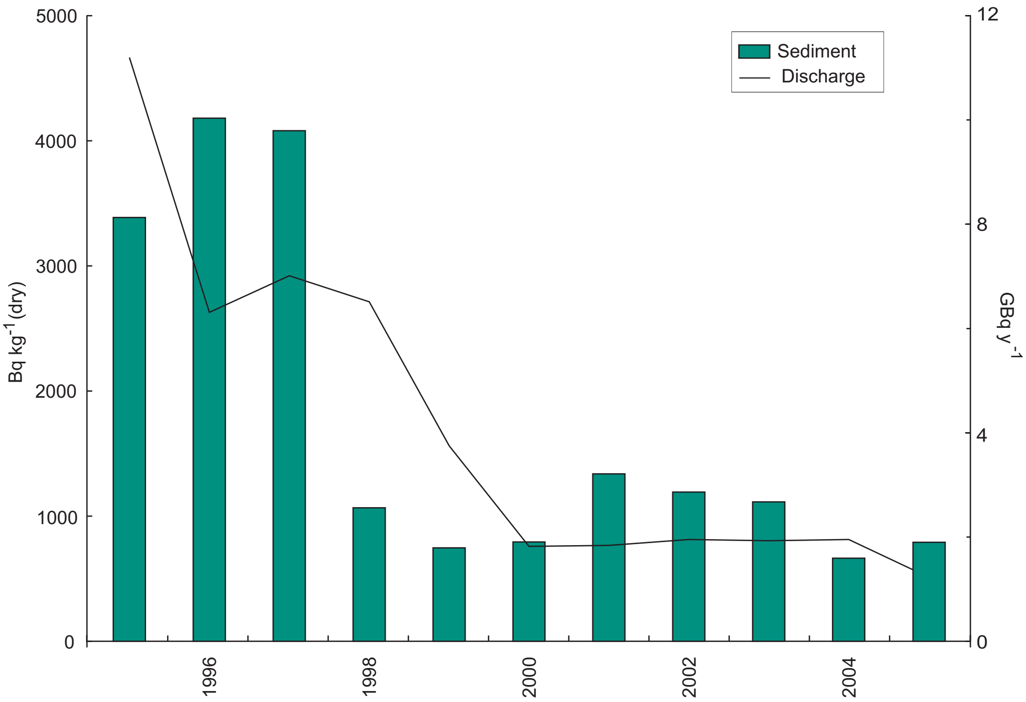
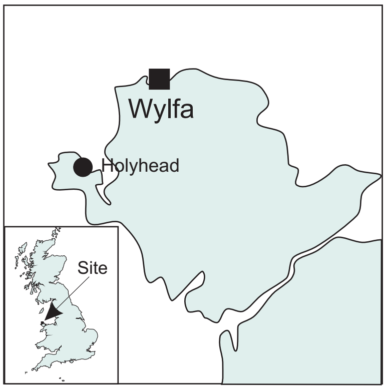


Figure 5.2 Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

The dose to the critical group of anglers was 0.008 mSv in 2005, which was less than 1% of the dose limit for members of the public of 1 mSv. The observed concentrations in lake sediments are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels.

5.12 Wylfa, Isle of Anglesey



This station generates electricity from two Magnox reactors. Gaseous and liquid wastes from this station were discharged in 2005 under authorisations granted by the Environment Agency. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is carried out on behalf of the Welsh Assembly Government. Such discharges and effects are very low.

The results of the programme in 2005 are given in Tables 5.13 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges. The concentrations were similar to those for 2004, and continued to show the effects of technetium-99 from Sellafield. A habits survey was undertaken in 2004. For marine pathways, the critical group remained as fish and shellfish consumers with an additional element of beach occupancy; however, consumption and occupancy rates reduced (Appendix 4). The dose to the critical group of high-rate fish and shellfish consumers was low, at 0.005 mSv, which was 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). Gamma dose rates, measured using portable instruments were similar to those found in 2004. The dose received by high-rate terrestrial food consumers remained low at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public. In April 2005, the site operators reported that the weekly advisory levels for tritium had been exceeded. The Food Standards Agency undertook extra analyses of tritium and carbon-14 in samples of local milk but found no elevated concentrations of either radionuclide.

Table 5.1. Individual radiation exposures – nuclear power stations, 2005

Site	Exposed population group[a]	Exposure, mSv				
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or the shoreline	Gaseous plume related pathways
England						
Berkeley and Oldbury	Seafood consumers	0.010	<0.005	-	0.008	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
Bradwell	Seafood consumers	0.012	<0.005	-	0.010	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Dungeness	Seafood consumers	0.008	<0.005	-	0.006	-
	Houseboat occupants	0.009	-	-	0.009	-
	Prenatal children of inhabitants and consumers of locally grown food	0.11	-	0.006	-	0.10
Hartlepool	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b,c]	<0.005	-	<0.005	-	-
Heysham	Seafood consumers	0.063	0.047	-	0.016	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Hinkley Point	Seafood consumers	0.018	<0.005	-	0.015	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Prenatal children of inhabitants and consumers of locally grown food	0.057	-	<0.005	-	0.055
Scotland						
Chapelcross	Seafood consumers	0.018	<0.005	-	0.016	-
	Wildfowlers	0.008	-	<0.005	<0.005	-
	Consumers of locally grown food[b]	0.025	-	0.025	-	-
Hunterston	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.011	-	-	0.011	-
	Consumers of locally grown food[b]	0.010	-	0.010	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	0.020	-	0.020	-	-
Wales						
Trawsfynydd	Anglers	0.008	<0.005	-	0.006	-
	Consumers of locally grown food[b]	0.005	-	0.005	-	-
Wylfa	Seafood consumers	0.006	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Excluding possible enhancement of naturally occurring radionuclides. See Section 5*

Nuclear power

Table 5.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25		<0.08	0.28	<0.19	
Bass	River Severn	2	1300		<0.20	2.6	<0.28	
Elvers	River Severn	1	<25		<0.08	0.18	<0.13	
Shrimps	Guscar	2	600	49	<0.14	0.54	<0.20	0.00010
Sediment	Hills Flats	2[E]				33		
Sediment	1 km south of Oldbury	2[E]				34		
Sediment	2 km south west of Berkeley	1[E]				40		
Sediment	Sharpness	2[E]				37		
Seawater	Local beach	1[E]			<0.46	<0.41		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples								
Salmon	Beachley	2		<0.18				
Bass	River Severn	2		<0.29				
Elvers	River Severn	1		<0.06				
Shrimps	Guscar	2	0.00071	0.00083	*	0.000018		
Sediment	Hills Flats	2[E]		<2.3				
Sediment	1 km south of Oldbury	2[E]		<2.0				
Sediment	2 km south west of Berkeley	1[E]		<2.6				
Sediment	Sharpness	2[E]		<2.2				
Seawater	Local beach	1[E]		<0.54			<1.0	4.9

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		8	<4.4	16	<0.39	<0.27	<0.30		
Milk	max		<4.5	17	0.73	<0.30	<0.33		
Milk[d]		1	<4.0	38					
Milk[e]		1	<4.0	35					
Apples		1	7.0	16	0.20	<0.30	<0.30		
Blackberries		1	<5.0	17	0.20	<0.30	<0.30		
Cabbage		1	5.0	4.0	0.50	<0.20	<0.20		
Carrots		1	<5.0	9.0	<0.10	<0.30	<0.30		
Honey		1	<7.0	86	<0.10	<0.20	<0.30		
Potatoes		1	<5.0	12	0.10	<0.30	<0.30		
Runner beans		1	<5.0	8.0	<0.10	<0.30	<0.30		
Wheat		1	<7.0	100	0.80	<0.30	<0.30		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<1.0	<0.32	<0.25	<0.035	0.23
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.31	<0.25	<0.044	0.25

* *Not detected by the method used*

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

[b] *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 value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *Additional milk sampling week commencing 23rd May 2005*

[e] *Additional milk sampling week commencing 13th June 2005*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2005

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
1 km south of Oldbury	Grass and mud	1	0.084
1 km south of Oldbury	Grass and sand	1	0.085
2 km south west of Berkeley	Mud and stones	1	0.084
Guscar Rocks	Salt marsh	2	0.087
Lydney Rocks	Salt marsh	2	0.10
Sharpness	Salt marsh and mud	1	0.088
Sharpness	NA	1	0.090
Hills Flats	Salt marsh and mud	1	0.091
Hills Flats	Salt marsh	1	0.087
Aust Rock	Mud	2[F]	0.081

NA Not available

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Table 5.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2005

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{60}Co	^{65}Zn	^{99}Tc	^{134}Cs	^{137}Cs	^{155}Eu
Marine samples								
Sole	Bradwell	2	<0.14	<0.40		<0.15	0.59	<0.25
Bass	Pipeline	1	<0.14	<0.52		<0.16	1.9	<0.21
Mullet	Pipeline	1	<0.20	<0.68		<0.21	0.76	<0.28
Lobsters	West Mersea	1	<0.04	<0.10		<0.04	0.40	<0.07
Native oysters	Tollesbury N. Channel	1	<0.11	<0.35		<0.12	0.46	<0.26
Pacific oysters	Goldhanger Creek	2	<0.12	<0.35		<0.12	0.35	<0.16
Winkles	Pipeline	2	<0.15	<0.38		<0.15	0.72	<0.28
Winkles	Heybridge Basin	2	<0.16	<0.40		<0.16	0.94	<0.29
Seaweed	Bradwell	2[E]	<2.1		30	<1.8	<4.5	
Leaf beet	Tollesbury	1	<0.03	<0.10		<0.04	<0.03	<0.10
Samphire	Tollesbury	1	<0.04	<0.13		<0.05	0.25	<0.11
Sediment	Pipeline	2[E]	<0.97				17	
Sediment	West Mersea 1	1[E]	<0.65				3.9	
Sediment	West Mersea 2	2[E]	<0.65				<8.2	
Sediment	Waterside	2[E]	<1.0				45	
Sediment	1.5 km east of pipeline	2[E]	<0.77				<0.89	
Seawater	Bradwell	2[E]	<0.39			<0.38	<0.32	

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Sole	Bradwell	2			<0.18				
Bass	Pipeline	1			<0.11				
Mullet	Pipeline	1			<0.14				
Lobsters	West Mersea	1			<0.04				
Native oysters	Tollesbury N. Channel	1	0.00082	0.0044	0.0023	0.000018	0.000076		
Pacific oysters	Goldhanger Creek	2			<0.08				
Winkles	Pipeline	2			<0.22				
Winkles	Heybridge Basin	2			<0.23				
Seaweed	Bradwell	2[E]			<2.3				
Leaf beet	Tollesbury	1			<0.10				
Samphire	Tollesbury	1			<0.10				
Sediment	Pipeline	2[E]			<1.2				
Sediment	West Mersea 1	1[E]			<0.86				
Sediment	West Mersea 2	2[E]			<1.0				
Sediment	Waterside	2[E]			<1.5				
Sediment	1.5 km east of pipeline	2[E]			<1.1				
Seawater	Bradwell	2[E]			<0.48			<2.6	13

Material	Location or selection[b]	No. of sampling observ- ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Total alpha	Total beta
Terrestrial samples								
Milk		6	<4.5	16	<0.53	<0.30		
Milk	max		<5.0	21	<1.0	<0.33		
Apples		2	<4.5	18	<0.10	<0.30		
Apples	max		<5.0	24				
Blackberries		1	<4.0	14	<0.20	<0.30		
Cabbage		1	<4.0	10	<0.60	<0.30		
Carrots		1	<4.0	15	<0.20	<0.30		
Lucerne		1	<4.0	12	1.4	<0.40		
Potatoes		2	<4.5	18	<0.15	<0.35		
Potatoes	max		<5.0	20	<0.20	<0.40		
Rabbit		1	<5.0	34	<0.60	<0.30		
Wheat		1	<8.0	130	<0.20	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.32	<0.10	0.33
Freshwater	Coastal ditch 1	1[E]	<4.0		1.6	<0.41	0.52	2.8
Freshwater	Coastal ditch 3	1[E]	18		3.0	<0.38	<0.43	7.7
Freshwater	Coastal ditch 4	1[E]	17		3.5	<0.17	<0.81	20

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.3(b). Monitoring of radiation dose rates near Bradwell, 2005

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and shingle	1	0.073
Bradwell Beach	Sand and shingle	1	0.064
Beach opposite power station, N side of estuary	Salt marsh	1	0.067
1.5 km E of pipeline	Shingle	1	0.065
1.5 km E of pipeline	Sand and shingle	1	0.068
Waterside	Salt marsh	2	0.066
West Mersea	Mud and sand	1	0.062
West Mersea	Mud and shingle	1	0.062

Table 5.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs	^{155}Eu
Marine samples										
Plaice	Pipeline	2	<25	<25		<0.10			<0.12	<0.19
Cod	Pipeline	1		<25		<0.05			0.40	<0.13
Whiting	Pipeline	1		<25		<0.07			0.30	<0.12
Bass	Pipeline	1		<25		<0.05			0.41	<0.14
Crabs	Hastings	1				<0.04			0.04	<0.13
Shrimps	Pipeline	2	<25	<25	34	<0.13			0.21	<0.21
Whelks	Pipeline	2				<0.11	<0.025		<0.07	<0.16
Cuttlefish	Hastings	1				<0.19			<0.15	<0.25
Seaweed	Copt Point	2[E]				<1.4		<2.5	<1.1	
Mud and sand	Rye Harbour	2				<0.67			1.5	<1.5
Sediment	Rye Harbour 1	2[E]				<0.79			<0.63	
Sediment	Rye Harbour 2	2[E]				<0.90			<0.70	
Sediment	Camber Sands	2[E]				<0.56			<0.44	
Seawater	Pipeline	2		47						
Seawater	Dungeness South	2[E]				<0.37			<0.32	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.17				
Cod	Pipeline	1			<0.12				
Whiting	Pipeline	1			<0.07				
Bass	Pipeline	1			<0.13				
Crabs	Hastings	1			<0.19				
Shrimps	Pipeline	2			<0.11				
Whelks	Pipeline	2	0.00071	0.0031	0.0047	*	0.00015		
Cuttlefish	Hastings	1			<0.13				
Seaweed	Copt Point	2[E]			<1.7				
Mud and sand	Rye Harbour	2	0.051	0.26	0.23	*	0.011		
Sediment	Rye Harbour 1	2[E]			<1.2				350
Sediment	Rye Harbour 2	2[E]			<1.3				170
Sediment	Camber Sands	2[E]			<0.79				
Seawater	Dungeness South	2[E]			<0.47			<2.8	15

Table 5.4(a). continued

Material	Location or selection[b]	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
Terrestrial Samples									
Milk		2	<4.5	15	<0.36	<0.26	<0.30		
Milk	max			16	<0.40	<0.28			
Milk[d]		1	5.0	15					
Milk[e]		1	<4.0	17					
Milk[f]		1	<4.0	40					
Milk[g]		1	<4.0	43					
Blackberries		1	<5.0	18	0.20	<0.30	<0.30		
Dried peas		1	<7.0	110	1.6	<0.50	<0.30		
Honey		1	<6.0	120	<0.10	<0.20	<0.20		
Potatoes		1	<4.0	19	0.30	<0.30	<0.30		
Sea kale		1	8.0	48	<0.50	<0.30	0.70		
Wheat		1	<8.0	94	0.80	<0.30	<0.30		
Grass		1				<0.30	<0.30		
Freshwater	Long Pits	2[E]	<4.0		<1.0	<0.48	<0.41	<0.045	<0.10
Freshwater	Pumping Station Well number 1	1[E]	<4.0		<1.0	<0.48	<0.38	<0.030	0.28
Freshwater	Pumping Station Well number 2	1[E]	<4.0		<1.0	<0.49	<0.40	<0.030	0.34
Freshwater	Pumping Station Well number 3	1[E]	<4.0		<1.0	<0.50	<0.39	<0.020	0.21
Freshwater	Reservoir	1[E]	<4.0		<1.0	<0.32	<0.25	<0.11	0.27

** Not detected by the method used*
[a] Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply
[b] 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 value is the most appropriate for dose assessments
[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime
[d] Additional milk sampling week commencing 14rd February 2005
[e] Additional milk sampling week commencing 2nd May 2005
[f] Additional milk sampling week commencing 20th June 2005
[g] Additional milk sampling week commencing 27th June 2005
[E] Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 5.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	2	0.052
Greatstone-on-Sea	Sand	1	0.055
Greatstone-on-Sea	Sand and shingle	1	0.051
Dungeness East	Shingle	2	0.052
Dungeness South	Shingle	2	0.053
Jury's Gap	Shingle	2	0.050
Rye Bay	Sand and shingle	2	0.056
Rye Harbour	Mud and sand	2[F]	0.065
Mean beta dose rates			µSv h^{-1}
Rye Harbour	Mud and sand	2[F]	<0.040

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Nuclear power

Table 5.5(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2005

Material	Location sampling	No. of observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{7}Be	^{14}C	^{60}Co	^{99}Tc	^{134}Cs	^{137}Cs	^{208}Tl
Marine samples											
Plaice	1.9 km ENE Hartlepool	1	<25	25		28	<0.06		<0.06	0.13	
Plaice	Pipeline	2	<25	<25		26	<0.06		<0.06	0.21	
Whiting	1.9 km ENE Hartlepool	1	<25	<25		22	<0.13		<0.12	0.52	
Cod	Pipeline	2					<0.05		<0.06	0.36	
Crabs	1.9 km ENE Hartlepool	1	<25	<25		40	<0.08		<0.08	<0.08	
Crabs	Pipeline	2				29	<0.06		<0.07	<0.06	
Winkles	Paddy's Hole	1	31	49			<0.04		<0.05	0.29	
Winkles	South Gare	1	<25	<25			<0.06		<0.07	<0.06	
Winkles	Seal Sands	1	<25	<25		220	<0.05		<0.06	0.10	
Mussels	South Gare	1	43	65		64	<0.16		<0.17	<0.15	
Mussels	The Heugh	1					<0.06		<0.07	<0.05	
Mussels	Pipeline	1	68	95		110	<0.04		<0.04	0.08	
Fucus vesiculosus	Pilot Station	2					<0.09	27	<0.10	0.13	
Fucus vesiculosus	North Gare	1	<25	<25		24	<0.07		<0.07	0.15	
Fucus vesiculosus	Pipeline	1	<25	<25		100	<0.09		<0.10	0.16	
Fucus vesiculosus	Greatham Creek	1	<25	<25		250	<0.07		<0.07	0.32	
Fucus vesiculosus	Seal Sands	1	<25	<25		220	<0.08		<0.09	0.33	
Seaweed	Pilot Station	2[E]					<1.7	46	<1.5	<1.3	
Sediment	Old Town Basin	2[E]					<0.75			3.0	
Sediment	Seaton Carew	2[E]					<0.61			<0.51	
Sediment	Paddy's Hole	2[E]			<12		<0.84			<2.4	24
Sediment	North Gare	2[E]			<5.4		<0.58			<0.47	1.9
Sediment	Greatham Creek	2[E]			<26		<1.3			7.9	21
Sediment	River Tees pos 1	1[E]		<15		<70	<2.0		<1.0	0.70	
Sediment	River Tees pos 2	1[E]		<15		<70	<2.0		<1.0	1.7	
Sediment	River Tees pos 3	1[E]		<15		<70	<2.0		<1.0	3.0	
Sediment	River Tees pos 4	1[E]		33		190	<2.0		1.4	8.4	
Sediment	River Tees pos 5	1[E]		<15		240	1.8		<1.2	11	
Sediment	River Tees pos 6	1[E]		<15		200	<2.0		<1.0	13	
Sediment	River Tees pos 7	1[E]		<15		220	2.8		1.4	14	
Sediment	River Tees pos 8	1[E]		<15		150	<2.0		<1.0	12	
Sediment	River Tees pos 9	1[E]		<15		620	1.2		<1.2	3.0	
Sea coal	Old Town Basin	2[E]					<0.82			<0.75	
Sea coal	Carr House Sands	2[E]					<1.4			<1.3	
Freshwater	R Tees pos 1	1[E]		21		<4.0	<0.10			<0.01	
Freshwater	R Tees pos 2	1[E]		10		<4.0	<0.10			<0.01	
Seawater	North Gare	2		<2.0							
Seawater	North Gare	2[E]					<0.32		<0.31	<0.25	

Table 5.5(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{210}Pb	^{210}Po	^{212}Pb	^{212}Bi	^{214}Pb	^{214}Bi	^{228}Ac	^{234}Th	^{234}Pa
Marine samples											
Plaice	1.9 km ENE Hartlepool	1		1.5	*			*	*	*	
Plaice	Pipeline	2			*			<0.07	<0.05		
Whiting	1.9 km ENE Hartlepool	1		0.57	*			*	*	*	
Cod	Pipeline	2			*			*	*	*	
Crabs	1.9 km ENE Hartlepool	1		18	*			*	*	*	
Crabs	Pipeline	2			*			*	*	*	
Winkles	Paddy's Hole	1	2.2	19	1.0			0.67	1.1	*	
Winkles	South Gare	1		9.0	0.31			0.39	0.29	*	
Winkles	Seal Sands	1		8.0	0.18			0.26	*	3.8	
Mussels	South Gare	1		45	0.42			*	*	*	
Mussels	The Heugh	1			*			*	*	*	
Mussels	Pipeline	1		27	*			*	*	7.2	
Fucus vesiculosus	Pilot Station	2			0.23			0.49	1.5	*	
Fucus vesiculosus	North Gare	1		0.78	*			0.42	0.75	12	
Fucus vesiculosus	Pipeline	1		1.1	0.34			1.2	2.8	14	
Fucus vesiculosus	Greatham Creek	1		1.6	0.57			0.76	2.0	13	
Fucus vesiculosus	Seal Sands	1		1.6	0.44			0.86	2.5	13	
Seaweed	Pilot Station	2[E]									
Sediment	Old Town Basin	2[E]									
Sediment	Seaton Carew	2[E]									
Sediment	Paddy's Hole	2[E]			70	77	36	34	66	<370	<38
Sediment	North Gare	2[E]			5.1	<30	6.2	<6.6	<5.2	<49	<17
Sediment	Greatham Creek	2[E]			64	72	38	37	52	<2400	<280
Sediment	River Tees pos 1	1[E]		5.0			<5.0	6		<25	
Sediment	River Tees pos 2	1[E]		29			21	24		71	
Sediment	River Tees pos 3	1[E]		40			24	25		58	
Sediment	River Tees pos 4	1[E]		46			24	23		110	
Sediment	River Tees pos 5	1[E]		37			25	29		100	
Sediment	River Tees pos 6	1[E]		44			25	27		74	
Sediment	River Tees pos 7	1[E]		42			28	29		77	
Sediment	River Tees pos 8	1[E]		40			24	24		97	
Sediment	River Tees pos 9	1[E]		24			16	16		96	
Sea coal	Old Town Basin	2[E]									
Sea coal	Carr House Sands	2[E]									
Freshwater	R Tees pos 1	1[E]		<0.010			<0.01	<0.01		<20	
Freshwater	R Tees pos 2	1[E]		<0.010			<0.01	<0.01		<21	
Seawater	North Gare	2									
Seawater	North Gare	2[E]									

Table 5.5(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples												
Plaice	1.9 km ENE Hartlepool	1	0.014	0.00043	0.012			<0.24			<28	110
Plaice	Pipeline	2						<0.05				
Whiting	1.9 km ENE Hartlepool	1	0.030	0.0011	0.028			<0.27			<28	120
Cod	Pipeline	2						<0.14				
Crabs	1.9 km ENE Hartlepool	1	0.081	0.0021	0.074			<0.07			<28	60
Crabs	Pipeline	2				0.00025	0.0016	0.0018	*	0.0000079		
Winkles	Paddy's Hole	1				0.0092	0.058	0.029	0.00011	0.000072		
Winkles	South Gare	1						<0.31				
Winkles	Seal Sands	1	1.0	0.028	0.90			<0.06			<28	140
Mussels	South Gare	1						<0.12			<28	38
Mussels	The Heugh	1						<0.06				
Mussels	Pipeline	1	0.76	0.028	0.66			<0.13			<28	72
Fucus vesiculosus	Pilot Station	2					<0.13					
Fucus vesiculosus	North Gare	1	2.1	0.079	1.8			<0.20			<28	260
Fucus vesiculosus	Pipeline	1	1.8	0.065	1.6			<0.11			<28	320
Fucus vesiculosus	Greatham Creek	1	1.3	0.038	1.1			<0.19			<28	300
Fucus vesiculosus	Seal Sands	1	1.4	0.040	1.2			<0.10			<28	330
Seaweed	Pilot Station	2[E]						<2.0				
Sediment	Old Town Basin	2[E]						<1.1				710
Sediment	Seaton Carew	2[E]						<0.83				
Sediment	Paddy's Hole	2[E]						<1.7				550
Sediment	North Gare	2[E]						<0.85				160
Sediment	Greatham Creek	2[E]						<2.0				920
Sediment	River Tees pos 1	1[E]	8.5	<1.5	5.3			<5.0			45	350
Sediment	River Tees pos 2	1[E]	21	2.6	17			<5.0			590	1100
Sediment	River Tees pos 3	1[E]	20	1.5	19			<5.0			670	970
Sediment	River Tees pos 4	1[E]	18	1.4	14			<5.0			610	1300
Sediment	River Tees pos 5	1[E]	16	2.5	13			<5.0			660	1400
Sediment	River Tees pos 6	1[E]	14	2.4	14			<10			760	1500
Sediment	River Tees pos 7	1[E]	17	2.7	16			<5.0			690	1400
Sediment	River Tees pos 8	1[E]	24	4.0	17			<5.0			600	1300
Sediment	River Tees pos 9	1[E]	9.8	2.1	8.3			<5.0			510	990
Sea coal	Old Town Basin	2[E]						<1.2				
Sea coal	Carr House Sands	2[E]						<1.9				
Freshwater	R Tees pos 1	1[E]	0.044	<0.010	0.039			<0.10				
Freshwater	R Tees pos 2	1[E]	0.050	<0.010	0.038			<0.10				
Seawater	North Gare	2										
Seawater	North Gare	2[E]						<0.63			<2.1	15

Table 5.5(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples									
Milk		6	<4.3	14	<0.40	<0.23	<0.28		
Milk	max		<4.5	17	<0.48	<0.25	<0.30		
Apples		1	<4.0	23	<0.10	<0.30	<0.30		
Beetroot		1	<4.0	15	<0.10	<0.30	<0.40		
Blackberries		1	<4.0	16	<0.20	<0.30	<0.40		
Cabbage		1	<5.0	<3.0	<0.20	<0.30	<0.30		
Honey		1	9.0	71	<0.20	<0.20	<0.20		
Potatoes		1	<5.0	25	0.20	<0.30	<0.20		
Runner beans		1	<4.0	15	0.20	<0.20	<0.30		
Wheat		1	<7.0	68	0.50	<0.30	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.27	<0.24	<0.05	0.14
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<1.0	<0.32	<0.27	<0.06	<0.25

* *Not detected by the method used*
[a] *Except for milk and water where units are Bq l^{-1}*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima*
If no 'max' value is given the mean value is the most appropriate for dose assessments
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.5(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2005

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
Fish Sands	Sand	2	0.067
Old Town Basin	Mud	1	0.068
Old Town Basin	Mud and sand	1	0.069
Carr House	Sand	2	0.061
Seaton Carew	Sand	2	0.066
Seaton Sands	Sand	2	0.063
North Gare	Sand	2	0.059
Paddy's Hole	Mud and pebbles	2	0.17
Greatham Creek Bird Hide	Mud and stones	1	0.081
Greatham Creek Bird Hide	Grass and mud	1	0.069

Table 5.6(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2005

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Marine samples									
Flounder	Flookburgh	3			100	<0.10			<1.0
Plaice	Flookburgh	1				<0.40			<3.7
Plaice	Morecambe	4	<25	36		<0.12	0.034	2.9	<1.3
Bass	Morecambe	2				<0.17			<1.8
Whitebait	Sunderland Point	1				<0.08	0.28		<0.63
Shrimps	Flookburgh	4			130	<0.09		2.6	<0.79
Cockles	Middleton Sands	2				1.6			1.0
Cockles[b]	Flookburgh	3			120	1.7	0.43	9.3	<2.4
Winkles	Red Nab Point	4				0.99			<1.7
Mussels	Morecambe	4	67	67	140	<1.0		200	<2.4
Fucus vesiculosus	Half Moon Bay	4				0.71		1200	<2.0
Seaweed	Half Moon Bay	2[E]				<2.0		570	<13
Sediment	Flookburgh	2[E]				<0.69			<6.6
Sediment	Half Moon Bay	2[E]				<0.87			
Sediment	Pott's Corner	2[E]				<0.75			
Sediment	Heysham Pipelines	2[E]				<0.74			
Sediment	Morecambe Central Pier	2[E]				<2.1			
Sediment	Sunderland Point	4[E]				2.3			<4.9
Sediment	Conder Green	4[E]				2.5			<6.8
Sediment	Sand Gate Marsh	4[E]				<1.7			<7.3
Turf	Conder Green	4				3.8			<12
Turf	Sand Gate Marsh	4				<1.3			<8.2
Samphire	Cockerham Marsh	1				<0.04			<0.42
Seawater	Pipeline	2		24					
Seawater	Heysham Harbour	1[E]				<0.46			<3.6

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu
Marine samples									
Flounder	Flookburgh	3	<0.22	<0.29	<0.10	12	0.00054	0.0026	
Plaice	Flookburgh	1	<0.61	<0.73	<0.36	6.3			
Plaice	Morecambe	4	<0.26	<0.31	<0.13	4.9			
Bass	Morecambe	2	<0.37	<0.38	<0.18	11			
Whitebait	Sunderland Point	1	<0.13	<0.17	<0.07	5.4	0.092	0.49	4.1
Shrimps	Flookburgh	4	<0.15	<0.23	<0.08	4.8	0.0040	0.022	0.18
Cockles	Middleton Sands	2	<0.08	0.71	<0.05	3.4	0.31	1.8	
Cockles[b]	Flookburgh	3	<0.22	<1.0	<0.12	4.6	0.48	2.4	20
Winkles	Red Nab Point	4	<0.16	1.4	<0.07	5.0	0.35	1.9	
Mussels	Morecambe	4	<0.17	1.3	<0.09	4.0	0.44	2.3	
Fucus vesiculosus	Half Moon Bay	4	<0.45	1.5	<0.17	5.3			
Seaweed	Half Moon Bay	2[E]	<2.3	<10	<1.9	7.2			
Sediment	Flookburgh	2[E]		<7.7	<0.69	320			
Mud and sand	Half Moon Bay	1					8.8	50	
Sediment	Half Moon Bay	2[E]				23			
Sediment	Pott's Corner	2[E]				34			
Sediment	Heysham Pipelines	2[E]				24			
Sediment	Morecambe Central Pier	2[E]				110			
Sediment	Sunderland Point	4[E]		<5.3	<0.62	68			
Sediment	Conder Green	4[E]		<7.4	<0.79	160			
Sediment	Sand Gate Marsh	4[E]		<7.9	<0.76	210			
Turf	Conder Green	4	<1.9	<8.2	<1.2	260			
Turf	Sand Gate Marsh	4	<1.3	<2.6	<0.91	120			
Samphire	Cockerham Marsh	1	<0.08	<0.10	<0.04	1.1			
Seawater	Half Moon Bay	1			*	0.21			
Seawater	Heysham Harbour	1[E]	<0.68		<0.46	<0.42			

Table 5.6(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Total alpha	Total beta
Marine samples							
Flounder	Flookburgh	3	0.0049	*	0.000017		
Plaice	Flookburgh	1	<0.25				
Plaice	Morecambe	4	<0.43				
Bass	Morecambe	2	<0.13				
Whitebait	Sunderland Point	1	0.84	0.0037	0.0011		
Shrimps	Flookburgh	4	0.036	*	*		
Cockles	Middleton Sands	2	4.8	*	0.0075		
Cockles[b]	Flookburgh	3	6.5	0.020	0.0085		
Winkles	Red Nab Point	4	3.5	0.0046	0.0056		
Mussels	Morecambe	4	4.3	*	0.0069		
Fucus vesiculosus	Half Moon Bay	4	0.79				
Seaweed	Half Moon Bay	2[E]	<2.4				
Sediment	Flookburgh	2[E]	190			740	740
Mud and sand	Half Moon Bay	1	86	*	0.089		
Sediment	Half Moon Bay	2[E]	21				
Sediment	Pott's Corner	2[E]	15				
Sediment	Pipeline	2[E]	20				
Sediment	Morecambe Central Pier	2[E]	110				
Sediment	Sunderland Point	4[E]	64			310	470
Sediment	Conder Green	4[E]	130			490	730
Sediment	Sand Gate Marsh	4[E]	130			550	710
Turf	Conder Green	4	180				
Turf	Sand Gate Marsh	4	72				
Samphire	Cockerham Marsh	1	0.65				25
Seawater	Heysham Harbour	1[E]	<0.52			<1.6	13

Material	Location 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	^{106}Ru	^{110m}Ag	^{137}Cs	Total alpha	Total beta
Terrestrial samples											
Milk		6	<4.9	16	<0.43	<0.30	<2.4	<0.30	<0.30		
Milk	max		<6.0	17	<0.55	<0.40	<2.6	<0.33	<0.33		
Apples		1	<4.0	7.0	<0.10	<0.30	<2.4	<0.30	<0.30		
Blackberries		1	<4.0	20	<0.20	<0.20	<2.4	<0.30	<0.30		
Cabbage		1	<4.0	11	0.70	<0.30	<1.5	<0.30	<0.20		
Honey		1	<8.0	140	<0.10	<0.20	<1.4	<0.20	0.20		
Onions		1	<4.0	14	0.20	<0.30	<1.5	<0.30	<0.30		
Potatoes		1	<5.0	17	<0.10	<0.40	<2.7	<0.30	<0.40		
Sprouts		1	7.0	7.0	1.4	<0.30	<2.0	<0.30	<0.30		
Freshwater	Lancaster	2[E]	<4.0		<1.0	<0.33			<0.28	<0.035	<0.10

* *Not detected by the method used*

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

[b] *The concentration of ^{210}Po was 20 Bq kg^{-1}*

[c] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[d] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
Greenodd Salt Marsh	Grass and mud	2	0.075
Sand Gate Marsh	Salt marsh	4[F]	0.085
Sand Gate Marsh	Salt marsh	2	0.088
Sand Gate Marsh	Grass and mud	2	0.095
Flookburgh	Salt marsh and mud	1	0.094
Flookburgh	Salt marsh	1	0.088
High Foulshaw	Salt marsh	1	0.079
High Foulshaw	Salt marsh and mud	1	0.079
High Foulshaw	Grass and mud	2	0.079
Arnside 1	Mud and sand	3	0.074
Arnside 1	Sand	1	0.081
Arnside 2	Salt marsh	4	0.096
Morecambe Central Pier	Mud and pebbles	1	0.082
Morecambe Central Pier	Pebbles and sand	1	0.077
Half Moon Bay	Rock and sand	1	0.071
Half Moon Bay	Pebbles and sand	1	0.072
Heysham pipelines	Mud and sand	1	0.080
Heysham pipelines	Sand	1	0.079
Middleton Sands	Sand	2	0.074
Sunderland	Mud	3	0.089
Sunderland	Grass and mud	1	0.076
Sunderland Point	Mud	3	0.090
Sunderland Point	Mud and sand	1	0.086
Colloway Marsh	Salt marsh	3	0.090
Colloway Marsh	Salt marsh and mud	1	0.083
Lancaster	Grass and mud	3	0.078
Lancaster	Grass	1	0.079
Aldcliffe Marsh	Salt marsh	3	0.10
Aldcliffe Marsh	Grass and mud	1	0.091
Conder Green	Mud	1	0.093
Conder Green	Salt marsh	4[F]	0.099
Conder Green	Grass and mud	3	0.084

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 5.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2005

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples												
Cod	Stolford	2	320	330	30	<0.11	<0.11			<0.22	<0.11	0.61
Shrimps	Stolford	2	240	260	44	<0.10	<0.10			<0.22	<0.11	0.58
Whelks	Stolford	1		2300	67	<0.14	<0.12			<0.27	<0.12	0.43
Seaweed	Pipeline	2[E]					<2.2	<0.50	22	<10	<1.8	<1.9
Sediment	1.6 km east of pipeline	2[E]					<1.8	<1.3				<25
Sediment	Pipeline	2[E]					<0.78	<1.6				7.1
Sediment	0.8 km west of pipeline	2[E]					<0.59	<1.4				4.1
Sediment	Stolford	2[E]					<0.73	<1.7				7.2
Sediment	Steart Flats	2[E]					<0.69	<1.7				16
Sediment	River Parrett	2[E]					<1.8	<1.6				38
Seawater	Pipeline	2[E]					<0.33	<0.020			<0.30	<0.24

Material	Location	No. of sampling observa-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{144}Ce	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Marine samples											
Cod	Stolford	2	<0.38	<0.16			<0.09				
Shrimps	Stolford	2	<0.39	<0.16	0.00011	0.00049	0.00069	*	0.000015		
Whelks	Stolford	1	<0.51	<0.19			<0.09				
Seaweed	Pipeline	2[E]	<5.6				<2.4				
Sediment	1.6 km east of pipeline	2[E]					<2.4				
Sediment	Pipeline	2[E]					<1.1				
Sediment	0.8 km west of pipeline	2[E]					<0.87				
Sediment	Stolford	2[E]					<1.0				
Sediment	Steart Flats	2[E]					<1.1				
Sediment	River Parrett	2[E]					<2.4				
Seawater	Pipeline	2[E]	<1.2				<0.63			<2.4	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Total alpha	Total beta
Terrestrial samples								
Milk		6	<4.5	16	<0.41	<0.26		
Milk	max		<5.0	20	0.80	<0.28		
Apples		1	<4.0	16	0.30	<0.30		
Blackberries		1	8.0	17	0.80	<0.30		
Cabbage		1	9.0	9.0	4.8	<0.40		
Onions		1	8.0	16	1.8	<0.30		
Potatoes		1	7.0	13	0.90	<0.30		
Rhubarb		1	6.0	4.0	0.20	<0.50		
Runner beans		1	6.0	8.0	1.1	<0.30		
Wheat		1	<7.0	98	1.2	<0.30		
Freshwater	Durleigh Reservoir	2[E]	<4.0		<1.3	<0.25	0.048	0.23
Freshwater	Ashford Reservoir	2[E]	<4.0		<1.0	<0.25	<0.034	<0.12

* *Not detected by the method used*

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

[b] *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 value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2005

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Sand	2	0.069
Burnham	Sand	2	0.065
River Parrett	Mud and sand	2[F]	0.078
Steart Flats	Sand	1	0.088
Steart Flats	Mud and sand	1	0.083
Stolford	Stones	1	0.066
Stolford	Rock and sand	1	0.074
Hinkley Point	Pebbles and sand	1	0.069
Hinkley Point	Shingle and rock	1	0.095
Kilve	Pebbles and stones	1	0.070
Kilve	Rock and slate	1	0.078
Watchet Harbour	Mud and rock	1	0.090
Watchet Harbour	Pebbles and stones	1	0.088
Blue Anchor Bay	Pebbles	1	0.078
Blue Anchor Bay	Sand and shingle	1	0.075

[F] Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency

Table 5.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], $Bq\ kg^{-1}$						
			^{3}H	^{14}C	^{60}Co	^{110m}Ag	^{134}Cs	^{137}Cs	^{238}Pu
Aquatic samples									
Cod	Sizewell	2	<25		<0.04	<0.09	<0.06	0.59	
Sole	Sizewell	2	<25		<0.05	<0.12	<0.06	0.24	
Crabs	Sizewell	2		31	<0.05	<0.10	<0.05	0.23	0.00011
Shrimps	Sizewell	1			<0.05	<0.10	<0.06	<0.06	0.00018
Oysters	Blyth Estuary	1			<0.08	<1.6	<0.09	<0.08	
Mussels	River Alde	2	<25		<0.19	<0.35	<0.18	<0.17	
Sediment	Rifle range	2^{E}			<0.45			<0.38	
Sediment	Aldeburgh	2^{E}			<0.41			<0.36	
Sediment	Southwold	2^{E}			<1.1			11	
Seawater	Aldeburgh	2	<1.5						
Seawater	Sizewell	2^{E}			<0.38	<0.48	<0.35	<0.30	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], $Bq\ kg^{-1}$					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples								
Cod	Sizewell	2		<0.13				
Sole	Sizewell	2		<0.10				
Crabs	Sizewell	2	0.00060	0.00068	*	0.000022		
Shrimps	Sizewell	1	0.00081	0.0014	*	*		
Oysters	Blyth Estuary	1		<0.06				
Mussels	River Alde	2		<0.13				
Sediment	Rifle range	2^{E}		<0.61				
Sediment	Aldeburgh	2^{E}		<0.58				
Sediment	Southwold	2^{E}		<1.7				
Seawater	Sizewell	2^{E}		<0.41			<3.2	23

Table 5.8(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{134}Cs	^{137}Cs	Total Cs
Terrestrial samples									
Milk		6	<4.6	17	<0.32		<0.28	<0.30	
Milk	max		<5.0	21	<0.38		<0.33	<0.33	
Apples		1	<5.0	15	0.30		<0.20	<0.30	
Barley		1	12	91	1.3		<0.30	<0.30	
Blackberries		1	<5.0	12	0.20		<0.30	<0.30	
Cabbage		1	<4.0	8.0	<0.40		<0.30	<0.30	
Carrots		1	7.0	<4.0	0.20		<0.20	<0.30	
Honey		1	<7.0	90	<0.10		<0.30	<0.30	
Pig offal		1	<8.0	20	1.0	0.018			0.47
Pig muscle		1	6.0	40	0.60	<0.0070			0.19
Potatoes		1	<4.0	18	<0.20		<0.30	<0.40	
Runner beans		1	<4.0	<3.0	0.20		<0.30	<0.30	
Freshwater	Nature Reserve	2[E]	<4.0		<1.0		<0.38	<0.32	
Freshwater	The Meare	2[E]	<4.0		<1.0		<0.48	<0.40	
Freshwater	Leisure Park	2[E]	<4.0		<1.0		<0.47	<0.38	

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Pig offal		1	<0.00050	<0.00060	<0.00040		
Pig muscle		1	<0.00010	0.00020	0.00040		
Freshwater	Nature Reserve	2[E]				<0.035	0.44
Freshwater	The Meare	2[E]				<0.038	0.44
Freshwater	Leisure Park	2[E]				<0.031	0.22

** Not detected by the method used*
[a] *Except for milk and water where units are Bq l^{-1} and for sediment where dry concentrations apply*
[b] *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 value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 5.8(b). Monitoring of radiation dose rates near Sizewell, 2005

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	2	0.13
Dunwich	Sand and shingle	1	0.066
Dunwich	Shingle	1	0.053
Rifle Range	Sand and shingle	1	0.060
Rifle Range	Shingle	1	0.062
Aldeburgh	Sand and shingle	2	0.058
Southwold Harbour	Mud and shingle	1	0.071
Southwold Harbour	Salt marsh and mud	1	0.065

Table 5.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Marine samples											
Flounder	Inner Solway	1		90	<0.17	0.29	<0.10	<0.96	<1.7	6.5	<1.7
Lemon sole	Inner Solway	1			<0.11	<0.33		<0.53	<0.78		<1.1
Plaice	Inner Solway	1			<0.14	<0.41		<0.66	<0.97	0.32	<1.4
Salmon	Inner Solway	1	<5.0		<0.10	<0.29		<0.62	<1.5		<0.81
Sea trout	Inner Solway	1	<5.0		<0.10	<0.16		<0.34	<0.85		<0.42
Shrimps	Inner Solway	3	<6.1		<0.10	<0.14	0.18	<0.17	<0.40	1.2	<0.40
Cockles	North Solway	6[F,S]	5.3	99	1.7	<0.13	0.60	<0.19	<0.29	12	<0.73
Mussels	North Solway	8[F,S]	<5.0	120	0.59	<014	0.88	<0.23	<0.40	100	<0.79
Winkles	Southerness	4	<5.0		1.0	<0.34	0.21	<0.38	<0.43	150	<1.3
Seaweed	Pipeline	4			0.84	<0.17		<0.26	<0.25	2600	<0.45
Seaweed	Dornoch Brow	1			0.34	<0.36		<0.37	<0.40		<1.1
Seaweed	Redkirk	1			1.5	<0.38		<0.82	<2.0		<0.82
Sediment	Southerness	1			0.41	<0.27		<0.21	<0.11		<0.71
Sediment	Pipeline	4	<5.0		2.6	<0.35		<0.64	<1.2		<5.5
Salt marsh	Dornoch Brow	1			2.8	<0.22		<0.29	0.37		6.9
Seawater	Pipeline	4	6.2		<0.10	<0.12		<0.15	<0.21		<0.25
Seawater	Southerness	3	6.6		<0.10	<0.11		<0.12	<0.13		<0.24

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples											
Flounder	Inner Solway	1	<0.28	<0.45	<0.17	15	<0.23	<0.45	0.0011	0.0024	
Lemon sole	Inner Solway	1	<0.17	<0.28	<0.11	2.7	<0.13	<0.25			
Plaice	Inner Solway	1	<0.22	<0.37	<0.13	4.0	<0.19	<0.37			
Salmon	Inner Solway	1	<0.11	<0.20	<0.10	0.19	<0.11	<0.17			
Sea trout	Inner Solway	1	<0.10	<0.11	<0.10	0.81	<0.10	<0.14			
Shrimps	Inner Solway	3	<0.11	<0.15	<0.10	3.3	<0.10	<0.13	0.0022	0.011	
Cockles	North Solway	6[F,S]	<0.11	0.67	<0.08	3.7	<0.14	<0.14	0.76	4.2	30
Mussels	North Solway	8[F,S]	<0.12	0.75	<0.09	2.6	<0.15	<0.15	0.56	3.0	29
Winkles	Southerness	4	<0.21	<0.82	<0.14	1.2	<0.17	<0.32	0.18	1.4	
Seaweed	Pipeline	4	<0.11	1.2	<0.10	11	<0.11	0.35	0.90	5.1	
Seaweed	Dornoch Brow	1	<0.16	0.63	<0.12	1.5	<0.14	<0.26			
Seaweed	Redkirk	1	<0.18	1.3	<0.13	50	<0.16	<0.31			
Sediment	Southerness	1	<0.11	1.1	<0.10	23	<0.17	0.92	2.8	16	
Sediment	Pipeline	4	<0.15	4.3	<0.11	200	<0.95	<1.3	11	81	
Salt marsh	Dornoch Brow	1	0.17	4.4	0.19	210	0.93	1.5			
Seawater	Pipeline	4	<0.10	<0.11	<0.10	<0.14	<0.10	<0.11			
Seawater	Southerness	3	<0.10	<0.11	<0.10	0.11	<0.10	<0.10	<0.00011	0.0013	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples							
Flounder	Inner Solway	1	0.0046				
Lemon sole	Inner Solway	1	<0.15				
Plaice	Inner Solway	1	<0.17				
Salmon	Inner Solway	1	<0.22				
Sea trout	Inner Solway	1	<0.12				
Shrimps	Inner Solway	3	0.024				
Cockles	North Solway	6[F,S]	10	*	0.015		
Mussels	North Solway	8[F,S]	7.0	0.0083	0.0058		
Winkles	Southerness	4	2.5				
Seaweed	Pipeline	4	7.9			14	530
Seaweed	Dornoch Brow	1	0.73			2.3	340
Seaweed	Redkirk	1	39			63	440
Sediment	Southerness	1	25				
Sediment	Pipeline	4	180				
Salt marsh	Dornoch Brow	1	150				
Seawater	Pipeline	4	<0.10				
Seawater	Southerness	3	<0.0011				

Table 5.9(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru
Terrestrial samples										
Milk		12	<27	<15	<1.0	<0.05	<0.10	<0.17	<0.20	<0.41
Milk	max		160	19	<1.3	<0.06		<0.21	<0.26	<0.47
Apples		1	23	19	<0.50	<0.05	<0.10	<0.06	<0.05	<0.25
Barley		1	7.5	82	2.7	<0.05	0.49		<0.07	<0.39
Blackberries		1	5.9	16	<0.50	<0.05	0.28		<0.05	<0.11
Cabbage		1	52	<15	0.75	<0.05	0.26		<0.09	<0.38
Carrots		1	51	<15	<0.50	<0.05	0.29		<0.09	<0.40
Crab Apples		1	9.7	21	<0.50	<0.05	0.18		<0.10	<0.42
Honey		1	110	39	<0.90	<0.05	<0.19	<0.05	<0.05	<0.12
Potatoes		1	56	18	0.71	<0.05	<0.10	<0.14	<0.14	<0.40
Red Elder		1	11	22	<0.50	<0.05	0.27		<0.05	<0.21
Rosehips		1	<5.0	45	<0.50	<0.05	1.1		<0.09	<0.39
Turnips		1	52	<15	0.87	<0.05	0.19	<0.08	<0.06	<0.35
Grass		4	<92	<16	<3.1	<0.05	0.56	<0.11	<0.12	<0.27
Grass	max		280	21	<6.0		1.2	<0.16	<0.18	<0.43
Soil		4	<27	<15	<4.9	<0.08	3.4	<0.15	<0.13	<0.44
Soil	max		83		<8.6	0.18	8.0	<0.18	<0.18	<0.55

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{110m}Ag	^{134}Cs	^{137}Cs	^{241}Am	Total alpha	Total beta
Terrestrial samples								
Milk		12	<0.05	<0.05	<0.05	<0.07		
Apples		1	<0.05	<0.05	<0.05	<0.08		
Barley		1	<0.05	<0.05	<0.05	<0.15		
Blackberries		1	<0.05	<0.05	<0.05	<0.05		
Cabbage		1	<0.05	<0.05	<0.05	<0.12		
Carrots		1	<0.05	<0.05	<0.05	<0.13		
Crab Apples		1	<0.05	<0.05	<0.05	<0.14		
Honey		1	<0.05	<0.05	0.89	<0.05		
Potatoes		1	<0.05	<0.05	0.12	<0.13		
Red Elder		1	<0.05	<0.05	<0.05	<0.07		
Rosehips		1	<0.05	<0.05	<0.05	<0.12		
Turnips		1	<0.05	<0.05	<0.05	<0.11		
Grass		4	<0.05	<0.05	<0.07	<0.09	1.7	120
Grass	max				0.09	<0.14	2.3	140
Soil		4	<0.06	<0.06	16	<0.61	250	1000
Soil	max		<0.08	<0.08	24	0.97	280	1200

[a] *Except for seawater and milk where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima*
If no 'max' value is given the mean value is the most appropriate for dose assessments
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[F,S] *Samples collected on behalf of the Food Standards Agency and SEPA*

Table 5.9(b). Monitoring of radiation dose rates near Chapelcross, 2005

Location	Ground type	No. of sampling observations	µGy h⁻¹
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.059
Glencaple Harbour	Mud and sand	4	0.086
Priestside Bank	Salt marsh	4	0.064
Powfoot Merse	Mud	4	0.075
Pipeline	Sand	4	0.084
Pipeline	Salt marsh	4	0.090
Pipeline 500m south	NA	1	0.077
Battlehill	Sand	3	0.075
Dornoch Brow	Mud and sand	4	0.080
Dornoch Brow	Salt marsh	4	0.084
Browhouses	NA	4	0.076
Redkirk	NA	3	0.065
Mean beta dose rates			µSv h⁻¹
Powfoot	Salt marsh	1	<1.0
Pipeline 500m north	NA	1	<1.0
Pipeline 500m south	NA	1	<1.0
Pipeline 500m east	NA	3	<1.0
Pipeline 500m west	NA	3	<1.0
Pipeline	Stake nets	4	<1.1

NA Not available

Table 5.9(c). Radioactivity in air near Chapelcross, 2005

Location	No. of sampling observations	Mean radioactivity concentration, mBq m⁻³		
		^{137}Cs	Total alpha	Total beta
Eastriggs	10	<0.010	<0.0087	<0.17
Kirtlebridge	12	<0.010	<0.0068	<0.17
Brydekirk	11	<0.010	<0.0078	<0.17

Nuclear power

Table 5.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{110m}Ag
Marine samples										
Cod	Millport	1		<0.10	<0.10	<0.10	<0.10	<0.38		<0.10
Hake	Millport	2		<0.10	<0.11	<0.10	<0.15	<0.18		<0.10
Crabs	Millport	2		<0.10	<0.10	<0.10	<0.12	<0.15	4.9	<0.10
Nephrops	Millport	2		<0.10	<0.12	<0.10	<0.14	<0.30		<0.10
Lobsters	Largs	1		<0.10	<0.14	<0.10	<0.22	<0.26	500	<0.10
Squat lobsters	Largs	3		<0.10	<0.10	<0.10	<0.12	<0.13	<0.87	<0.10
Winkles	Pipeline	2		0.39	<0.31	0.35	<0.34	<1.1		0.52
Scallops	Largs	3		<0.10	<0.10	<0.10	<0.13	<0.15		<0.10
Oysters	Hunterston	1		<0.10	<0.10	<0.10	<0.10	<0.10		<0.10
Seaweed	N of pipeline	2		2.6	<0.24	0.48	<0.33	<0.60		<0.17
Seaweed	S of pipeline	2		3.9	<0.12	1.0	<0.14	<0.49		<0.22
Sediment	Fairlie	1		<0.10	<0.10	0.11	<0.19	<0.16		<0.10
Sediment	Millport	1		<0.10	<0.13	<0.10	<0.26	<0.26		<0.12
Sediment	Ardneil Bay	1		<0.10	<0.10	<0.10	<0.15	<0.13		<0.10
Sediment	Gulls Walk	1		<0.10	<0.20	<0.10	<0.25	<0.88		<0.11
Seawater	Pipeline	2	8.9	<0.10	<0.14	<0.10	<0.20	<0.13		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{125}Sb	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine samples									
Cod	Millport	1	<0.10	0.68	<0.12	<0.10			<0.10
Hake	Millport	2	<0.13	1.6	<0.31	<0.15			<0.14
Crabs	Millport	2	<0.11	<0.18	<0.22	<0.12	0.011	0.057	<0.11
Nephrops	Millport	2	<0.12	<0.39	<0.27	<0.13			<0.12
Lobsters	Largs	1	<0.21	0.60	<0.47	<0.19			<0.12
Squat lobsters	Largs	3	<0.11	0.57	<0.21	<0.12	0.0034	0.014	0.010
Winkles	Pipeline	2	<0.29	0.48	<0.78	<0.29	0.021	0.096	0.22
Scallops	Largs	3	<0.11	<0.24	<0.23	<0.13	0.0035	0.014	0.010
Oysters	Hunterston	1	<0.13	0.20	<0.14	<0.13			<0.10
Seaweed	N of pipeline	2	<0.35	1.2	<0.57	<0.34			<0.20
Seaweed	S of pipeline	2	0.37	1.1	<0.25	<0.12			<0.12
Sediment	Fairlie	1	0.27	7.1	<0.48	<0.15			0.37
Sediment	Millport	1	<0.24	6.1	<0.87	<0.45			<0.34
Sediment	Ardneil Bay	1	<0.13	2.6	<0.40	<0.21			<0.19
Sediment	Gulls Walk	1	<0.18	5.5	<0.66	<0.22			<0.26
Seawater	Pipeline	2	<0.16	<0.10	<0.36	<0.15			<0.10

Table 5.10(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1} ^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples								
Milk		6	<5.2	<15	<1.1	<0.05	<0.10	<0.25
Milk	max		<6.2	<16	<1.5			
Apples		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Barley		1	<5.0	81	2.0	<0.05	0.54	<0.07
Blackberries		1	<5.0	18	1.8	<0.05	0.26	<0.05
Carrots		1	6.2	24	<0.50	<0.05	<0.10	<0.11
Cauliflower		1	<5.0	<15	<0.50	<0.05	<0.10	<0.06
Crab apples		1	<5.0	30	<0.50	<0.05	0.27	<0.06
Free range eggs		1	<5.0	26	<0.50	<0.05	<0.10	0.08
Honey		1	<5.0	49	<17	<0.05	<0.19	<0.05
Nettles		1	5.2	18	<0.78	<0.05	2.1	<0.57
Pheasant		1	<5.0	<15	15	<0.09	0.72	<0.39
Pig muscle		1	<5.0	19	1.7	<0.05	0.16	<0.18
Potatoes		1	<5.0	<15	<0.50	<0.05	0.13	<0.05
Rabbit		1	<5.0	24	4.6	<0.12	<0.10	<0.75
Rowan berries		1	<5.0	40	<0.50	<0.05	<0.10	<0.10
Turnips		1	<5.0	16	<0.50	<0.05	0.74	<0.05
Grass		3	<5.9	<22	6.7	<0.05	0.71	<0.12
Grass	max		7.8	30	15		1.2	<0.18
Soil		3	<5.0	<15	<2.2	<0.05	1.2	<0.21
Soil	max				<2.9		1.5	<0.33

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1} ^{110m}Ag	^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Terrestrial Samples								
Milk		6	<0.05	<0.09	<0.27	<0.06		
Milk	max		<0.06	<0.22	<0.32	<0.07		
Apples		1	<0.05	<0.05	<0.09	<0.05		
Barley		1	<0.05	0.06	<0.29	<0.13		
Blackberries		1	<0.05	<0.05	<0.11	<0.05		
Carrots		1	<0.05	0.07	<0.26	<0.11		
Cauliflower		1	<0.05	<0.05	<0.21	<0.11		
Crab apples		1	<0.05	<0.05	<0.33	<0.14		
Free range eggs		1	<0.05	<0.05	<0.21	<0.08		
Honey		1	<0.05	0.27	<0.18	<0.09		
Nettles		1	<0.05	0.15	<0.26	<0.12		
Pheasant		1	<0.11	0.70	<0.49	<0.13		
Pig muscle		1	<0.10	0.82	<0.32	<0.13		
Potatoes		1	<0.05	<0.05	<0.13	<0.06		
Rabbit		1	<0.14	0.25	<0.69	<0.17		
Rowan berries		1	<0.05	0.28	<0.25	<0.11		
Turnips		1	<0.05	<0.05	<0.27	<0.13		
Grass		3	<0.05	<0.16	<0.18	<0.08	53	280
Grass	max			0.32	<0.24	<0.11	160	570
Soil		3	<0.07	14	<0.45	<0.21	200	570
Soil	max		<0.08	16	<0.48	<0.22	260	780

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 5.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2005

Location	Ground type	No. of sampling observa-tions	µGy h[-1]
Mean gamma dose rates at 1m over substrate			
Largs Bay	NA	2	0.061
Kilchatten Bay	NA	2	<0.049
Millport	NA	2	<0.047
Gulls Walk	Mud	2	0.056
0.5 km north of pipeline	Sand	2	0.058
0.5 km south of pipeline	Sand and stones	2	0.073
Ardneil Bay	NA	2	<0.051
Ardrossan Bay	NA	2	<0.047
Beta dose rates			µSv h[-1]
Millport	NA	1	<1.0
Fairlie	NA	1	<1.0

NA Not available

Table 5.10(c). Radioactivity in air near Hunterston, 2005

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m[-3]		
		^{137}Cs	Total alpha	Total beta
Fencebay	12	<0.010	0.012	<0.18
West Kilbride	11	<0.011	<0.0088	<0.13
Crosbie Mains	10	<0.010	<0.010	<0.15

Table 5.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag
Marine samples								
Cod	Pipeline	2			<0.16	<0.14		<0.16
Cod	White Sands	2			<0.13	<0.12		<0.13
Crabs	Cove	1		25	<0.10	<0.10	1.4	<0.11
Lobsters	Cove	1			<0.10	<0.10	<0.75	<0.10
Nephrops	Dunbar	3			<0.11	<0.10		<0.11
Winkles	Pipeline	2			<0.14	0.23		1.2
Fucus vesiculosus	Pipeline	2			1.2	0.53		<0.21
Fucus vesiculosus	Thornton Loch	2			<0.54	<0.18	160	<0.10
Fucus vesiculosus	White Sands	2			<0.10	<0.10		<0.10
Seaweed	Pease Bay	2			<0.10	<0.10		<0.10
Fucus serratus	Coldingham Bay	2			<0.11	<0.10		<0.10
Sediment	Dunbar	1			<0.10	<0.10		<0.14
Sediment	Barns Ness	1			<0.10	<0.10		<0.12
Sediment	Thornton Loch	1			<0.10	<0.10		<0.10
Sediment	Heckies Hole	1			<0.10	<0.10		<0.16
Sediment	Eyemouth	1			<0.10	<0.10		<0.10
Salt marsh	Belhaven Bay	1			<0.10	<0.10		<0.10
Seawater	Pipeline	2	<1.5		<0.10	<0.10		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Marine samples									
Cod	Pipeline	2	0.34	<0.31			<0.19		
Cod	White Sands	2	0.37	<0.28			<0.17		
Crabs	Cove	1	<0.10	<0.26			<0.13		
Lobsters	Cove	1	<0.10	<0.23			<0.13		
Nephrops	Dunbar	3	0.23	<0.24	0.0039	0.015	0.021		
Winkles	Pipeline	2	<0.13	<0.27			<0.15	4.8	110
Fucus vesiculosus	Pipeline	2	0.20	<0.23			<0.14		
Fucus vesiculosus	Thornton Loch	2	0.18	<0.17			<0.13		
Fucus vesiculosus	White Sands	2	0.20	<0.16			<0.12		
Seaweed	Pease Bay	2	<0.15	<0.10			<0.12		
Fucus serratus	Coldingham Bay	2	<0.11	<0.15			<0.12		
Sediment	Dunbar	1	4.9	<0.27			<0.38		
Sediment	Barns Ness	1	2.4	1.3			<0.35		
Sediment	Thornton Loch	1	1.40	<0.24			0.26		
Sediment	Heckies Hole	1	3.5	1.2			<0.46		
Sediment	Eyemouth	1	2.3	0.60			<0.21		
Salt marsh	Belhaven Bay	1	0.71	<0.19			<0.18		
Seawater	Pipeline	2	<0.10	<0.10			<0.10		

Table 5.11(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial samples								
Milk		1	<5.0	<15	<0.87	<0.05	<0.10	<0.19
Blackberries		1	6.2	<15	0.58	<0.05	<0.10	<0.34
Cabbage		1	<5.0	<15	0.50	<0.05	0.14	<0.09
Cheese		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Courgettes		1	<5.0	<15	<0.28	<0.05	<0.10	<0.05
Eggs		1	<5.0	37	<2.5	<0.05	<0.10	<0.13
Elderberries		1	5.0	22	<0.50	<0.05	<0.10	<0.05
Goats' milk		3	<5.0	<15	<0.50	<0.05	<0.10	<0.20
Plums		1	<5.0	15	<0.50	<0.05	<0.10	<0.05
Potatoes		1	<5.0	20	<0.50	<0.05	<0.10	<0.05
Rowanberries		2	<7.9	29	<0.68	<0.05	<0.18	<0.12
Rowanberries	max		11	31	0.86		0.26	<0.17
Spring greens		1	<5.0	<15	<0.55	<0.05	0.48	<0.05
Turnips		1	<5.0	<15	0.95	<0.05	0.15	<0.07
Wheat		1	<5.0	75	<2.4	<0.05	0.93	<0.07
Grass		3	<5.2	28	1.9	<0.05	0.50	<0.34
Grass	max		5.7	29	3.6		0.58	<0.38
Soil		3	<5.0	<15	<3.8	<0.05	1.6	<0.41
Soil	max				<5.7	<0.06	2.4	<0.63

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{110m}Ag	^{137}Cs	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Milk		1	<0.05	<0.05	<0.05		
Blackberries		1	<0.06	<0.05	<0.07		
Cabbage		1	<0.05	<0.05	<0.14		
Cheese		1	<0.05	<0.05	<0.12		
Courgettes		1	<0.05	<0.05	<0.05		
Eggs		1	<0.05	<0.05	<0.07		
Elderberries		1	<0.05	<0.05	<0.05		
Goats' milk		3	<0.05	<0.05	<0.10		
Plums		1	<0.05	<0.05	<0.05		
Potatoes		1	<0.05	<0.05	<0.10		
Rowanberries		2	<0.05	<0.05	<0.12		
Rowanberries	max				<0.13		
Spring greens		1	<0.05	<0.05	<0.12		
Turnips		1	<0.05	<0.05	<0.14		
Wheat		1	<0.05	<0.05	<0.15		
Grass		3	<0.05	<0.08	<0.13	1.3	230
Grass	max			0.15	<0.22	2.4	420
Soil		3	<0.08	8.0	<0.29	250	760
Soil	max		<0.09	12	0.38	310	970

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk and goats' milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

Table 5.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Heckies Hole	Sediment	2	0.058
Dunbar Inner Harbour	Sand	2	0.082
Belhaven Bay	Salt marsh	2	0.046
Barns Ness	Mud, sand and stones	2	0.053
Skateraw	Sand	2	<0.048
Thornton Loch	Sand	2	<0.047
Pease Bay	Sand	2	0.050
St Abbs Head	Mud	2	0.089
Coldingham Bay	Sand	2	0.049
Eyemouth	Mud	2	0.060
Mean beta dose rates on fishing gear			µSv h^{-1}
Cove	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 5.11(c). Radioactivity in air near Torness, 2005

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Innerwick	12	<0.010	<0.0071	<0.14
Cockburnspath	11	<0.012	<0.011	<0.17

Table 5.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples											
Brown trout	Trawsfynydd Lake	6		32		<0.17	4.4	<0.56	<0.18	45	<0.48
Rainbow trout	Trawsfynydd Lake	6				<0.16		<0.36	<0.16	1.4	<0.49
Perch	Trawsfynydd Lake	6				<0.20	1.4	<0.80	<0.22	110	<0.60
Rudd	Trawsfynydd Lake	1				<0.20		<0.67	<0.22	56	<0.58
Mud	Pipeline	1				11		<5.9	1.5	1600	4.5
Sediment	Trawsfynydd Lake shore	2[E]				<1.1	<3.0	<16	<1.3	860	
Sediment	Bailey Bridge	2[E]				<7.0	44	<37	<3.5	770	
Sediment	Fish farm	2[E]				12	16	<22	<2.7	1500	
Sediment	Footbridge	2[E]				<1.1	<2.0	<12	<1.0	440	
Sediment	Cae Adda	2[E]				<1.9	6.1	<11	<1.0	440	
Freshwater	Cold Lagoon	2							*	0.01	
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.30			<0.30	<0.24	
Freshwater	Gwylan Stream	2[E]	<4.0		<1.0	<0.30			<0.30	<0.25	
Freshwater	Diversion culvert	2[E]	<4.0		<1.0	<0.30			<0.31	<0.26	
Freshwater	Hot Lagoon	2[E]	<4.0		<1.0	<0.28			<0.29	<0.25	
Freshwater	Afon Prysor	2[E]	<4.0		<1.0	<0.29			<0.31	<0.26	
Freshwater	Trawsfynydd Lake	2[E]	<4.0		<1.0	<0.30			<0.28	<0.25	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Freshwater samples										
Brown trout	Trawsfynydd Lake	6	<0.41	0.00012	0.00039	0.00073	*	0.000024		
Rainbow trout	Trawsfynydd Lake	6	<0.29	0.000055	0.00027	0.00074	*	*		
Perch	Trawsfynydd Lake	6	<0.50	0.000052	0.00033	0.00069	*	*		
Rudd	Trawsfynydd Lake	1	<0.52			<0.48				
Mud	Pipeline	1	<4.7	11	29	49	0.52	1.3		
Sediment	Trawsfynydd Lake shore	2[E]				3.2				
Sediment	Bailey Bridge	2[E]		4.5	16	63				
Sediment	Fish farm	2[E]		14	34	57				
Sediment	Footbridge	2[E]		<0.98	2.6	3.2				
Sediment	Cae Adda	2[E]		<0.84	2.0	3.7				
Freshwater	Public supply	2[E]							<0.025	<0.10
Freshwater	Gwylan Stream	2[E]							<0.020	0.14
Freshwater	Diversion culvert	2[E]							<0.030	<0.11
Freshwater	Hot Lagoon	2[E]							<0.10	0.12
Freshwater	Afon Prysor	2[E]							<0.070	0.39
Freshwater	Trawsfynydd Lake	2[E]							<0.030	<0.11

Table 5.12(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs
Terrestrial Samples									
Milk		2	<4.4	15		<0.30	0.060		
Milk	max		<4.5	16		<0.33	0.066		
Apples		1	<5.0	16	<0.10	<0.30		<0.30	0.40
Blackberries		1	4.0	16	0.30	<0.30		<0.30	0.50
Carrots		1	<4.0	8.0	0.20	<0.30		<0.30	<0.30
Cauliflower		1	<5.0	9.0	1.0	<0.30		<0.30	0.30
Eggs		1	<5.0	26	0.70	<0.40		<0.30	<0.30
Honey		1	10	110		<0.90		<0.70	2.9
Potatoes		1	7.0	13	0.30	<0.50		<0.30	<0.40
Sheep muscle		2	<5.5	24		<0.40	0.022		
Sheep muscle	max		<6.0	32			0.025		
Sheep offal		2	<7.5	30		<0.30	0.20		
Sheep offal	max		<8.0	42			0.25		

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			Total Cs	^{154}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am
Terrestrial Samples							
Milk		2	0.30	<0.31			
Milk	max		0.45	<0.38			
Apples		1		<0.30	<0.00010	<0.00020	<0.00020
Blackberries		1		<0.60	0.00010	<0.00020	0.00070
Carrots		1		<0.30	<0.00010	<0.00020	0.00050
Cauliflower		1		<0.30			
Eggs		1		<0.50	<0.00010	<0.00010	0.00060
Honey		1		<0.80			
Potatoes		1		<0.40	<0.00010	<0.00020	<0.00020
Sheep muscle		2	0.50	<0.25	<0.00010	<0.00020	<0.00020
Sheep muscle	max			<0.30			0.00020
Sheep offal		2	0.51	<0.45	<0.00035	<0.00035	<0.00020
Sheep offal	max		0.66	<0.60	<0.00040	<0.00040	0.00020

** Not detected by the method used*
[a] Except for milk and water where units are Bq l^{-1}, and for sediment where dry concentrations apply
[b] 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 value is the most appropriate for dose assessments
[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime
[E] Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 5.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Pebbles and stones	2	0.10
Lake shore	Mud and stones	1	0.095
Lake shore	Pebbles and rock	1	0.091
Bailey Bridge	Pebbles and stones	2	0.091
Fish Farm	Stones	1	0.10
Fish Farm	Pebbles and rock	1	0.10
Cae Adda	Pebbles and stones	2	0.089

Table 5.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{238}Pu
Marine samples										
Plaice	Pipeline	2	<25	<25	71	<0.05		<0.13	1.3	
Crabs	Pipeline	2				<0.15	4.3	<0.32	0.68	0.0040
Bass	Outfall	1	47	36		<0.16		<0.41	3.8	
Lobsters	Pipeline	2				<0.06	150	<0.12	0.74	
Winkles	Cemaes Bay	2	<25	<25	45	<0.11		0.57	0.42	0.028
Fucus vesiculosus	Cemaes Bay	2				<0.09	280	<0.30	1.1	
Seaweed	Cemaes Bay	2[E]				<2.4	730	<12	<1.9	
Sediment	Cemaes Bay	2[E]				<0.63			5.3	
Sediment	Cemlyn Bay	2[E]				<0.45			3.2	
Seawater	Cemaes Bay	2[E]				<0.32			<0.26	
Seawater	Cemlyn Bay	2[E]				<0.31			<0.24	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.18				
Crabs	Pipeline	2	0.023		0.077	0.000035	0.00014		
Bass	Outfall	1			<0.33				
Lobsters	Pipeline	2			0.14				170
Winkles	Cemaes Bay	2	0.16	1.2	0.20	*	0.00019		
Fucus vesiculosus	Cemaes Bay	2			0.16				
Seaweed	Cemaes Bay	2[E]			<2.7				
Sediment	Cemaes Bay	2[E]			<0.95				
Sediment	Cemlyn Bay	2[E]			<1.2				
Seawater	Cemaes Bay	2[E]			<0.63			<1.6	9.6
Seawater	Cemlyn Bay	2[E]			<0.45			<2.6	14

Material	Location or selection[b]	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
Terrestrial samples									
Milk		6	<4.5	17	<0.60	<0.32	<0.29		
Milk	max		<5.0	20	<0.95	<0.40	<0.30		
Milk[d]		1	<4.0	22					
Milk[d]		1	<4.0	18					
Milk[e]		1	<4.0	28					
Milk[f]		1	<4.0	19					
Apples		1	8.0	12	<0.10	<0.30	<0.30		
Blackberries		1	8.0	45	3.4	<0.30	<0.30		
Honey		1	<7.0	93	<0.10	<0.20	<0.30		
Oats		1	<7.0	72	1.9	<0.60	<0.40		
Onions		1	<2.0	6.0	0.30	<0.30	<0.40		
Potatoes		1	<5.0	20	0.20	<0.40	<0.30		
Rhubarb		1	4.0	10	<0.10	<0.40	<0.30		
Spinach		1	<4.0	<3.0	<0.10	<0.30	<0.20		
Freshwater	Public supply	1[E]	<4.0		<1.0	<0.30	<0.24	<0.020	0.17

** Not detected by the method used*

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *Additional milk sampling week commencing 28th March 2005*

[e] *Additional milk sampling week commencing 11th April 2005*

[f] *Additional milk sampling week commencing 18th April 2005*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

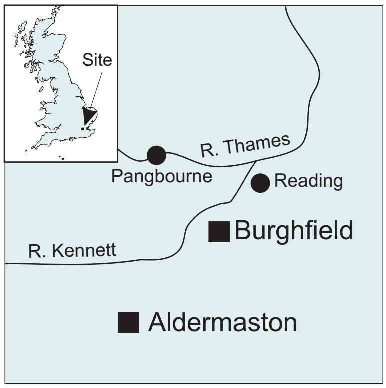
Table 5.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2005

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	1	0.076
Cemaes Bay	Rock and sand	1	0.068
Cemlyn Bay	Pebbles and sand	2	0.068

6. DEFENCE ESTABLISHMENTS

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and the Scottish Environment Protection Agency undertaken routinely near nine defence-related establishments in the UK. In addition, the MoD makes arrangements for monitoring at other defence sites where contamination may occur. Low-level gaseous discharges occur from Burghfield in Berkshire and the operator carries out environmental monitoring at this site. Monitoring at nuclear submarine berths is also carried out by the MoD (DSTL, 2005).

6.1 Aldermaston, Berkshire



The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low levels of radioactive waste to the environment. In 2005, the site was authorised to discharge aqueous radioactive waste to the sewage works at Silchester and to Aldermaston Stream. The Pangbourne pipeline, previously discharging aqueous waste to the River Thames at Pangbourne, officially closed on 16 March 2005. The replacement disposal route, the new waste treatment plant, is still undergoing commissioning and has not yet come online (Health and Safety Executive, 2005b). Samples of milk, other terrestrial foodstuffs, freshwater, fish and sediments were collected. The sampling locations are shown in Figure 4.1. Monitoring of the aquatic environment at Newbridge is undertaken to indicate control or background levels upstream of nuclear establishments located in the Thames catchment.

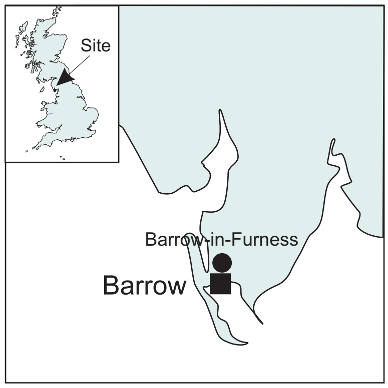
The results of measurements of radionuclides concentrations are shown in Tables 6.1(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2004. Levels of tritium were generally below the LoD though some enhancements were observed in sediments collected from road gullypots very close to the site. Caesium-137 concentrations were detected in sediment from the Thames and water courses near the site and were similar to those observed in recent years. Currently, routine discharges from AWE do not include significant levels of radiocaesium. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. A habit survey has established that the critical group affected by discharges into the river can be represented by anglers whose occupancy of the river bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established but the assessment has conservatively included consumption of fish at a low rate of 1 kg $year^{-1}$. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2). Consumption of locally harvested crayfish was also considered as a pathway for radiation exposure. Exposures were much less than 0.005 mSv using consumption data from the habits survey. The gross alpha and gross beta activity concentrations in the freshwater samples were below the WHO screening levels for drinking water. The drinking water pathway has been shown to be insignificant (Environment Agency, 2002a).

The concentrations of radioactivity in milk, vegetables, fruit and environmental indicator materials were also very low. Results for tritium, caesium-137, uranium and transuranic radionuclides were generally similar to those for 2004. Natural background or weapon test fallout would have made a significant contribution to the levels detected. The reported results for caesium-137 in soils were broadly similar to the values observed in 2004. Concentrations of uranium in soil were broadly similar to those found elsewhere in the area. Taking into account measured levels of plutonium and other radionuclides in local foodstuffs, the dose to consumers of local food in 2005, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

In May 2005, an unintentional release of tritium occurred, whilst handling legacy material. The releases occurred because a container, thought to be empty, was opened in an inappropriate building with insufficient precautions. The impact was very low because the release was less than the authorised discharge limit. The Environment Agency served an Enforcement Notice, requiring improvement to management systems.

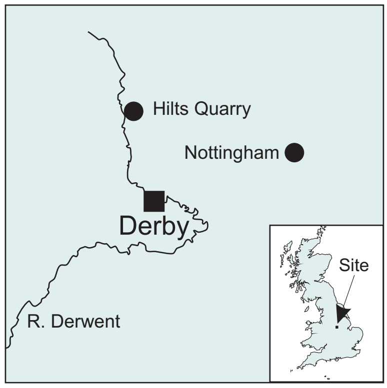
The Environment Agency is holding drop-in sessions for the public to discuss proposals for the future regulation of radioactive waste disposal from AWE. Public consultation on the limits and conditions under which AWE can dispose of radioactive waste at its two sites, at Aldermaston and Burghfield, began on 15 May 2006 (Environment Agency, 2006e).

6.2 Barrow, Cumbria



Discharges from submarine related operations at the site are very low. The Food Standards Agency's monitoring of Barrow is limited to grass sampling. In 2005, no tritium activity was detected (Table 6.3(a)). Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 3) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2005.

6.3 Derby, Derbyshire

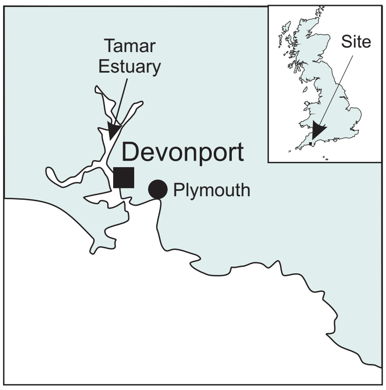


Rolls-Royce Marine Power Operations Ltd (RRMPOL) carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Megaloughton Lane Sewage Treatment Works to the River Derwent and very low levels of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including the LLWR at Drigg.

Results of monitoring at Derby are presented in Table 6.3(a). Routine sampling and analysis of uranium activity in grass and soil samples taken around the site found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. The gross alpha and gross beta activity levels in river water from the River Derwent were less than the WHO screening levels for drinking water and doses from using the river as a source of drinking water would be much less than 0.005 mSv y^{-1} (Table 6.2).

Table 6.3(a) also includes the results of monitoring of water from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for controlled burial of solid low level radioactive waste. Isotopes of uranium detected in the stream water were at levels similar to those seen elsewhere in Derbyshire (Table 9.15).

6.4 Devonport, Devon



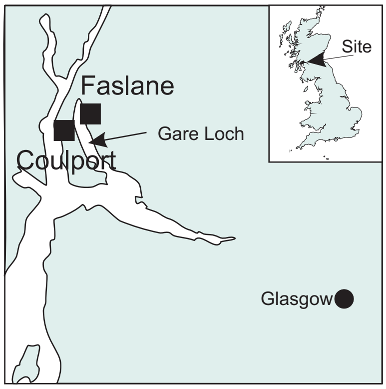
Devonport consists of two parts: the Naval Base which is owned and operated by the MoD, and Devonport Royal Dockyard which is owned and operated by Devonport Royal Dockyard Limited (DRDL). DRDL refits, refuels, repairs and maintains the Royal Navy's nuclear powered submarines and has an authorisation granted by the Environment Agency to discharge liquid wastes to the Hamoaze, which is part of the Tamar Estuary and to the local sewer and gases, mists and dusts to atmosphere. The MoD Naval Base is permitted to discharge liquid wastes to the sewer under an administrative agreement with the Environment Agency.

In June 2005, the Environment Agency served an Enforcement Notice on DRDL, following a spillage of approximately 16-20 litres of low activity water (containing cobalt-60) during commissioning of a decontamination process at 9 Dock (Environment Agency, 2005f). Monitoring showed no radioactivity was discharged to the environment and there was no hazard to the public or the environment. The Enforcement Notice requires DRDL to review, and improve where appropriate, arrangements for managing, maintaining and operating all equipment used in the processing, discharge and sampling waste at 9 Dock. Commissioning operations immediately stopped and these will not recommence until a full investigation is carried out and steps taken to prevent a recurrence.

The routine monitoring programme in 2005 consisted of measurements of gamma dose rate and analysis of fish, shellfish, fruit, grass and sediments. The results given in Tables 6.3(a) and (b) were similar to those in 2004 where comparisons can be drawn. Trace quantities of caesium-137, technetium-99 and americum-241 were found in the marine environment. These were most likely to have originated from Chernobyl and from spent fuel reprocessing elsewhere. Activation products were below LoDs. A habits survey in 2004 has established that there are two dominant critical groups for marine pathways, (i) fish and shellfish consumers and (ii) occupants of houseboats. Taking account of relevant consumption of marine foods and occupancy times, doses to both groups were estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2). Similarly the dose to high- rate consumers of fruit was less than 0.005 mSv. The radiological significance of this site continued to be low.

Defence

6.5 Faslane and Coulport, Argyll and Bute

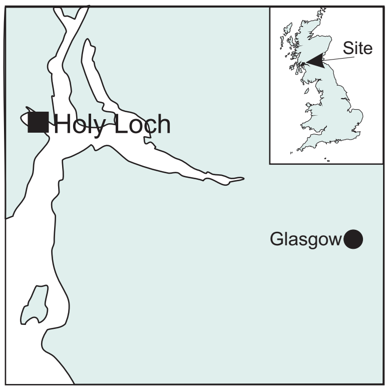


The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Naval Services, a subsidiary of Babcock Support Services Limited, operate at HMNB Clyde in partnership with MoD. However, MoD remains in control of the undertaking, through the Naval Base Commander, Clyde, in relation to radioactive waste disposal.

Work on the new effluent plant that the MoD plan to build at Faslane has been subject to delays and is now not scheduled to be commissioned until 2008. Consequently, the Scottish Environment Protection Agency has not progressed the determination of the application made by MoD in 2003, which relates to the disposal of liquid and gaseous wastes from the proposed plant.

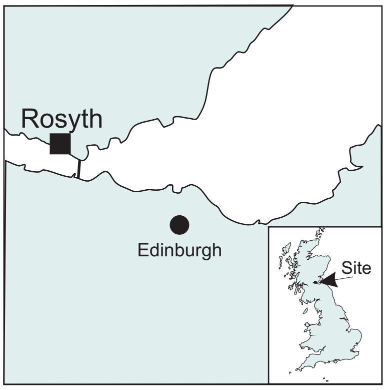
Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between the Scottish Environment Protection Agency and the MoD. The discharges made during 2005 are shown in Appendix 1. The disposal of solid radioactive waste from each site is also made under letters of agreement between the Scottish Environment Protection Agency and the MoD. Disposals of solid waste from the sites continued during 2005. Habit surveys have been used to investigate exposure pathways, the most recent of which identified fish consumption and external radiation from the shore as the major pathways of exposure. The scope of the monitoring programme reflects these pathways and included the analysis of seawater, sediment and fish samples. Results are given in Tables 6.3(a) and (b). These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield, and to weapons testing and Chernobyl fallout. Additionally, measurements of gamma dose rates made in the surrounding area were difficult to distinguish from natural background. Taking into account occupancy and consumption rate data from the habit survey, the dose to the critical group from external radiation and the consumption of fish was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.6 Holy Loch, Argyll and Bute



A small programme of monitoring at Holy Loch continued in order to determine the effects of past discharges from the US submarine support facilities which closed in March 1992. Low levels of cobalt-60 detected in sediments from the Loch are due to these earlier operations. Measurements of gamma dose rates in intertidal areas (Table 6.3(b)) showed similar levels with previous years. Additionally, the detected activity of cobalt-60 in sediment from the Loch was similar to that for 2004. The external radiation dose to the critical group was less than 0.005 mSv in 2005, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.7 Rosyth, Fife



Following the Government decision to have nuclear submarine refit work carried out at Devonport, submarines are no longer re-equipped, maintained or refuelled at the Rosyth site. The site is operated by Babcock Engineering Services who have completed assessment work in preparation of site decommissioning, which is expected to commence in 2006.

Radioactive waste produced during decommissioning will be disposed of under the conditions of an authorisation granted to Rosyth Royal Dockyard Limited in November 2004. Operational wastes continued to be discharged under separate, continuing, authorisations for such wastes.

The Scottish Environment Protection Agency's routine monitoring programme included sampling and analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 6.3(a) and (b). The radioactivity levels detected were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. A habits survey was undertaken in 2005. For marine pathways, the critical group remained as fish and shellfish consumers with an additional element of intertidal occupancy. Consumption and occupancy rates were increased (Appendix 4). The dose to the critical group of local fishermen in 2005 was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.2).

6.8 Vulcan NRTE, Highland

The Vulcan Nuclear Reactor Test Establishment operated by the MoD (Procurement Executive) is located adjacent to the UKAEA Dounreay site and the impact of its discharges is considered along with those from Dounreay in Section 4.

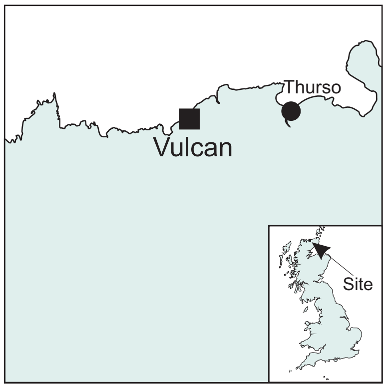


Table 6.1(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2005

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{57}Co	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Pike	Newbridge	1	<25	<25	<0.07	<0.10			
Pike	Outfall (Pangbourne)	1	<25	<25	<0.06	0.15			
Pike	Staines	1	<25	<25	<0.04	0.10			
Pike	Shepperton	1	<25	<25	<0.04	0.13			
Pike	Teddington	1	<25	<25	<0.03	0.14			
Flounder	Beckton	1		<25	<0.06	0.37			
Signal crayfish	Ufton Bridge - Theale	1	<25	25	<0.05	<0.10	0.036	0.00080	0.028
Nuphar lutea	Newbridge	1		<25	<0.03	0.10			
Nuphar lutea	Staines	1		<25	<0.03	<0.05			
Sediment	Pangbourne	4[E]				9.0	9.8	<0.66	10
Sediment	Mapledurham	4[E]				7.3	12	<0.57	11
Sediment	Aldermaston	4[E]				2.7	10	<0.64	8.3
Sediment	Spring Lane	4[E]				<0.76	9.1	<0.63	7.7
Sediment	Stream draining south	4[E]				<1.0	12	<0.75	11
Sediment	Reading (Kennet)	4[E]				<3.8	13	<0.80	12
Gullypot sediment	Falcon Gate	1[E]		80		<3.7	16	1.1	14
Gullypot sediment	Main Gate	1[E]		36		<0.32	14	1.1	16
Gullypot sediment	Tadley Entrance	1[E]		35		8.3	15	<0.55	15
Gullypot sediment	Burghfield Gate	1[E]		60		<1.2	13	0.76	14
Freshwater	Pangbourne	4[E]		<4.0		<0.23	<0.011	<0.0055	<0.012
Freshwater	Mapledurham	4[E]		<4.0		<0.23	0.019	<0.0050	0.014
Freshwater	Aldermaston	4[E]		11		<0.21	0.012	<0.0050	<0.012
Freshwater	Spring Lane	4[E]		<4.1		<0.19	<0.0058	<0.0058	<0.0068
Freshwater	Reading (Kennet)	4[E]		<4.0		<0.23	<0.0093	<0.0055	<0.0073
Crude liquid effluent	Silchester treatment works	4[E]		25		<0.27	<0.0058	<0.0055	<0.0065
Final liquid effluent	Silchester treatment works	4[E]		55		<0.32	<0.0083	<0.0053	<0.0088
Sewage sludge	Silchester treatment works	4[E]		<66		<0.27	0.52	<0.40	0.50

Material	Location	No. of sampling observations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Freshwater samples									
Pike	Newbridge	1	0.000023	0.00020	0.00023	*	*		
Pike	Outfall (Pangbourne)	1	0.000017	0.00011	0.00017	*	*		
Pike	Staines	1			<0.07				
Pike	Shepperton	1			<0.06				
Pike	Teddington	1			<0.11				
Flounder	Beckton	1			<0.09				
Signal crayfish	Ufton Bridge - Theale	1			<0.09				
Nuphar lutea	Newbridge	1			<0.05				
Nuphar lutea	Staines	1			<0.04				
Sediment	Pangbourne	4[E]	<0.62	<0.41	2.6			<190	300
Sediment	Mapledurham	4[E]	<0.52	<0.35	2.3			170	200
Sediment	Aldermaston	4[E]	<0.70	2.1	7.5			200	<280
Sediment	Spring Lane	4[E]	<0.63	<0.45	<2.4			240	400
Sediment	Stream draining south	4[E]	<0.60	<0.61	<4.2			220	350
Sediment	Reading (Kennet)	4[E]	<0.73	<0.70	5.5			<180	390
Gullypot sediment	Falcon Gate	1[E]	<0.47	0.97	<6.0			380	760
Gullypot sediment	Main Gate	1[E]	0.49	0.38	<0.85			380	630
Gullypot sediment	Tadley Entrance	1[E]	<0.70	0.88	<2.9			410	740
Gullypot sediment	Burghfield Gate	1[E]	<0.50	<0.30	<2.3			220	390
Freshwater	Pangbourne	4[E]	<0.012	<0.0058	<0.013			<0.28	0.37
Freshwater	Mapledurham	4[E]	<0.012	<0.0060	<0.017			<0.13	0.34
Freshwater	Aldermaston	4[E]	<0.012	<0.0055	<0.0083			<0.046	0.19
Freshwater	Spring Lane	4[E]	<0.012	<0.0088	<0.0098			<0.028	0.17
Freshwater	Reading (Kennet)	4[E]	<0.0088	<0.0050	<0.012			<0.031	<0.15
Crude liquid effluent	Silchester treatment works	4[E]	<0.013	<0.0055	<0.42			<0.093	0.62
Final liquid effluent	Silchester treatment works	4[E]	<0.011	<0.0060	<0.48			<0.059	<0.51
Sewage sludge	Silchester treatment works	4[E]	<0.19	<0.13	<0.49			<4.6	<13

Table 6.1(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk		4	<4.4	<0.26				<0.0061
Milk	max		<4.5	<0.28				
Beetroot		1	<5.0	<0.30				<0.033
Blackberries		1	<4.0	<0.30				<0.033
Cabbage		1	6.0	<0.30				<0.034
Carrots		1	<5.0	<0.30				<0.032
Potatoes		1	<5.0	<0.30				<0.033
Rabbit		1	<6.0	<0.40	0.0013	<0.00060	<0.00090	<0.033
Runner beans		1	<4.0	<0.30	0.0015	<0.00060	<0.0011	<0.033
Wheat		1	<7.0	<0.30				<0.032
Grass	Location 5	1[E]	<25	<2.7	<0.18	<0.18	<0.18	
Grass	Location 7	1[E]	<25	<1.8	<0.16	<0.16	<0.16	
Grass	Location 9	1[E]	33	<1.5	0.71	<0.32	0.43	
Soil	Location 5	1[E]	40	54	15	<0.48	15	
Soil	Location 7	1[E]	38	12	22	<0.57	25	
Soil	Location 8	1[E]	28	25	13	<0.77	14	
Soil	Location 9	1[E]	100	12	15	<1.0	16	
Soil		2[#]						48
Soil	max				9.8	0.33	9.2	58

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha	Total beta
Terrestrial samples							
Milk		4	<0.00010	<0.00010	<0.00016		
Milk	max				<0.00020		
Beetroot		1	<0.00010	0.00010	0.00040		
Blackberries		1	<0.00010	0.00010	0.00030		
Cabbage		1	0.00010	0.00020	0.00020		
Carrots		1	<0.00010	0.00030	0.00030		
Potatoes		1	<0.00010	<0.00020	<0.00020		
Rabbit		1	0.00060	<0.0013	0.00070		
Runner beans		1	0.00010	0.00020	0.00030		
Wheat		1	<0.00010	0.00010	0.00050		
Grass	Location 5	1[E]	<0.19	<0.090		5.8	220
Grass	Location 7	1[E]	<0.16	<0.070		<5.0	130
Grass	Location 9	1[E]	<0.60	<0.40		8.0	82
Soil	Location 5	1[E]	<0.76	1.9		270	430
Soil	Location 7	1[E]	<0.55	0.41		350	540
Soil	Location 8	1[E]	<0.70	0.65		310	290
Soil	Location 9	1[E]	<0.90	<0.70		310	590

** Not detected by the method used*

[a] Except for milk, sewage effluent and water where units are Bq l^{-1} and for sediment and soil where dry concentrations apply (except for those soil samples marked with a [#] which are wet concentrations)

[b] Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments

[c] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

[E] Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency

Table 6.1(b). Monitoring of radiation dose rates near Aldermaston, 2005

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	3	0.069
Pangbourne, riverbank	Grass and marsh	1	0.066
Mapledurham, riverbank	Mud	3	0.065
Mapledurham, riverbank	Mud and pebbles	1	0.069

Table 6.2. Individual radiation exposures - defence sites, 2005

Site	Exposed population group[a]	Exposure, mSv				
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water
Aldermaston	Anglers	<0.005	<0.005	-	<0.005	-
	Consumers of locally harvested crayfish	<0.005	<0.005	-	-	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Derby	Consumers of drinking water[c]	<0.005	-	-	-	<0.005
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Houseboat occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-
Holy Loch	Anglers	<0.005	-	-	<0.005	-
Rosyth	Boat users	<0.005	-	<0.005	<0.005	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Includes a component due to natural sources of radionuclides*
[c] *Water is from rivers and streams and not tap water*

Table 6.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2005

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}										
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu
Barrow													
Grass	Barrow	2[F]		<5.0									
Derby													
Sediment	River Derwent, downstream	4					<0.78						
Sediment	River Derwent, upstream	1					<0.55						
Water	River Derwent, downstream	4					<0.38						
Water	River Derwent, upstream	1					<0.32						
Water	Fritchley Brook, downstream of Hilt's Quarry	1		<4.0			<0.32					<0.28	
Devonport													
Ballan wrasse	Plymouth Sound	2[F]				<0.12	<0.09	<0.35	<0.20	*	<0.10	0.18	<0.15
Crabs	Plymouth Sound	1[F]			18	<0.13	<0.11	<0.31	<0.23	*	<0.11	<0.09	<0.16
Shrimps/prawns	Lynher Estuary	1[F]			39	<0.18	<0.15	<0.45	<0.40	*	<0.17	<0.14	<0.35
Winkles	Torpoint (South)	1[F]				<0.23	<0.19	<0.58	<0.44	*	<0.20	<0.17	<0.28
Cockles	Southdown	1[F]				<0.17	<0.18	<0.40	<0.37	*	<0.18	<0.15	<0.25
Mussels	R Lynher	2[F]	<25	<25		<0.08	<0.08	<0.22	<0.19	*	<0.08	<0.10	<0.16
Fucus vesiculosus[c]	Kinterbury	2[F]				<0.08	<0.09	<0.23	<0.16	*	<0.09	0.16	<0.16
Mud[d]	Kinterbury	2[F]				<0.75	<0.68	<1.8	<1.7	<5.4	<1.2	3.3	<2.3
Sediment	Torpoint (South)	2		<25			<1.3					<1.4	
Sediment	Lopwell	2		<25			<1.4					<3.3	
Seawater	Torpoint (South)	2		<4.0	<4.0		<0.31						
Seawater	Millbrook Lake	2		<4.0	<4.0		<0.42						
Beetroot/swede		1[F]		<5.0			<0.30				<0.20	<0.30	
Blackberries		1[F]		<4.0			<0.30				<0.30	<0.30	
Cabbage		1[F]		<5.0			<0.20				<0.30	<0.30	
Lettuce		1[F]		<5.0			<0.30				<0.30	<0.30	
Faslane													
Fish	Carnban boatyard	1				0.14	<0.10	0.21	<0.25		<0.10	1.8	<0.22
Seaweed	Rhu	1				<0.10	<0.10	<0.16	<0.13		<0.10	0.46	<0.13
Sediment	Carnban boatyard	1				<0.10	<0.10	<0.15	<0.14		<0.10	4.3	0.60
Seawater	Carnban boatyard	2		2.3		<0.10	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10
Holy Loch													
Sediment	Mid Loch	1				<0.10	<0.10	<0.15	<0.17		<0.10	6.1	0.99
Rosyth													
Seaweed	East of dockyard	1				<0.10	<0.10	<0.10	<0.10		<0.10	0.16	<0.10
Sediment	East of dockyard	1				<0.10	<0.10	<0.18	<0.15		<0.10	18	1.8
Sediment	Port Edgar	1				<0.10	<0.10	<0.48	<0.29		<0.14	20	2.2
Sediment	West of dockyard	1				<0.10	<0.10	<0.14	<0.12		<0.10	1.8	<0.23
Sediment	East Ness Pier	1				<0.10	<0.10	<0.16	<0.13		<0.10	3.3	0.71
Sediment	Blackness Castle	1				<0.10	<0.10	<0.28	<0.20		<0.10	8.9	<0.30
Sediment	Charlestown Pier	1				<0.12	<0.10	<0.29	<0.25		<0.10	21	1.4
Seawater	East of dockyard	2		<1.0		<0.10	<0.10	<0.13	<0.11		<0.10	<0.10	<0.12

Table 6.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{228}Th	^{230}Th	^{232}Th	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Total alpha	Total beta
Derby												
Sediment	River Derwent, downstream	4					24	<1.1	23		480	670
Sediment	River Derwent, upstream	1					20	<0.94	20		350	650
Grass		2[F]				0.38						
Grass	max					0.55	0.11	0.0056	0.11			
Soil		2[F]				120						
Soil	max					180	41	1.2	32			
Water	River Derwent, downstream	4									<0.038	0.17
Water	River Derwent, upstream	1									0.036	0.17
Water	Fritchley Brook, downstream of Hilt's Quarry	1	<0.0070	<0.0050	<0.0050		0.031	<0.0050	0.023		0.043	0.14
Devonport												
Ballan wrasse	Plymouth Sound	2[F]								<0.07		
Crabs	Plymouth Sound	1[F]								<0.08		
Shrimps/prawns	Lynher Estuary	1[F]								<0.32		
Winkles	Torpoint (South)	1[F]								<0.13		
Cockles	Southdown	1[F]								<0.13		
Mussels	R Lynher	2[F]								<0.12		
Fucus vesiculosus[c]	Kinterbury	2[F]								<0.12		
Mud[d]	Kinterbury	2[F]								0.12		
Faslane												
Fish	Carnban boatyard	1								<0.12		
Seaweed	Rhu	1								<0.10		
Sediment	Carnban boatyard	1								<0.20		
Seawater	Carnban boatyard	2								<0.10		
Holy Loch												
Sediment	Mid Loch	1								0.81		
Rosyth												
Seaweed	East of dockyard	1								<0.10		
Sediment	East of dockyard	1								1.7		
Sediment	Port Edgar	1								<0.42		
Sediment	West of dockyard	1								<0.17		
Sediment	East Ness Pier	1								0.47		
Sediment	Blackness Castle	1								<0.26		
Sediment	Charlestown Pier	1								1.3		
Seawater	East of dockyard	2								<0.10		

* *Not detected by the method used*

[a] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

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

[c] *The concentration of ^{99}Tc was 0.36 Bq kg^{-1}*

[d] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.019, 0.35 and 0.00068 Bq kg^{-1} respectively*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the environment agencies*

Table 6.3(b). Monitoring of radiation dose rates near defence establishments, 2005

Establishment	Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate				
Devonport	Kinterbury	Mud	2[F]	0.077
Devonport	Torpoint South	Mud and stones	1	0.12
Devonport	Torpoint South	Shale and shingle	1	0.12
Devonport	Lopwell	Mud and rock	1	0.10
Devonport	Lopwell	Grass and mud	1	0.10
Faslane	Gareloch Head	Mud, sand and stones	2	<0.053
Faslane	Gulley Bridge Pier	Sand and stones	2	0.059
Faslane	Rhu	Gravel	2	0.057
Faslane	Helensburgh	NA	2	0.060
Faslane	Carnban boatyard	Mud and sand	2	0.085
Holy Loch	North Sandbank	Mud and sand	1	0.050
Holy Loch	Kilmun Pier	Sand and stones	1	0.068
Holy Loch	Mid-Loch	Sand	1	0.051
Rosyth	Blackness Castle	Mud and sand	2	0.061
Rosyth	Charlestown Pier	NA	2	0.053
Rosyth	East Ness Pier	NA	2	0.054
Rosyth	East of Dockyard	Sand	2	0.058
Rosyth	Port Edgar	Mud	2	0.063
Rosyth	West of Dockyard	Mud and sand	2	0.061

NA Not available

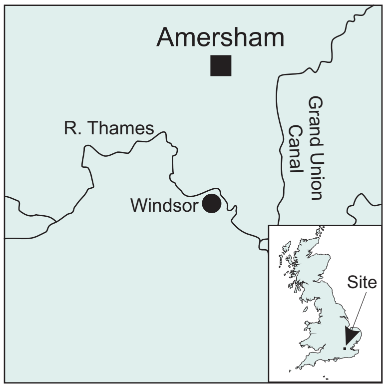
[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the environment agencies*

Defence

7. RADIOCHEMICAL PRODUCTION

GE Healthcare manufactures radioactively labelled materials for use in medicine, research and industry. The company's principal establishment is located in Amersham, Buckinghamshire and it also operates from Cardiff and on the Harwell site. The environmental effects of the Harwell facilities are covered by general monitoring of the Harwell site (Section 4). In February 2004, the Environment Agency launched a consultation exercise to consider an application from Amersham plc to vary the authorisation it holds for disposals from the Harwell site (Environment Agency, 2004d). The application reflects the progressive reductions in the company's operations involving radioactivity at the site and the extensive programme to decommission redundant facilities on the site. The revised authorisations came into effect in 2005.

7.1 Grove Centre, Amersham, Buckinghamshire



Discharges of liquid radioactive wastes are made under authorisation to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Discharges of gaseous wastes are also authorised. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials. The monitoring locations are shown in Figure 4.1. Monitoring at Newbridge, well upstream on the Thames, acts as a control site and gives an indication of background levels in the catchment.

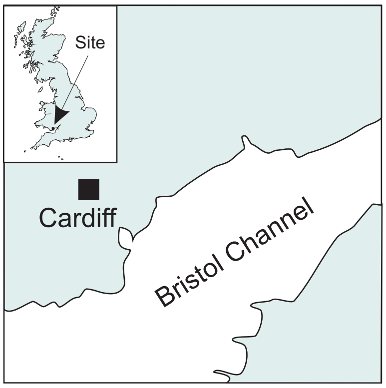
The results are presented in Tables 7.1(a) and (b). The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Tritium concentrations in biota in the Thames and the Grand Union Canal were below the LoD. Concentrations in material from Maple Lodge Sewage Works were similar to those in 2004, with the exception of total tritium. The levels of tritium were small in terms of any radiological effect. Gross alpha and gross beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates above the banks of the canal were indistinguishable from background.

The activity concentrations in milk, grass and soil crops were generally lower than the limits of detection. However, low levels of sulphur-35 and iodine-125 were detected in a few samples. Caesium-137 activity detected in soil near the site is likely to be due to global fallout from testing of weapons or from the Chernobyl accident. It is possible that the relatively high total alpha concentration in soil (800 Bq kg^{-1}) could be due to sources on the Amersham site. Sampling is being carried out by the site operator to provide further characterisation. In August 2005, the site operator identified tritium in the groundwater under the site. Sampling is being carried out by the operator to investigate the source of the contamination, and to confirm the findings that the impact on public drinking water supplies is very low.

A consumption and occupancy habits survey in the vicinity of the site was undertaken in 2004. Considering pathways downstream of the release point for discharges of liquid effluents, no consumers of fish, shellfish or freshwater plants were identified directly. However, there was hearsay evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg $year^{-1}$ for fish has therefore been assumed. Occupancy of the river and canal banks was confirmed as continuing by anglers and others, and this pathway has also been assessed. The dose in 2005 from fish consumption and external radiation was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 7.2).

The dose to the critical group of local terrestrial food consumers was assessed as being less than 0.018 mSv, which was less than 2% of the annual dose limit for members of the public. This estimate includes a contribution of 0.012 mSv from estimates of concentrations of discharged radionuclides in air.

7.2 Maynard Centre, Cardiff, South Glamorgan



A second laboratory, situated near Cardiff, produces radiolabelled compounds used in research and diagnostic kits used in medicine for the testing of clinical samples and radio-pharmaceuticals. Liquid wastes are discharged into the Ystradyfodwg and Pontypridd public sewer (YP). This joins the Cardiff East sewer, which after passing through a new waste water treatment works discharges into the Severn estuary near Orchard Ledges. During periods of high rainfall, effluent from the YP sewer has been known to overflow into the River Taff. In addition, there is run-off from the site into the river. The authorisation for OrthoClinical Diagnostics Ltd a tenant on the site was revoked in 2004 and consequently no discharges were made by them in 2005.

On 19th July 2004, the Environment Agency issued an Enforcement Notice to GE Healthcare requiring the company to carry out a full investigation of ground contamination near the Cardiff site (Environment Agency, 2004e). The contamination had been found by the company in ground outside the boundary of the Site Nuclear Licence, but still on land owned by GE Healthcare. The contamination was due to a crack in the pipeline for discharge to the YP sewer, which has now been repaired. Samples taken in the ground near the pipeline indicated low levels of contamination and the investigation has now been completed.

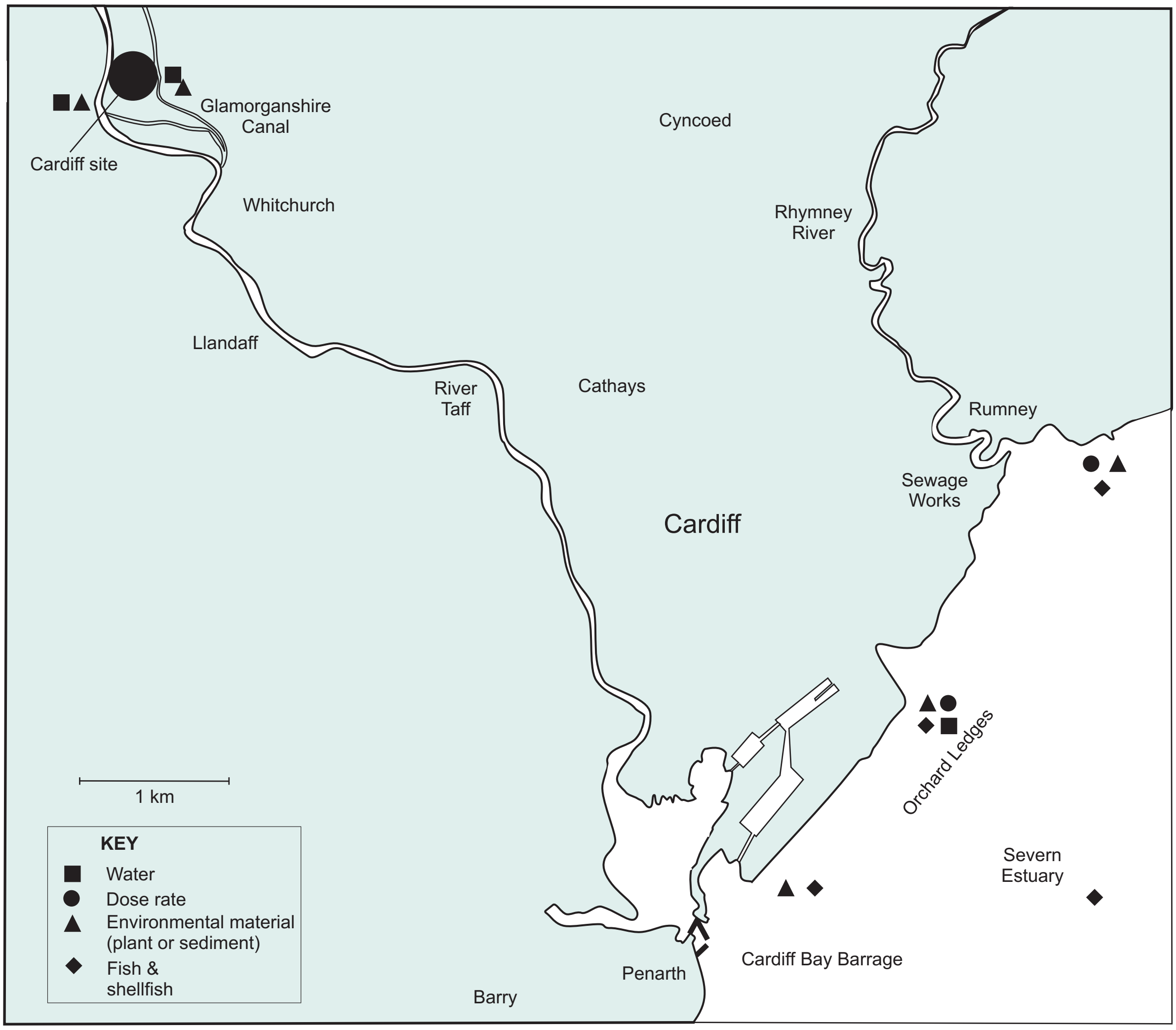


Figure 7.1 Monitoring locations at Cardiff (excluding farms)

Routine monitoring, carried out on behalf of the Welsh Assembly Government, includes consideration of consumption of locally produced food and external exposure over muddy, intertidal areas (Figure 7.1). Measurements of external exposure are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, *Fucus* seaweed, soil and grass provide additional information. Earlier monitoring and research has targeted organic tritium in foodstuffs (Food Standards Agency, 2001b, Swift, 2001; Williams *et al*., 2001; Leonard *et al*., 2001 and McCubbin *et al*., 2001). A full review of monitoring data for tritium bioaccumulation has been undertaken (Rowe *et al*., 2001). A local habits survey was completed in 2003 and the assessment of exposures given below takes the results into account.

The results of routine monitoring in 2005 are presented in Tables 7.3(a) and (b). The main effect of liquid discharges is seen in enhanced tritium and carbon-14 activities in samples above background levels. The results of sample analyses show that virtually all of the total tritium in marine samples was associated with organic matter. The tritium is strongly bound to organic matter and has the potential to transfer through the marine foodchain from small organisms to accumulate in fish. The dose coefficients for this form of tritium differ from those for tritiated water (see Appendix 5) and the estimates of dose for members of the public take this into account. The trends in concentrations of tritium and carbon-14 in seafood and their relationship to discharges are shown in Figures 7.2 and 7.3. There were similar concentrations of both tritium and carbon-14 in seafood in 2005, despite a small increase in the carbon-14 discharge. The lower tritium levels, in comparison to previous years, were most probably due to a reduction in the organically bound components of the discharge.

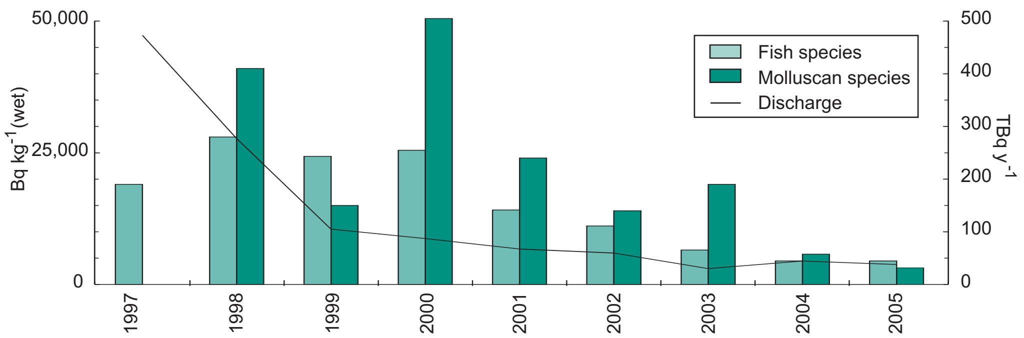


Figure 7.2 Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

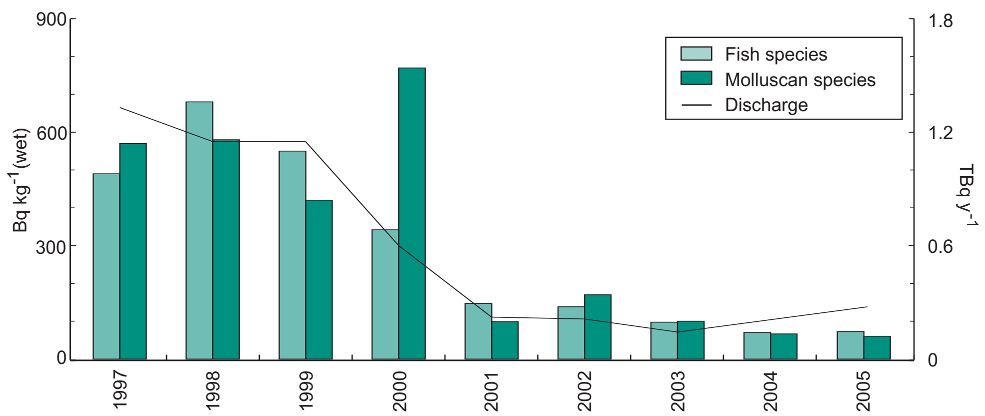


Figure 7.3 Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

7. Radiochemical production

In April 2004, the Environment Agency issued a new authorisation for the site. Limits were reduced for all the radionuclides and the management conditions were improved. The new authorisation required the introduction of new technology to be developed to reduce the discharges of tritium and carbon-14 in the future. GE Healthcare has continued work on a new treatment process called Project Paragon. At present some tritium effluent, which includes a significant proportion of the organic form is withheld and stored on site pending the introduction of the plant. Once the new plant is commissioned, both the stored waste and future arisings of carbon 14 and tritium will be treated where possible to reduce and recycle the radionuclides. Provided the treatment plant is successful this should significantly reduce the discharges of tritium and carbon-14 in the future. Discharges of organic tritium in 2005 were similar to those in 2004. The current levels of discharge are likely to be maintained until the plant becomes fully operational.

Tritium continued to be detected in run-off water from the River Taff and the Glamorganshire Canal, neither of which is used as a source of water for the public water supply. Concentrations in run-off from the site into the River Taff increased in 2005 from 61 (2004) to 100 Bq l^{-1}. The data indicate that a significant proportion of the tritium present in water is associated with organic matter. Concentrations in sediment from the local canal were similar to those in 2004. Both freshwater and sediment can be affected by episodic events and there are difficulties in obtaining representative samples. There were also decreases in concentrations in seawater from 30 Bq l^{-1} in 2004 to 12 Bq l^{-1} in 2005. In each of the sample categories above, the effects were localised and were not observed further afield in the Bristol Channel (Section 9), or indeed in seafood.

Concentrations of other radionuclides in aquatic samples were low and can largely be explained by other sources such as Chernobyl, weapon test fallout and discharges from other establishments. Gamma and beta dose rates over sediment, as measured using portable instruments, were generally difficult to distinguish from those expected from the natural background. Using an increased dose coefficient for tritium, the dose to the critical group of prenatal children of fish and shellfish consumers in 2005 was 0.027 mSv. This was less than 3% of the dose limit for members of the public of 1 mSv (Table 7.2). This estimate includes a small contribution due to external radiation. The tritium dose coefficient was revised to account for recent evidence from an experiment involving the uptake and retention of tritium fed to rats (see Appendix 5). The prenatal age group was introduced this year following the recommendations of the HPA (see Section 2). The dose to this age group in 2004 was 0.029 mSv. The dose to the next highest age group in 2005, adults, was 0.020 mSv. For anglers on the banks of the River Taff, the dose from inadvertently ingesting sediment and occupancy of the river bank water was estimated to be much less than 0.005 mSv. There was a small contribution to this dose from the presence of tritium and other radionuclides from the site, however, the largest contribution was estimated from the inadvertent ingestion of caesium-137 which is more likely to be due to other sources.

Exposures from aquatic pathways to groups representative of the area surrounding the Severn Estuary have been kept under review (Figure 7.4). All doses from Cardiff, Hinkley Point and Berkeley/Oldbury were well within the annual dose limit for members of the public of 1 mSv. The dose estimates take into account the revised dose coefficients for tritium and include consideration of prenatal children. The observed reduction in the doses for Cardiff, in recent years, is largely due to the reductions in concentrations of tritium and carbon-14 in seafood (Figures 7.2 and 7.3). Doses for Hinkley Point and Berkeley/Oldbury have remained relatively constant and very low.

The habits survey in 2003 identified consumers of wildfowl collected near Cardiff. Although samples of wildfowl were not monitored in 2005, an assessment has been undertaken making use of data from an earlier RIFE report when levels in the aquatic environment were much the same as in 2005 (Food Standards Agency and Scottish Environment Protection Agency, 2000). The dose from high-rate consumption of wildfowl based on current consumption data was less than 0.005 mSv.

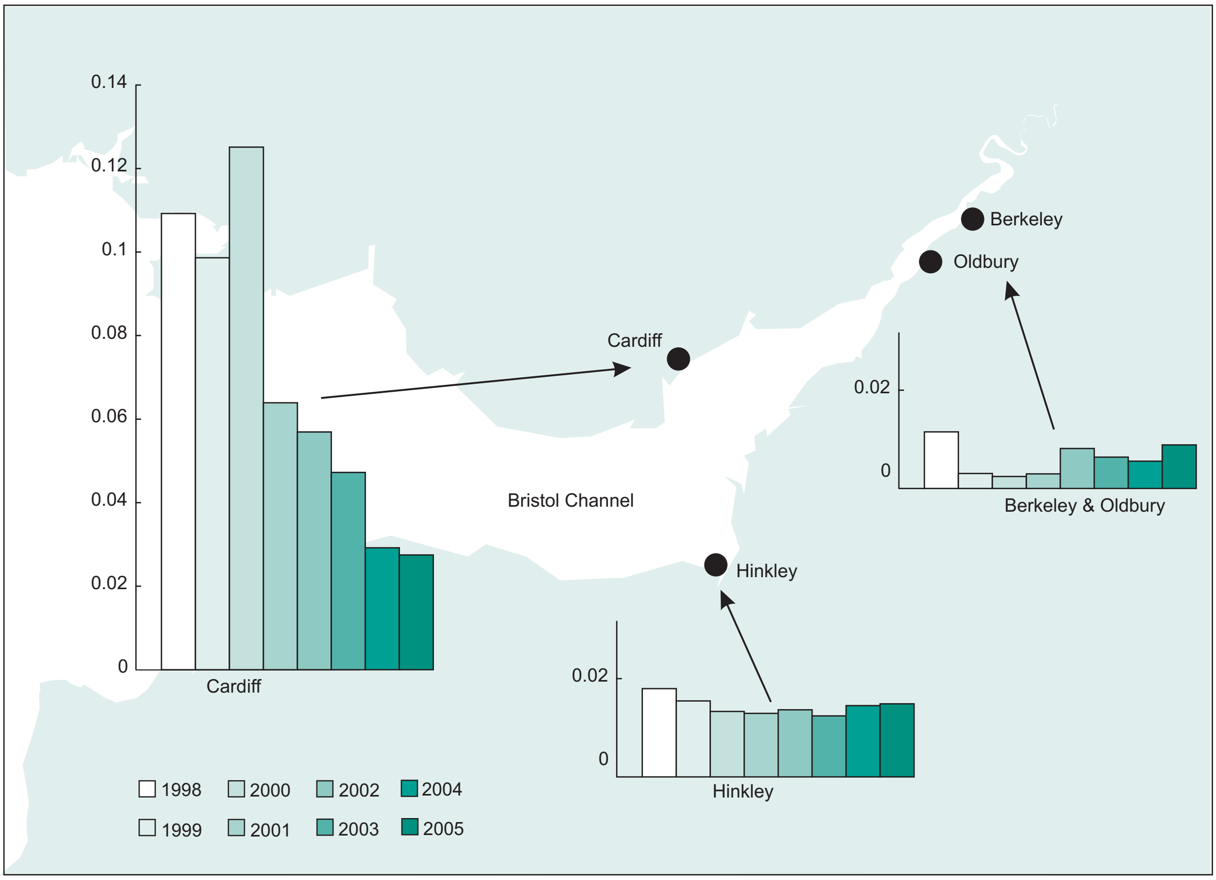


Figure 7.4 Individual radiation exposures to seafood consumers from artificial radionuclides in the Severn Estuary, 1998-2005

The main effects of gaseous discharges were also seen in results for tritium and carbon-14. The incidence of detection of enhanced carbon-14 and tritium activities in a wide range of terrestrial samples is relatively high in comparison with other nuclear sites. Sulphur-35 was detected at levels similar to those found in the general diet survey (see Section 9). All these measurements were of low radiological significance.

The maximum estimated dose to local terrestrial food consumers was to the 1-year-old age group. This critical group received 0.011 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. The largest contribution was from carbon-14 in milk. The estimate includes a small contribution from modelled concentrations of radionuclides in air (Appendix 2).

Table 7.1(a). Concentrations of radionuclides in food and the environment near Amersham, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{57}Co	^{58}Co	^{65}Zn	^{125}I	^{131}I
Freshwater samples												
Pike	Newbridge	1	<25	<25				<0.07	<0.64	<0.41		*
Pike	Outfall (Grand Union Canal)	1	<25	<25	25			<0.03	<0.08	0.12		*
Pike	Staines	1	<25	<25				<0.04	<0.17	<0.20		*
Pike	Shepperton	1	<25	<25				<0.04	<0.19	<0.19		*
Pike	Teddington	1	<25	<25				<0.03	<0.07	<0.11		*
Flounder	Beckton	1		<25				<0.06	<0.27	<0.36		*
Rainbow trout	River Chess	1						<0.06	<0.27	<0.32		*
Signal crayfish	River Chess	1						<0.05	<0.21	<0.28		*
Nuphar lutea	Newbridge	1		<25				<0.03	<0.18	<0.19		*
Nuphar lutea	Outfall (Grand Union Canal)	1		<25				0.15	<0.12	0.38		*
Nuphar lutea	Staines	1		<25				<0.03	<0.16	<0.17		*
Watercress	River Chess	1						<0.02	<0.09	<0.10		*
Mud	Outfall (Grand Union Canal)	1										
Sediment	Outfall (Grand Union Canal)	2[E]						<2.2		<1.7	<0.39	<2.9
Sediment	Upstream of outfall (Grand Union Canal)	2[E]						<4.6		<3.1	<0.94	<7.7
Freshwater	Maple Cross	2[E]		<4.0				<0.84		<0.49	<0.30	<2.4
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]		<4.0				<1.1		<0.53	<0.25	<2.5
Freshwater	River Chess	1[E]		<4.0				<0.81		<0.43	<0.30	<1.8
Freshwater	River Misbourne downstream	1[E]		7.6				<1.6		<0.98	<0.30	<2.6
Freshwater	River Misbourne (Chalfont St Giles)	1[E]		<4.0				<1.6		<1.1	<0.30	<2.9
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		340		<0.71	<1.0	<1.3	<0.37	<0.80	<0.30	
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]		<130		<1.0	<2.6	<1.2	<0.28	<0.65	<0.30	
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]		200		<1.8	<1.0	<1.2	<0.32	<0.69	<0.25	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Total alpha	Total beta
Freshwater samples										
Pike	Newbridge	1	<0.10	0.000023	0.00020	0.00023	*	*		
Pike	Outfall (Grand Union Canal)	1	0.21			<0.10				
Pike	Staines	1	0.10			<0.07				
Pike	Shepperton	1	0.13			<0.06				
Pike	Teddington	1	0.14			<0.11				
Flounder	Beckton	1	0.37			<0.09				
Rainbow trout	River Chess	1	<0.10			<0.10				
Signal crayfish	River Chess	1	0.10			<0.07				
Nuphar lutea	Newbridge	1	0.10			<0.05				
Nuphar lutea	Outfall (Grand Union Canal)	1	<0.04			<0.03				
Nuphar lutea	Staines	1	<0.05			<0.04				
Watercress	River Chess	1	<0.03			<0.07				
Mud	Outfall (Grand Union Canal)	1		0.017	0.74	0.30	0.0029	0.0010		
Sediment	Outfall (Grand Union Canal)	2[E]	<0.59						170	320
Sediment	Upstream of outfall (Grand Union Canal)	2[E]	5.5						190	250
Freshwater	Maple Cross	2[E]	<0.19						<0.063	0.62
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<0.21						<0.053	0.20
Freshwater	River Chess	1[E]	<0.18						<0.050	<0.10
Freshwater	River Misbourne downstream	1[E]	<0.38						<0.050	<0.10
Freshwater	River Misbourne (Chalfont St Giles)	1[E]	<0.40						<0.020	<0.10
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<0.31			<0.45			<0.098	0.58
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<0.24			<0.40			<1.1	11
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<0.26			<0.40			<0.088	<0.58

Table 7.1(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], $Bq\ kg^{-1}$									
			^{3}H	^{35}S	^{57}Co	^{65}Zn	^{75}Se	^{125}I	^{131}I	^{137}Cs	Total alpha	Total beta
Terrestrial samples												
Milk		2	<4.8	<0.30			<0.44	<0.045	<0.012	<0.29		
Milk	max		<5.3	<0.33			<0.45	<0.059	<0.014	<0.30		
Apples		1	<4.0	<0.10			<0.40	<0.042		<0.30		
Beetroot		1	<5.0	<0.10			<0.20	0.067		<0.30		
Blackberries		1	<5.0	2.1			<0.50	<0.013		<0.30		
Cabbage		1	<4.0	0.80			<0.30	<0.013		<0.30		
Courgettes		1	<5.0	<0.10			<0.30	0.10		<0.30		
Runner beans		1	<4.0	<0.10			<0.30	<0.034		<0.30		
Spinach and Calabrese		1	<4.0	1.0			<0.40	0.15		<0.30		
Wheat		1	<10	0.60			<0.30	0.058		<0.30		
Grass	Next to site	1[E]		3.5	<6.6	<3.9		<1.7	<4.4	<1.6	<5.0	120
Grass	Orchard next to site	1[E]		6.3	<9.5	<5.7		<3.0	<19	<2.2	<5.0	160
Grass	Water Meadows (River Chess)	1[E]		7.4	<10	<5.1		<3.0	<17	<2.0	<5.0	130
Soil	Next to site	1[E]			<2.1	<1.1		<0.60	<5.2	13	570	1500
Soil	Orchard next to site	1[E]			<3.9	<2.8		<0.80	<10	18	800	730
Soil	Water Meadows (River Chess)	1[E]			<2.4	<1.1		<0.60	<5.1	6.6	330	480

** Not detected by the method used*

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

[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *The concentration of ^{3}H as tritiated water was <170 $Bq\ l^{-1}$*

[e] *The concentration of ^{3}H as tritiated water was <130 $Bq\ l^{-1}$*

[f] *The concentration of ^{3}H as tritiated water was <120 $Bq\ l^{-1}$*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 7.1(b). Monitoring of radiation dose rates near Amersham, 2005

Location	Ground type	No. of sampling observa-tions	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
Grand Union Canal	Grass and mud	1	0.062
Grand Union Canal	Grass and soil	1	0.062
Grand Union Canal	Grass	2	0.058

Table 7.2. Individual radiation exposures – radiochemical sites, 2005

Site	Exposed population group[a]	Exposure, mSv					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways
Amersham	Anglers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food[b]	0.018	-	0.006	-	-	0.012
Cardiff	Prenatal children of seafood consumers	0.027	0.024	-	<0.005	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Consumers of locally grown food[b]	0.011	-	0.008	-	-	<0.005

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*

Table 7.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
			Organic ^{3}H[g]	^{3}H	^{14}C	^{99}Tc	^{125}I	^{131}I	^{134}Cs	^{137}Cs	^{155}Eu
Marine samples											
Cod	East of new pipeline	1		510	30			*	<0.16	0.72	<0.22
Flounder	East of new pipeline	3	9700	11000	120			*	<0.09	0.55	<0.16
Sole	East of new pipeline	2		6500	130			*	<0.17	0.35	<0.23
Mullet	East of new pipeline	1		83	44			*	<0.08	0.41	<0.19
Lesser spotted dogfish	Off Orchard Ledges	2	1100	1200	51			*	<0.14	0.60	<0.30
Skates/Rays	Off Orchard Ledges	2	1600	1800	82			*	<0.10	1.1	<0.18
Mussels	Orchard Ledges	2	3000	3300	60			*	<0.13	0.58	<0.27
Fucus vesiculosus	Orchard Ledges	2	67	81	23			*	<0.08	0.62	<0.17
Seaweed	Orchard Ledges	2[E]		64	<25	<7.6	<1.6				
Mud	Orchard Ledges East	2	68	87				<6.8	1.8	28	<2.3
Sediment	East of new pipeline	2[E]		130	<25		<0.74			13	
Sediment	West of new pipeline	2[E]		85	<25		<0.68			13	
Seawater	Orchard Ledges East	2		10							
Seawater[h]	Orchard Ledges	2[E]		12	<4.0		<0.25				

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}										
			Organic ^{3}H[g]	^{3}H	^{14}C	^{32}P	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Total alpha	Total beta
Terrestrial samples													
Milk		6	<5.7	<7.3	19	<0.35	<0.31	<0.035		<0.24	<0.26		
Milk	max		10	17		<0.38	<0.48	<0.038		<0.25	<0.28		
Barley		1		<7.0	89		3.9	<0.16		<0.30	<0.40		
Blackberries		1	10	83	12		<0.20	<0.038		<0.30	<0.30		
Cabbage		1	40	66	12		0.60	<0.035		<0.30	<0.30		
Honey		1		<7.0	94		<0.20	<0.038		<0.20	<0.30		
Leeks		1	<18	18	14		0.30	<0.076		<0.30	<0.30		
Onions		1	<49	46	19		0.90	<0.045		<0.20	<0.30		
Potatoes		1	9.0	54	24		0.50	<0.034		<0.30	<0.30		
Rape oil		1		<6.0	75		1.1	<0.11		<0.30	<0.30		
Strawberries		1	<44	44	33		<0.10	<0.052		<0.30	<0.40		
Swede		1	10	28	15		0.60	<0.038		<0.30	<0.30		
Grass		5	<98	200	150					<0.30	<0.37		
	max		<150	280	180								
Silage		2	<15	17	63								
	max		21	24	76								
Soil		3								<0.33	4.3		
	max									<0.40	8.6		
Sediment	Canal	2[E]		390	130			<1.5			7.6		
Freshwater[d]	Run off into River Taff	2[E]		100	<4.0			<0.20	<0.60		<0.28	<0.040	0.17
Freshwater[e]	Canal	2[E]		35	<4.0			<0.25	<0.64		<0.34	<0.055	<0.10
Freshwater[f]	River Taff	2[E]		<17	<4.0			<0.20	<0.52		<0.26	<0.044	<0.20

* *Not detected by the method used*

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

[b] *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 value is the most appropriate for dose assessments*

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[d] *The concentration of ^{3}H as tritiated water was <62 Bq l^{-1}*

[e] *The concentration of ^{3}H as tritiated water was 19 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <4.0 Bq l^{-1}*

[g] *The organic fraction may be higher than the total tritium value for some analyses due to uncertainties in the analytical methods for tritium. For dose assessments in this report, the higher of the two values has been used*

[h] *The concentration of ^{3}H as tritiated water was <4.6 Bq l^{-1}*

[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 7.3(b). Monitoring of radiation dose rates near Cardiff, 2005

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	1	0.069
East of Pipeline	Rock and sand	1	0.069
West of Pipeline	Pebbles	2	0.11
Mean beta dose rates			$\mu Sv\ h^{-1}$
Orchard Ledges East	Mud	2[F]	*

* *Not detected by the method used*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

8. INDUSTRIAL AND LANDFILL SITES

This section considers the effects of (i) the main disposal site on land for solid radioactive wastes in the UK, near Drigg in Cumbria, as well as other landfill sites which have received small quantities of solid wastes and (ii) other sites where industries have introduced radioactivity into the environment. Solid wastes are also disposed of on site at Dounreay (Section 4).

8.1 Drigg, Cumbria

The main function of the national LLWR at Drigg is to receive low level solid radioactive wastes from Sellafield and other UK sites and to dispose of them in vaults on land. It is operated by BNGSL, part of BNFL.

The Environment Agency has recently completed a public consultation on its proposals for the future regulation of radioactive waste disposals at the site and has published a proposed Decision Document, which it submitted to Defra and Department of Health Ministers in February 2006 (Environment Agency, 2006f). The proposal contained three main features:

- combination of the existing four separate authorisations into one modern authorisation
- modification of the conditions of authorisation for solid waste disposal on site to take account of the possible effects of coastal erosion in the future
- updated conditions regarding discharge of radioactivity to atmosphere and of contaminated water via a pipeline to the Irish Sea.

Ministers have now published their conclusions and have chosen not to exercise their powers of direction under section 23 of RSA 93 (Department for Environment, Food and Rural Affairs and Department of Health, 2006). The Environment Agency has subsequently issued its new authorisation, which became effective on 1st May 2006.

The 2005 disposal authorisation allowed for the discharge of leachate from the trenches through a marine pipeline. The limits for activity to be discharged through the marine pipeline and for concentrations of residual activity in the Drigg Stream are given in Appendix 1. These discharges are small compared with those discharged from the nearby Sellafield site. Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme that is described in Section 3. The contribution to exposures due to LLWR discharges is negligible compared with that attributable to Sellafield and any effects of LLWR discharges in the marine environment could not, in 2005, be distinguished from those due to Sellafield.

The results of analyses of spot samples of water and sediment taken from the Drigg stream are given in Table 8.1. The concentrations of total alpha and total beta activity were significantly below the limits specified in the authorisation. The gross beta concentrations were similar to the WHO screening levels for drinking water. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use by, for example, campers could take place. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2004. They reflect the legacy of direct discharges of leachate from the disposal site into the stream (BNFL, 2002). This practice stopped in 1991.

In the past, groundwater from some of the trenches on the LLWR site moved eastwards towards a railway drain along the perimeter of the site. Radioactivity from the LLWR was detected in the drain water. BNFL took steps in the early 1990s to reduce ingress of water into the trenches and built a "curtain wall" to reduce lateral migration of leachate into the drain. The results of monitoring in the drain show that levels of radioactivity are now very low and have reduced significantly since the curtain wall was constructed. The concentrations of gross alpha and gross beta activity were similar to those for 2004 and were approximately the same as WHO screening values for drinking water. Low concentrations of tritium were detected.

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

Results for 2005 are given in Table 8.1. Evidence in support of the proposition that radioactivity in leachate from the LLWR might be transferring to foods was very limited. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 3). The radiation dose to the critical group, including a component due to Chernobyl and weapon test fallout, was 0.019 mSv which was less than 2% of the dose limit for members of the public of 1 mSv (Table 8.2).

8.2 Other landfill sites

Some organisations are authorised by the Scottish Environment Protection Agency in Scotland or the Environment Agency in England and Wales to dispose of solid wastes containing low levels of radioactivity to approved landfill sites. Waste with very low levels of radioactivity can also be disposed of in general refuse. Radioactivity in wastes can migrate into leachate and in some cases can enter the groundwater. The Scottish Environment Protection Agency and the Environment Agency carry out monitoring of leachates. The distribution of landfill sites considered in 2005 is shown in Figure 8.1 and the results are presented in Tables 8.3 and 8.4. The results, in common with previous years, show very low levels of caesium-137 in leachate and evidence for migration of tritium from some of the discharge sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al*., 1998). Inadvertent ingestion of leachate (2.5 l y^{-1}) from the site with the highest observed concentration of tritium (Aberdeen) would result in a dose of less than 0.005 mSv or less than 0.5% of the dose limit for members of the public of 1 mSv (Table 8.2).

Levels of uranium isotopes enhanced above natural background levels were found in leachate and borehole water samples taken from near the Whitehaven (Rhodia Consumer Specialities Ltd) site in Cumbria. This could be due to the historical operations involving the manufacture of phosphoric acid from phosphate ore, which resulted in the discharge of phosphogypsum as liquid slurry containing thorium and uranium. The levels are significantly less than Generalised Derived Limits (GDL) for freshwater (the GDL for each uranium isotope is 20 Bq kg^{-1} (Harvey *et al*., 2000)). GDLs, which are reference levels, are defined in Appendix 3. Surface waters from this site are not known to be used as a source of drinking water.

8.3 Phosphate processing, Whitehaven, Cumbria

Previous surveys (Rollo *et al*., 1992) have established that an important man-made source of naturally occurring radionuclides in the marine environment has been the chemical plant at Whitehaven in Cumbria which used to manufacture phosphoric acid from imported phosphate ore. Phosphogypsum, containing thorium, uranium and their daughter products, was discharged as a liquid slurry by pipeline to Saltom Bay. Processing of phosphate ore ceased in 1992 and processing of phosphoric acid at the plant ceased at the end of 2001. However, there is an environmental legacy from past operations. Such sources are said to give rise to TNORM. Decommissioning of the plant was undertaken in 2002 and released small quantities of

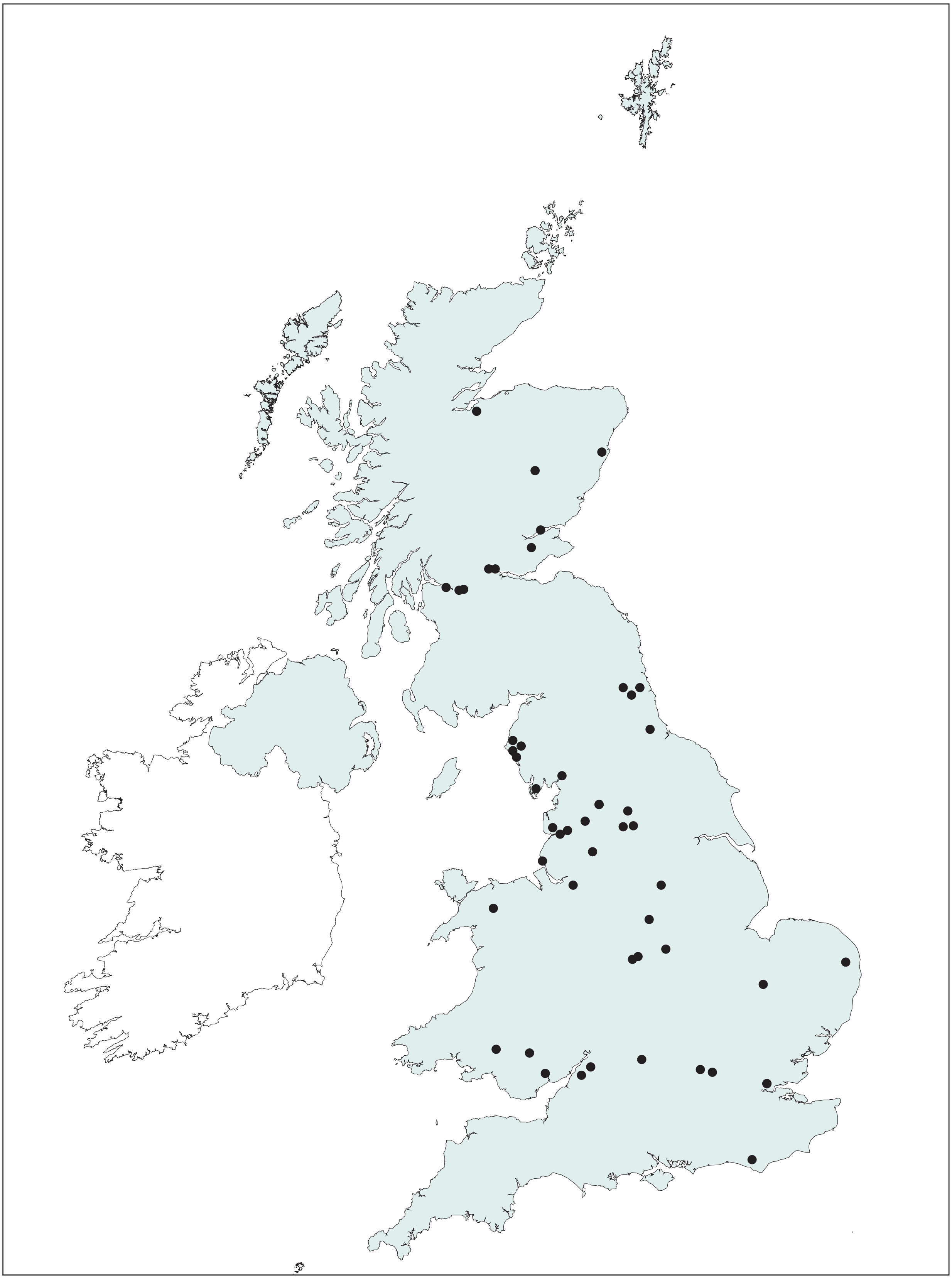


Figure 8.1 Landfill sites monitored in 2005

uranium to sea, but discharges were very much lower than in previous years. The plant was subsequently demolished in 2004 and the authorisation to discharge radioactive wastes revoked by the Environment Agency.

The results of routine monitoring for naturally occurring radioactivity near the site in 2005 are shown in Table 8.5. Analytical effort has focused on lead-210 and polonium-210 that concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally occurring radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figure 8.2 shows how concentrations of polonium-210 in winkles have decreased substantially since 1990, and more dramatically since 1992. It also demonstrates the seasonal variations in concentrations that have been previously observed (Rollo *et al*., 1992). Concentrations of polonium-210 in 2005 were generally lower than those in 2004. Taking into account the ranges of values observed, it is now difficult to distinguish the measured total concentrations from those expected due to natural sources. Estimates of concentrations due to natural sources are given in Appendix 6. There were small enhancements for some samples above the expected natural background median levels for marine species, particularly in Saltom Bay, but the majority were within the ranges observed in the undisturbed marine environment. It is nevertheless considered prudent to continue to estimate doses based on the difference between observed concentrations and median levels indicative of natural background.

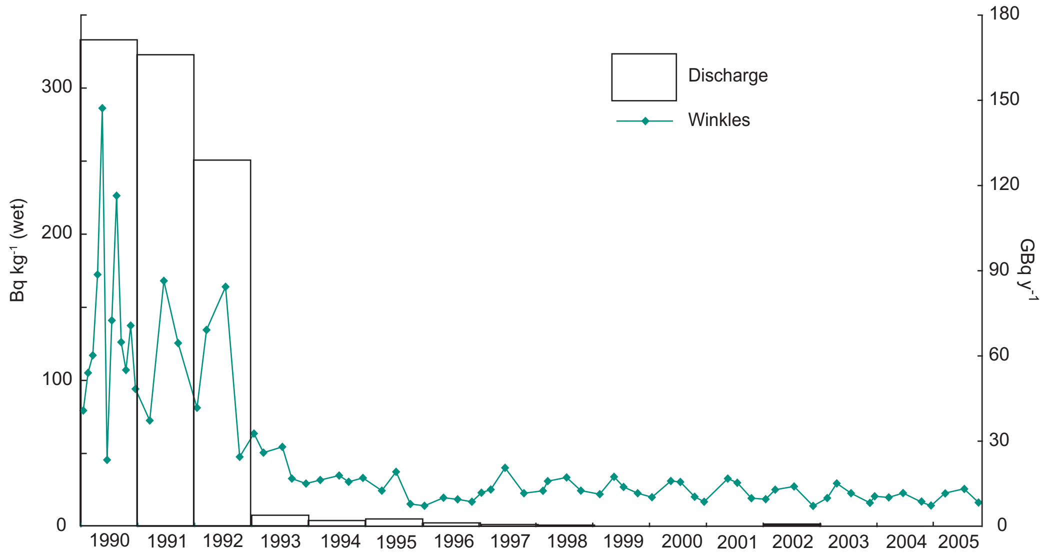


Figure 8.2 Polonium-210 discharge from Whitehaven and concentration in winkles at Parton

The critical radiation exposure pathway is internal irradiation, due to the ingestion of naturally occurring radioactivity in local fish and shellfish. A single group of high-rate consumers is considered in this report. Centred on the Sellafield site to the south of Whitehaven, the group includes people with habits relating to the immediate area around Whitehaven, including Saltom Bay and Parton. It is identical to the group used to assess the impact of the Sellafield site (Section 3). An additional, smaller group limited to the immediate area around Saltom Bay is no longer assessed separately because the larger group provides adequate protection and a more robust assessment. The estimated contribution due to background median levels of naturally occurring radionuclides has been subtracted. Consumption rates for the critical group were reviewed and revised in 2005. The assessment is based on averaging the consumption rates over a five year period from 2000 – 2004. Dose coefficients for polonium-210 were updated in 2004 to reflect new results from research involving the consumption of mussels and cockles containing natural levels of polonium-210 (Appendix 5). A conservative gut transfer factor of 0.8 is taken to apply to seafood generally, but we have adopted a value of 0.5 for molluscs where specific experimental evidence is available.

The critical group dose from enhanced naturally occurring radionuclides (i.e. TNORM) was 0.23 mSv in 2005, about half the estimate for 2004 (Table 8.2). The reduction was mostly due to the decrease in concentrations of polonium-210. The fish and shellfish consumed also contained artificial radionuclides due to Sellafield discharges. The additional exposure due to artificial radionuclides has been calculated using data from Section 3. In 2005, these exposures added a further 0.22 mSv to the doses above resulting in a total dose to this group of up to 0.46 mSv. The estimated doses in 2005 are therefore below the dose limit for members of the public of 1 mSv.

8.4 Aberdeen

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

SEPA has begun a consultation on proposals to vary the authorisation of Scotoil operations (Scottish Environment Protection Agency, 2006c). The proposals include reduced discharge limits and a requirement for Scotoil to implement a new discharge route.

Monitoring in the vicinity of discharges from Scotoil has included sampling of mussels from Aberdeen Harbour. It was concluded that it was unlikely that, should consumption occur, the dose from normal levels of naturally occurring radiation would be enhanced due to Scotoil operations (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999). More recent surveys in 2004 found enhanced concentrations of lead-210 and radium-226 in sub-tidal samples from the Albert Basin and the River Dee (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005). Further monitoring was undertaken in 2005 and the results are provided in Table 8.6.

Radiation dose rates and concentrations of radionuclides over the greater part of the beach were indistinguishable from the normal levels expected within the range of natural background. However, there was a localised area (about 50 metres by 25 metres) in the Footdee part of Aberdeen Beach when dose rates were up to about 10 times natural background and concentrations of polonium-210, radium-226 and actinium-228 in surface sediments were also enhanced. A multi-agency Incident Management Team involving the local authority, health board and government health and environment specialists was established to address the issue and an assessment was made of the potential risk to people in the area considering external exposure, inhalation and ingestion pathways (Scottish Environment Protection Agency, 2006d). The assessment suggested that the additional exposure by members of the public who regularly use the southern end of Aberdeen beach was less than 0.1 mSv in 2005. As a consequence Aberdeen City Council considered that it was not necessary to close any part of the beach on public health grounds.

The Incident Management Team has declared the incident closed. SEPA will continue to check this area of the beach as part of its routine annual monitoring programme.

8.5 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected in Dalgety Bay in Fife since at least 1990. Contamination is likely to be due to past military operations at the Donibristle naval airbase, which closed in 1959. The airbase played a role as an aircraft repair, refitting and salvage yard. It is believed that waste was incinerated and the resultant ash and clinker was disposed of in an area of ground that, as a result of erosion, is now exposed and adjacent to the foreshore. Some of the incinerated material contained items which had been painted with luminous paint containing radium-226.

In June 1990, environmental monitoring showed elevated radiation levels in the Dalgety Bay area. The monitoring was undertaken as part of the routine environmental monitoring programme for Rosyth Nuclear Dockyard carried out in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material was removed for analysis, which indicated the presence of radium-226. Further investigation confirmed that the contamination could not have originated from the dockyard and was most likely to be associated with past practices related to the nearby former HMS Donibristle/HMS Merlin military airfield. Since this initial discovery, there have been several monitoring exercises to determine the extent of this contamination.

The data from the most recent monitoring exercise, conducted during March 2006, was used to undertake a screening risk assessment. The monitoring survey report and screening risk assessment have recently been published (RWE Nukem (2006) and Scottish Environment Protection Agency (2006e)). The screening risk assessment considered the range of activities of radium-226 in samples removed from the beach, the likelihood of encountering such items and various modes of exposure - ingestion, inhalation and external exposure. The report is available on the SEPA website at http://www.sepa.org.uk/radioactivity/publications.htm.

Table 8.1. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2005

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk		1	<4.5	13	<0.30	0.082	<0.48	<0.43	<0.0048	<2.2	<0.62	<0.016
Blackberries		1	<5.0	20	<0.30	0.43	<0.40	<0.30		<1.9	<0.50	<0.041
Cabbage		1	<5.0	6.0	<0.30	0.26	<0.60	<0.40	<0.023	<2.9	<0.60	0.061
Carrots		1	<5.0	13	<0.20	0.30	<0.30	<0.20		<0.90	<0.60	<0.021
Duck		1	7.0	25	<0.40	0.021	<0.50	<0.30	<0.022	<2.5	<0.60	<0.025
Eggs		1	8.0	25	<0.30	0.019	<0.50	<0.30		<2.4	<0.70	<0.021
Potatoes		1	<5.0	23	<0.30	0.035	<0.60	<0.40	<0.030	<2.6	<0.60	<0.043
Rabbit		1	6.0	22	<0.20	0.080	<0.50	<0.30	<0.024	<2.0	<0.90	0.038
Sheep muscle		1	10	11	<0.40	0.011	<0.50	<0.30	<0.035	<2.2	<0.70	<0.040
Sheep offal		1	8.0	34	<0.40	0.029	<0.50	<0.30	<0.034	<2.0	<0.70	<0.035
Grass		2							<0.29			
Grass	max								0.55			
Sediment	Drigg Stream	4[E]			<0.96	<9.2	<2.6	<1.5		<7.1	<7.6	
Freshwater	Drigg Stream	4[E]	13		<0.19	<0.11						
Freshwater	Railway Drain	1[E]	30		<0.09	1.4						

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.24	<0.32	0.25	<1.1				
Blackberries		1			0.13	<0.80				
Cabbage		1			0.16	<1.2				
Carrots		1			0.24	<0.80				
Duck		1			1.5	<1.1				
Eggs		1			0.13	<2.4				
Potatoes		1			0.26	<1.0				
Rabbit		1			3.4	<2.3				
Sheep muscle		1			1.8	<1.0				
Sheep offal		1			0.86	<1.1				
Sediment	Drigg Stream	4[E]	<0.86	160		<3.8	17	17	13	11
Freshwater	Drigg Stream	4[E]	<0.19	<0.16			<0.0065	<0.0065	<0.0062	<0.0050
Freshwater	Railway Drain	1[E]	<0.09	<0.09			<0.0050	<0.0070	<0.0050	<0.0050

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (wet)[b], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Total alpha	Total beta
Milk		1					<0.00018	<0.00018	<0.032	<0.00040		
Blackberries		1					0.00050	0.0014	<0.049	0.0043		
Cabbage		1					<0.00040	<0.00030	<0.066	0.00070		
Carrots		1					0.00070	0.0014	<0.059	0.0027		
Duck		1					<0.00050	<0.00050	<0.10	0.00070		
Eggs		1					<0.00030	<0.00030	<0.049	0.00060		
Potatoes		1					<0.00020	0.00050	0.088	0.0010		
Rabbit		1					<0.00040	0.0028	<0.067	0.0095		
Sheep muscle		1					<0.00020	0.0015	<0.076	0.0041		
Sheep offal		1					0.0082	0.045	0.39	0.039		
Grass	max		0.017	<0.00050	0.015	0.077						
Soil		1	7.4	0.29	7.2	47						
Sediment	Drigg Stream	4[E]	23	<0.85	24		4.3	24	160	20	470	970
Freshwater	Drigg Stream	4[E]	0.022	<0.0058	0.020		<0.010	<0.0058	<1.6	<0.011	<0.047	0.67
Freshwater	Railway Drain	1[E]	0.039	<0.0050	0.027		<0.015	<0.0060	<1.0	<0.010	0.053	3.5

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*

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

[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*

[E] *Measurements are made on behalf of the Food Standards Agency unless labelled "E". in that case they are made on behalf of the Environment Agency*

Table 8.2. Individual radiation exposures – industrial and landfill sites, 2005

Site	Exposed population group[a]	Exposure, mSv					
		Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas	Intakes of sediment and water
Drigg	Consumers of locally grown food[b]	0.019	-	-	0.019	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers[b]	<0.005	-	-	-	-	<0.005
Whitehaven	Seafood consumers[c]	0.46	0.19	0.23	-	0.030	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *Includes the effects of discharges from the adjacent Sellafield site*

Table 8.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2005

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	23	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	360	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	1200	<15	0.05	<0.05
Clackmannanshire	Black Devon	1	41	<15	<0.08	<0.12
Dunbartonshire	Birdstone	1	<5.0		<0.05	<0.05
Dundee City	Riverside	1	<5.0	<15	0.07	<0.05
Edinburgh	Braehead	1	<5.0	<15	0.22	<0.05
Fife	Balbarton	1	120	<15	<0.05	<0.05
Fife	Melville Wood	1	170	<15	<0.05	<0.05
Highland	Longman Tip	1	10	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	440	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	160	<15	<0.05	<0.05

Table 8.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2005

Area/ location	Sample source	No. of sampling observ- ations	Mean radioactivity concentration, Bq l^{-1} Total ^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
City of Bristol																			
Crooks Marsh Farm, Avonmouth	Leachate	2		58	<4.0	<4.9	<0.25	<0.35	<31	<0.22								<0.19	3.0
Cambridgeshire																			
Milton Landfill, Cambridge	Site borehole	1		150		41	<0.20			<0.17		<0.0070	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	1.4	41
Milton Landfill, Cambridge	Ground water borehole	1		<4.0		<9.6	<0.46			<0.41		<0.0060	<0.0050	<0.0050	0.014	<0.0050	0.011	<0.050	0.79
Milton Landfill, Cambridge	Phase 2 borehole 3.6	1		190		<4.6	<0.20			<0.17		<0.013	<0.011	<0.0050	<0.0050	<0.0050	<0.0050	<0.20	12
Milton Landfill, Cambridge	Phase 2 borehole 3.7	1		40		11	<0.19			<0.17		<0.0070	<0.0050	<0.0050	<0.0050	<0.0050	0.0050	<0.23	36
Carmarthenshire																			
Cefnbrynbrain	Liquid	1									<0.050								
Cheshire																			
Northwich Tip	Borehole WM5G	2		<4.7		<6.9	<0.37			<0.31		<0.0070	<0.0050	<0.0050	<0.0070	<0.0055	<0.0055	<0.20	7.9
Northwich Tip	Borehole WM6G	2		230		<6.4	<0.28			<0.24		<0.0070	<0.018	<0.0050	<0.0065	<0.0050	<0.0090	<1.0	9.9
Northwich Tip	Borehole WM20G	2		<4.0		<6.4	<0.30			<0.24		<0.014	<0.023	<0.0050	<0.0095	<0.0055	<0.0085	<4.7	7.1
Cleveland																			
Bewley ICI Tip	On-site stream (downstream)	2		110		<9.2	<0.32			<0.26		<0.0095	<0.0055	<0.0075	0.048	<0.0085	0.047	<0.69	10
Bewley ICI Tip	On-site stream (upstream)	2		<6.1		<11	<0.31			<0.26		<0.0075	<0.0070	<0.0055	0.035	<0.0050	0.032	<0.43	13
Cumbria																			
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1		<4.0		8.8	<0.09			<0.09		<0.0070	<0.0050	<0.0050	0.084	<0.0050	0.088	<0.20	12
Rhodia Consumer Specialties Ltd, Ufex	Leachate	2		<4.0		57	<0.13			0.43		<0.0070	<0.013	<0.0050	2.9	0.11	3.0	<3.6	<35
Alco Landfill	Borehole	2		42	<4.0	<3.1	<0.18	<0.20	<160	<0.15								<0.19	<0.39
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1		<4.0		<1.1	<0.08			<0.08		<0.0070	<0.0050	<0.0050	<0.0050	<0.0050	<0.0060	0.020	0.29
Greater London																			
Murex Ltd	Local water (East stream)	1		<4.0		3.8	<0.09			<0.09		<0.0090	<0.0060	<0.0070	0.010	<0.0060	0.011	<1.0	3.3
Murex Ltd	Local water (West stream)	1		8.9		2.7	<0.08			<0.08		<0.0050	<0.0050	<0.0050	0.026	<0.0060	0.026	<0.88	3.2
Glamorgan																			
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	1200	1100	<4.0														
Trecatti Landfill, Merthyr Tydfil	Treated leachate	2	1800	1600	<4.0														
Gwynedd																			
Cilgwyn Quarry	Leachate	2		420	<4.0	<5.0	<0.25	<0.35	<3.9	<0.22								<0.11	3.9
Cilgwyn Quarry	2nd pit	2		<4.0	<4.0	<5.9	<0.29	<0.30	<3.2	<0.24								<0.041	<0.10

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}														
			$^{3}H^{a}$	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Hertfordshire																	
Braziers Landfill	Borehole W2	1	<4.0		<1.1	<0.08			<0.08	<0.0070	<0.0050	<0.0050	0.018	<0.0050	0.010	0.062	0.16
Braziers Landfill	Borehole W5	2	<4.0		<3.5	<0.19			<0.17	<0.0065	<0.016	<0.0050	0.019	<0.0050	0.016	<0.058	0.22
Braziers Landfill	Borehole W9	2	<4.0		<1.2	<0.09			<0.09	<0.0085	<0.0065	<0.0050	0.015	<0.0050	0.0085	<0.051	0.23
Cole Green Landfill	Local water (culvert)	1	<4.0		<1.3	<0.10			<0.10	0.011	0.015	<0.0050	0.020	<0.0050	0.014	<0.060	0.26
Cole Green Landfill	Static borehole	1	33		6.3	<0.08			<0.08	<0.0060	<0.0050	<0.0050	0.041	<0.0080	0.027	<0.28	8.2
Lancashire																	
Magnesium Electron, Swinton	Local water	1	<4.0		<1.1	<0.08			<0.08	<0.0060	<0.0050	<0.0050	0.0090	<0.0050	0.010	<0.020	0.37
Belthorne Mine Shaft	Local water (brook)	2	<4.0		<1.2	<0.09			<0.09	<0.0075	<0.013	<0.0050	<0.018	<0.0050	<0.018	<0.031	0.43
Clifton Marsh	Borehole 6	2	65		<4.2	<0.20			<0.21	<0.0080	0.0070	<0.0060	0.042	<0.0055	0.041	<0.15	2.4
Clifton Marsh	Borehole 19	2	<4.0		<1.6	<0.09			<0.09	<0.0090	0.0075	<0.0050	0.026	<0.0050	0.018	<0.25	7.3
Clifton Marsh	Borehole 40	2	<4.0		<2.7	<0.14			<0.13	<0.0075	<0.020	<0.0050	<0.011	<0.0055	<0.013	<0.10	1.4
Clifton Marsh	Borehole 59	1	42		3.8	<0.08			<0.08	<0.0080	<0.0050	<0.0060	<0.0050	<0.0060	<0.0060	<0.10	2.7
Ulnes Walton	River Lostock (downstream)	1	<4.0		<4.1	<0.23			<0.20	<0.0070	<0.020	<0.0050	0.016	<0.0050	0.016	<0.030	0.34
Ulnes Walton	River Lostock (upstream)	1	<4.0		<6.0	<0.28			<0.24	<0.0070	<0.020	<0.0050	0.016	<0.0050	0.013	<0.030	0.33
Ulnes Walton	Pond	1	<4.0		<5.9	<0.28			<0.24	0.010	<0.020	<0.0050	1.8	0.063	1.7	2.2	1.3
Near Whittle Hill Quarry	River Lostock	1	<4.0		<1.2	<0.08			<0.09	<0.0060	<0.0050	<0.0050	<0.012	<0.0080	<0.011	<0.020	0.22
River Yarrow	Local water	1	<4.0		<1.1	<0.08			<0.08	0.0090	<0.0050	<0.0050	<0.0080	<0.0050	<0.0080	<0.030	0.13
Merseyside																	
Sefton Meadows Tip	Local water	1	<4.0	<4.0	<3.8	<0.21	<0.30	<1.6	<0.19							0.19	0.18
Arpley Landfill	Borehole 25 (groundwater)	2	45	<4.0	<4.1	<0.20	<0.30	<2.2	<0.18							<0.23	0.72
Norfolk																	
Strumpshaw Landfill	Leachate (borehole BH2)	2	<4.0	<4.0	<8.0	<0.40	<0.35	<17	<0.32							<0.057	0.22
Strumpshaw Landfill	Leachate (borehole BH3)	2	<4.0	<4.0	<4.8	<0.25	<0.30	<9.3	<0.22							<0.061	0.18
Strumpshaw Landfill	Reservoir	1	<4.0	<4.0	<3.7	<0.22	<0.30	<4.9	<0.18							<0.050	<0.10
Strumpshaw Landfill	Water abstraction	1	<4.0	<4.0	<9.9	<0.46	<0.30	<10	<0.38							<0.54	1.2
Nottinghamshire																	
School of Agriculture, Nottingham	Local water (stream)	1	<4.0		<9.8	<0.48			<0.41	<0.0050	0.0080	<0.0050	0.044	<0.0050	0.023	<0.07	0.78
Oxfordshire																	
Stanford in the Vale	Local water	2	<4.4		<1.9	<0.10			<0.09	<0.0080	<0.013	<0.0055	0.0085	<0.0050	<0.0085	<0.021	<0.14
Stanford in the Vale	Borehole 15	2	<4.0		<4.6	<0.19			<0.17	<0.0070	<0.018	<0.0050	<0.0080	<0.0050	<0.0060	<0.18	0.16
South Glamorgan																	
Lamby Way Tip	Borehole 1A	2	17	<4.0	<9.7	<0.49	<0.20	<0.64	<0.40							<0.25	2.2
South Gloucestershire																	
Berwick Lane Landfill, Hallen	Local water	2	33														

Table 8.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}														
			$^{3}H^{a}$	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
South Yorkshire																	
Beighton Tip, Sheffield	Local water	1	<4.0	<4.0	<9.5	<0.49	<0.30	<0.96	<0.40							<0.050	0.40
Beighton Tip, Sheffield	Borehole	1	51	<4.0	<4.1	<0.21	<0.20	<0.66	<0.19							<0.21	51
Sussex																	
Beddingham Quarry	Leachate (site 1)	2	190	<4.0	<4.7	<0.20	<0.30	<21	<0.17							<0.17	4.0
Beddingham Quarry	Stream (site 2)	2	<4.0	<4.0	<5.7	<0.30	<0.30	<33	<0.25							<0.084	0.30
Beddingham Quarry	Leachate (site 3)	2	390	<4.0	15	<0.27	<0.30	<7.5	<0.22							<0.56	18
Tyne and Wear																	
High Urpeth Tip	Local water (downstream)	1	<4.0		<9.6	<0.49			<0.41	<0.0070	<0.0050	<0.0050	0.0050	<0.0050	0.0080	<0.026	0.33
Kibblesworth Colliery	Liquid (sampling point)	1	<4.0		<9.9	<0.49			<0.39	<0.0070	<0.0050	<0.0050	0.023	<0.0050	0.0070	<0.11	0.58
Ryton Tip, Gateshead	Local water	1	<4.0	<4.0	<9.7	<0.49	<0.30	<0.83	<0.40							<0.059	0.69
West Yorkshire																	
Gelderd Road Tip, Leeds	Borehole	2	8.3	<4.0	<7.0	<0.33	<0.25	<1.5	<0.28							<0.15	1.7
Dean House Farm Tip	Borehole	2	9.3	<4.0	<6.3	<0.31	<0.25	<0.60	<0.26							<0.25	4.3
Wilson Road Tip	Borehole	2	23	<4.0	33	<0.30	<0.20	<0.47	<0.23							<1.5	31

[a] *As tritiated water*

Table 8.5. Concentrations of naturally occurring radionuclides in the environment, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Phosphate processing, Whitehaven										
Winkles	Saltom Bay	4	25	0.75						
Winkles	Parton	4	19	1.8	0.54	0.88	0.40	1.4	0.046	1.3
Winkles	North Harrington	1	17							
Winkles	Nethertown	4	18							
Winkles	Drigg	1			0.65	0.68	0.48			
Winkles	Tarn Bay	1	9.9							
Mussels	Parton	4	42	2.3						
Mussels	Nethertown	4	50	2.8						
Limpets	St Bees	2	16							
Cockles	Ravenglass	2	23							
Crabs	Parton	4	15	0.089	0.083	0.015	0.0084	0.071	0.0031	0.063
Crabs	Sellafield coastal area	4	9.8	0.19						
Lobsters	Parton	4	11	0.094	0.054	0.015	0.0071	0.036	0.0012	0.034
Lobsters	Sellafield coastal area	4	11	<0.030						
Cod	Parton	2	0.48	0.014	0.018	0.0037	0.0016	0.029	0.00094	0.025
Flounder	Whitehaven	1	3.4							
Other samples										
Plaice	1.9 km ENE Hartlepool	1	1.5					0.014	0.00043	0.012
Whiting	1.9 km ENE Hartlepool	1	0.57					0.030	0.0011	0.028
Winkles	Paddy's Hole (Hartlepool)	1	19	2.2						
Winkles	South Gare (Hartlepool)	1	9.0							
Winkles	Seal Sands (Hartlepool)	1	8.0					1.0	0.028	0.90
Winkles	Kirkcudbright	1	3.3							
Mussels	Ribble Estuary	2			0.27	0.75	0.14			
Mussels	South Gare (Hartlepool)	1	45							
Mussels	Pipeline (Hartlepool)	1	27					0.76	0.028	0.66
Limpets	Kirkcudbright	1	10							
Cockles	Southern North Sea	2			0.54	0.29	0.39			
Cockles	Ribble Estuary	1			0.50	0.42	0.20			
Cockles	Flookburgh	2	20							
Crabs	1.9 km ENE Hartlepool	1	18					0.081	0.0021	0.074
Crabs	Kirkcudbright	1	0.026							
Lobsters	Kirkcudbright	1	0.73							
Shrimps	Ribble Estuary	2			0.0098	0.019	0.0042			
Fucus vesiculosus	Pipeline (Hartlepool)	1	1.1					1.8	0.065	1.6
Fucus vesiculosus	Greatham Creek (Hartlepool)	1	1.6					1.3	0.038	1.1
Fucus vesiculosus	North Gare (Hartlepool)	1	0.78					2.1	0.079	1.8
Fucus vesiculosus	Seal Sands (Hartlepool)	1	1.6					1.4	0.040	1.2
Sediment	Rascarrel Bay	1						5.4	0.39	4.7

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

Table 8.6 Monitoring at Aberdeen, 2005

Location and sample type	No. of sampling observ-ations	Gamma radiation dose rate, µGy h^{-1} at 1 m above surface	Radioactivity concentration (dry)[a], Bq kg^{-1}		
			^{210}Po	^{226}Ra	^{228}Ac
Aberdeen Beach position 1, sand 0-2cm	1			4000	630
Aberdeen Beach position 1, sand 2-4cm	1			8000	1100
Aberdeen Beach position 1, sand 4-6cm	1		1600	12000	1700
Aberdeen Beach position 2, sand surface	1			1500	300
Aberdeen Beach position 2, sand 1-3cm	1			2100	340
Aberdeen Beach position 2, sand 6-8cm	1		330	230	48
Aberdeen Beach position 2, sand 11-13cm	1		700	1600	200
Aberdeen Beach position 2, sand 22-25cm	1			660	86
Aberdeen Beach position 2, sand 27-30cm	1			430	70
Aberdeen Beach position 2, sand 31-33cm	1			600	86
Aberdeen Beach position 3, sand 0-2cm	1			380	72
Aberdeen Beach position 4, mud and sand	1			2700	600
Aberdeen Beach position 5, sand and stones 30cm	1			600	110
Aberdeen Beach position 6, sand and stones 30cm	1			2500	250
Aberdeen Beach position 7, sediment	1			10	12
Aberdeen Beach position 8, sediment	1			12	14
Aberdeen Beach position 9, sediment	1			28	13
Aberdeen Beach position 10, sediment	1			21	14
Aberdeen Beach position 11, sediment	1			24	15
Aberdeen Beach position 12, sediment	1			11	11
Aberdeen Beach position 13, sediment	1			10	13
Nigg Bay, sediment	1			24	33
Aberdeen Beach position 14, sediment	1	0.63			
Aberdeen Beach position 14, sediment[b]	1	0.61			
Aberdeen Beach position 14, sediment[c]	1	0.15			
Aberdeen Beach position 15, sediment	1	0.30			
Aberdeen Beach position 16, sediment	1	0.079			
Aberdeen Beach position 17, sediment	1	0.073			
Aberdeen Beach position 18, sediment	1	0.074			
Aberdeen Beach position 19, sediment	1	0.070			
Aberdeen Beach position 20, sediment	1	0.061			
Aberdeen Beach position 21, sediment	1	0.058			
Aberdeen Beach position 22, sediment	1	0.071			
Aberdeen Beach position 23, sediment	1	0.066			

[a] *A conversion factor of 0.5 has been used to convert wet weights to dry weights*
[b] *In contact with substrate*
[c] *After material removed and replaced with fresh sand*

Industrial/ landfill

9. CHERNOBYL AND REGIONAL MONITORING

9.1 Chernobyl

Following the Chernobyl accident of 1986, radiocaesium is detected in sheep grazing certain upland areas in the UK, which were subjected to heavy rainfall after the accident. Restrictions are in place on the movement, sale and slaughter of sheep from these areas, in order to prevent animals from entering the food chain above the action level of 1,000 Bq kg^{-1} of caesium; a level based on the recommendations of an EU expert committee in 1986. A programme of live monitoring, known as the Mark and Release Scheme, allows food safety to be protected, whilst allowing established sheep farming practices to continue. Results of the monitoring programme for 2005 are given in Table 9.1.

In the summer of 2005, whole flock monitoring surveys of sheep on selected farms in the post-Chernobyl restricted areas of Cumbria, Wales and Scotland were carried out (Food Standards Agency, 2006b,c,d). The results of the survey in Scotland identified one farm where controls could be lifted and this decision was implemented in January 2006, leaving 10 farms subject to restrictions. It is planned that further whole flock monitoring surveys will be conducted on restricted farms in all areas during the summer of 2006.

There remain a total of 374 farms, or part farms, and approximately 200,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of over 95 per cent since 1986, when approximately 9,700 farms and 4,225,000 sheep were under restriction. All remaining restrictions in Northern Ireland were lifted in 2000.

Sampling locations for freshwater fish are now limited to Cumbria and southern Scotland, areas of relatively high deposition of fallout from Chernobyl. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 9.2 presents concentrations of caesium-134 and caesium-137 in fish and water. Other artificial radionuclides from the Chernobyl accident are no longer detectable. The highest concentration was 160 Bq kg^{-1} in perch, with overall levels generally similar to those in recent years and substantially less than the 1000 Bq kg^{-1} level reached shortly after the accident. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al*., 2000) and the effective ecological half-life of radiocaesium during the late 1990s has been shown to be between 6 and 30 years.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously stated. A consumption rate of fish of 37 kg $year^{-1}$, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is conservative (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have much lower radiocaesium concentration. In 2005, estimated doses were less than 0.1 mSv.

9.2 Channel Islands

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

The results for 2005 are given in Table 9.3. Nuclides, which can be attributed to routine releases from the nuclear industry, were detected in some samples (cobalt-60 and technetium-99). However, all concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the critical group of high-rate fish and shellfish consumers gives a dose of less than 0.005 mSv in 2005, which is less than 0.5% of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources therefore continued to be of negligible radiological significance.

Results for milk and crop samples are given in Table 9.10 and Table 9.11, respectively, and form parts of the programme considered in Sections 9.6 and 9.7, respectively.

9.3 Isle of Man

The Food Standards Agency carries out an on-going programme of radioactivity monitoring on behalf of the Department of Local Government and the Environment on the Isle of Man for a range of terrestrial foodstuffs. The results complement the Isle of Man Government's own independent radiation monitoring programme (www.gov.im/dlge/enviro/govlabs) and in conjunction with those additional results provides a comprehensive assessment of environmental radioactivity levels on the Isle of Man. Results of aquatic monitoring are presented in Section 3 because of their significance in relation to Sellafield, but are also included here for completeness (Table 9.4).

Radioactivity monitoring on the Island serves two purposes: first to monitor the continuing effects of radiocaesium deposition resulting from the Chernobyl accident in 1986 and second 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 discharges into the Irish Sea and sea-to-land transfer; and (ii) gaseous discharges of tritium, carbon-14 and sulphur-35 and atmospheric transport.

Most radionuclides were present below the limits of detection of the methods used. Carbon-14 was detected in local milk and crops at activity concentrations close to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Levels of strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of 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. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2005.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2005 was 0.019 mSv (0.022 mSv in 2004) or less than 2% of the dose limit for members of the public of 1 mSv.

The effects of liquid discharges from BNG Sellafield in the Irish Sea are discussed fully in Section 3. The dose to the critical group of Manx fish and shellfish consumers was 0.008 mSv in 2005 (similar to 2004) or less than 1% of the dose limit.

9.4 Northern Ireland

The Environment and Heritage Service in Northern Ireland undertake monitoring of the far field effects of liquid discharges into the Irish Sea from Sellafield (Environment and Heritage Service, 2004). The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 9.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 9.5(a) and (b).

In 2005, the main effects of Sellafield were evident as concentrations of technetium-99, caesium-137 and actinides in marine samples. Observed concentrations and dose rates were less than those found nearer to Sellafield and were similar to those in 2004.

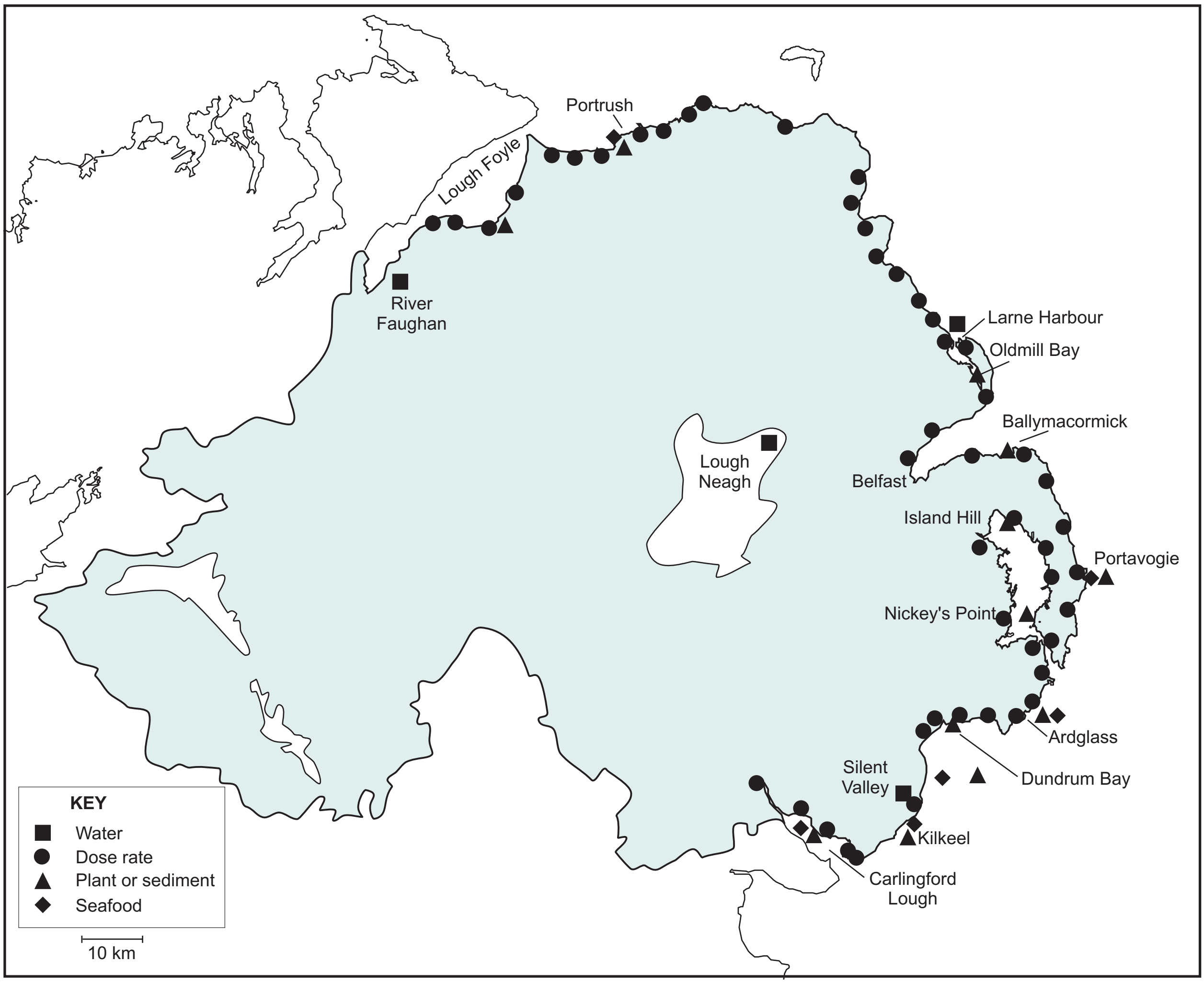


Figure 9.1 Monitoring locations in Northern Ireland

The critical group of high-rate fish and shellfish consumers has been established by a survey of consumption and occupancy habits (Smith *et al*., 2002). The dose to the critical group on the basis of the results from monitoring the marine environment in 2005 was 0.020 mSv, which is 2% of the dose limit for members of the public. The majority of results are below the LoD, with the LoDs being higher than in 2004, due to the method of analysis used being less sensitive than the previously used radiochemical ones. The resultant increase in dose from 0.01 mSv in 2004 is thus only due to differences in reported detection limits and not due to increases in actual activity concentrations.

9.5 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 UK. Most samples are derived from the Food Standards Agency's TDS. The design of the UK TDS has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al*., 1983). The relative importance of each food category within a group reflects its importance in the diet and is based on an average of three previous years of consumption data from the National Food Survey (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al*., 1983). These samples are analysed for a range of food constituents including radioactivity. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both naturally occurring and man-made origins were measured in samples in 2005. The results are provided in Tables 9.6 and 9.7.

There was some evidence for the effects of radioactive waste disposal into the environment reaching the general diet in the form of positively detected amounts of tritium being determined. However, all of the results for man-made radionuclides were low. Many were close to the limits of detection for the various analytical methods used. There was some variability from region to region, but in general no more than is usually detected from the programme. Concentrations of lead-210 and polonium-210 were higher at Tonbridge than in other areas. Within the normal variability observed, there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 9.6 and 9.7 have been assessed for adults, infants and 10-year-old and prenatal children. In all cases the exposures of infants were higher than other age groups. The data are summarised in Table 9.8. The most important man-made radionuclide was strontium-90 derived from weapons test fallout. The nationwide mean dose for all man-made radionuclides was low at 0.002 mSv.

The mean dose due to consumption of naturally occurring radionuclides (excluding potassium-40*) was 0.24 mSv, similar to the value for 2004 of 0.15 mSv. In addition to potassium-40 the most important radionuclides continued to be lead-210 and polonium-210. The results demonstrate that radionuclides from natural sources are by far the most important source of exposure in the average diet of consumers and man-made radionuclides only contributed about 1% of the mean dose.

The maximum exposures from diet in each region are also provided in Table 9.8. The highest exposure in the UK was estimated to be 1.8 mSv based on sampling at Tonbridge, with over 99% of the dose being derived from lead-210 and polonium-210 levels.

The concentrations found in a survey of radioactivity in canteen meals collected across the UK (Table 9.9) were generally similar to the mean concentrations found in UK diet.

9.6 Milk

The programme of milk sampling at dairies in the UK continued in 2005. The aim is to collect samples and analyse them monthly for their radionuclide content. The programme, together with that for crops presented in the following section, provides useful information with which to compare data from farms close to nuclear sites and other establishments which may enhance concentrations above background levels. Some of this data is supplied to the EC as part of the requirements under the EURATOM treaty (e.g. Joint Research Centre, 2005).

Where measurements are comparable, detected activity concentrations of all radionuclides in 2005 were similar to those for previous years. These results are summarised in Table 9.10. Tritium and sulphur-35 results were close to or below their respective limits of detection. Mean and maximum values for carbon-14 from all dairies were similar and at expected background levels. The mean concentration of strontium-90 was less than 0.04 Bq l^{-1}. In the past, the levels of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. However, the levels are now very low and it is less easy to distinguish this trend. Northern Ireland had the highest concentrations of caesium-137.

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* *The potassium content of the body is under strict homeostatic so remains constant in the body and thus the dose does not vary with levels in the environment so is often treated separately from doses due to other naturally occurring radionuclides.*

The assessed doses from consumption of dairy milk at average rates were highest for the one-year-old infant age group. For the range of radionuclides analysed, the dose was less than 0.005 mSv. Previous surveys (e.g. Food Standards Agency and Scottish Environment Protection Agency, 2002) have shown that if a full range of nuclides are analysed and assessed the dose is dominated by naturally-occurring lead-210 and polonium-210 and man-made radionuclides contribute less than 10%.

9.7 Crops

The nationwide programme of monitoring naturally occurring and man-made radionuclides in crops continued in 2005 (Table 9.11). Tritium activity was close to or below the LoD in all samples. The activities of carbon-14 detected in crop samples were mainly close to those expected from consideration of background sources. Within the normal variability observed, the concentrations of other radionuclides in crops were similar to those observed in 2004.

In May 2005, a screening instrument for radioactivity was triggered at Portsmouth Docks by the presence of caesium-137 in a consignment of freeze-dried berries being imported into the UK. 15 samples were analysed and the results are given in Table 9.12. The activity concentrations ranged from 15 – 1900 Bq kg^{-1} (dry). As a result the buyer did not accept the consignment and it was returned to France.

9.8 Airborne particulate, rain and freshwater

Monitoring of radioactivity in air and rain took place at eight locations as part of a UK wide monitoring programme of background sampling under the EURATOM Treaty. The results are given in Table 9.13. The programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an ad-hoc basis by gamma-ray spectrometry. Caesium-137 concentrations were all below or close to the limits of detection. These levels in air, typical of recent years, remain less than 0.01% of those observed in 1986, the year of the Chernobyl reactor accident. Concentrations of beryllium-7, a naturally-occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2004. Concentrations in air and rainwater are very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2005 (Figure 9.2). Sampling is designed to be representative of the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples are representative of natural waters before treatment and supply to the public water system. The results in Tables 9.14, 9.15 and 9.16, show that concentrations of tritium are all below the EU indicator limit for tritium of 100 Bq l^{-1}. Concentrations of gross alpha and gross beta were all below the WHO screening values for drinking water of 0.5 and 1.0 Bq l^{-1}, respectively.

Results for the River Thames, which receives authorised discharges from GE Healthcare, UKAEA Harwell and AWE Aldermaston, are consistent with those from the regulatory monitoring in the vicinity of the site's discharge points.

The mean annual dose from consumption of drinking water in the UK was assessed as 0.027 mSv in 2005 (Table 9.17). The estimated doses were dominated by naturally occurring radionuclides. The annual dose from artificial radionuclides in drinking water was less than 0.001 mSv. The highest annual dose was estimated to be 0.036 mSv due to radionuclides in a source of drinking water from Haweswater Reservoir in Cumbria.

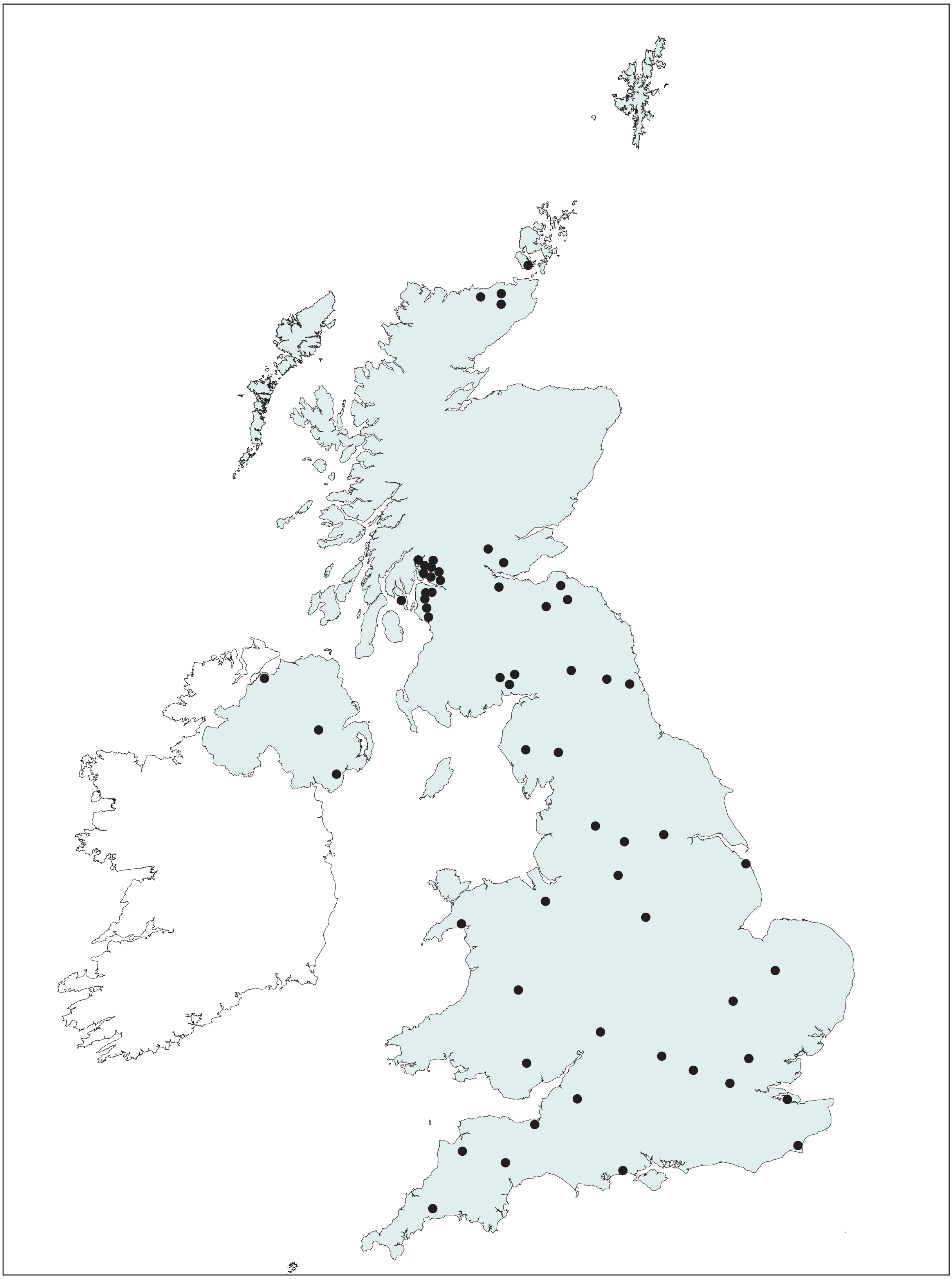

Figure 9.2 Drinking water sampling locations

9.9 Seawater surveys

The UK government is committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally-occurring radioactive substances, and close to zero for artificial radioactive substances (Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000b) and provide information that can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al*., 1998; Kershaw *et al*., 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Evidence to help gauge progress towards achievement of the Government's vision for radionuclides and other hazardous substances is set out in a recent report (Department of Environment, Food and Rural Affairs, 2005a).

The research vessel programme on radionuclide distribution currently comprises of annual surveys of the Bristol Channel/western English Channel and biannual surveys of the Irish Sea and the North Sea. In 2005, coverage was extended to northern Scottish waters with the assistance of the Marine Laboratory (Aberdeen). The results of the 2005 cruises are presented in Figures 9.3 – 9.9. Shoreline sampling is also carried out around the UK, and the data are given in Table 9.18. Much of the shoreline sampling is directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, commentary is found in the relevant site section.

The 2005 caesium-137 data for the Irish Sea (Figure 9.3) show similar levels to those observed from sampling in recent years, the general distribution being one of falling concentrations as the distance from Sellafield increases. The concentrations now observed are only a small percentage of those prevailing in the late 1970s, typically up to 30 Bq l^{-1} (Baxter *et al*., 1992), when discharges were substantially higher.

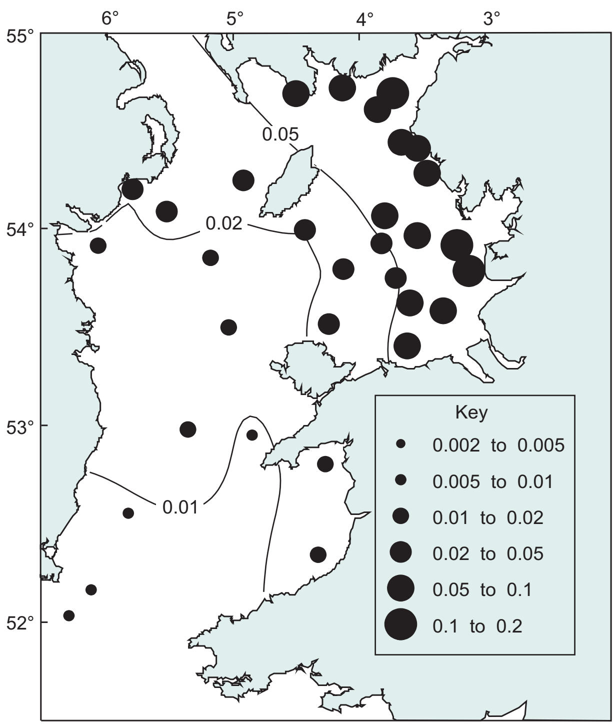

Figure 9.3 ***Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the Irish Sea, June 2005***

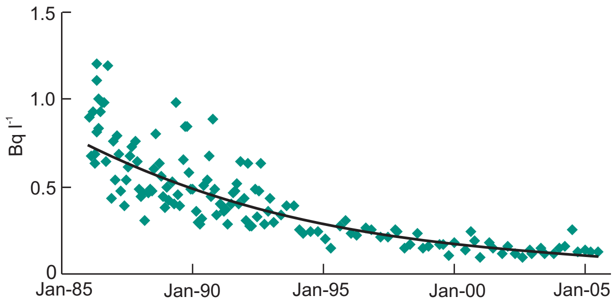

Figure 9.4 ***Temporal variation of dissolved caesium-137 in shoreline seawater close to Sellafield (at St Bees), 1986-2005***

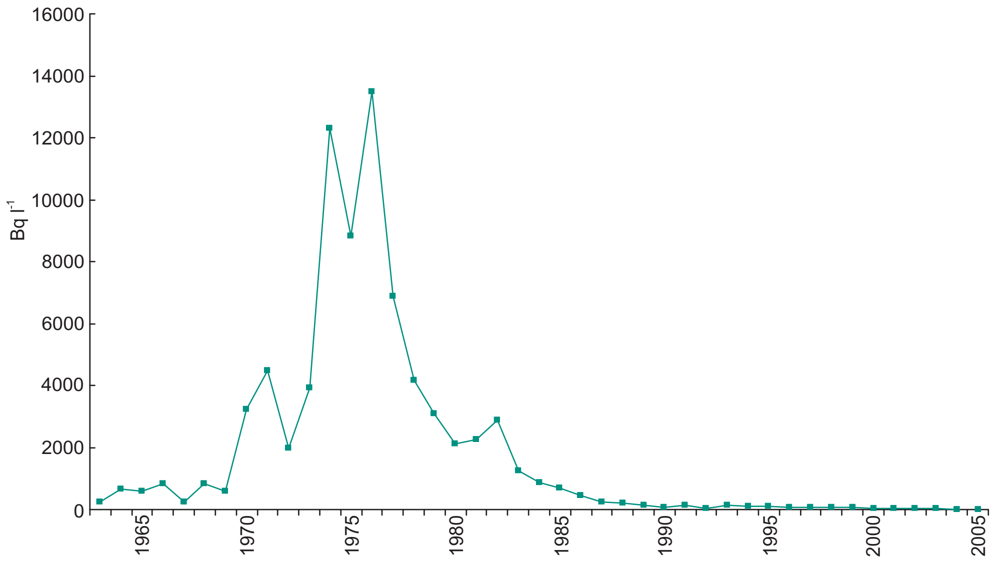

Figure 9.5 Concentrations of caesium-137 in the Northern Irish Sea, 1963-2005

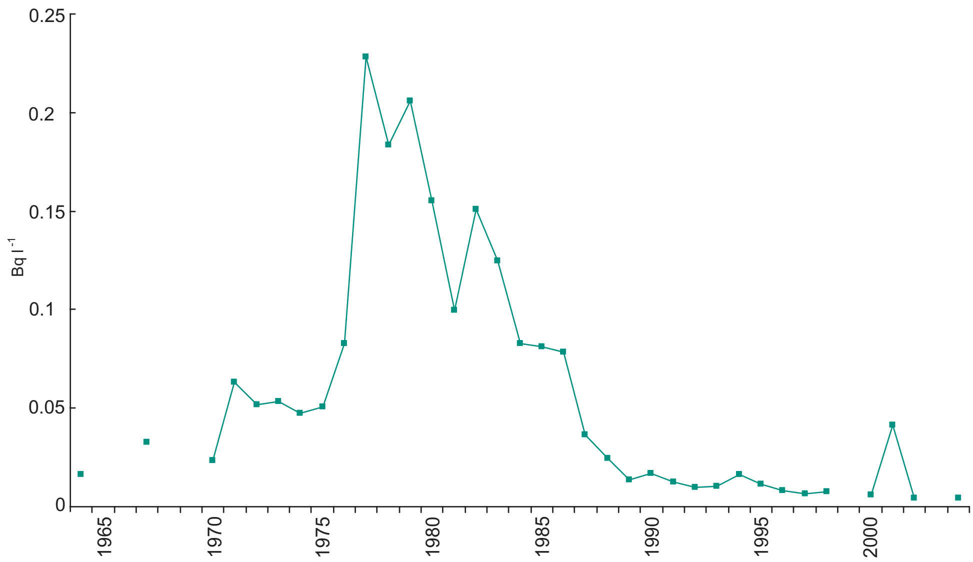

Figure 9.6 Concentrations of caesium-137 in the Northern North Sea, 1964-2004

The predominant source term is remobilisation into the water column of previously discharged activity that became associated with seabed sediments and, to a lesser extent, recent discharges from the Sellafield site. Consequently, levels in seawater have shown a near exponential decrease with time since the commissioning of the SIXEP waste treatment process in the mid 1980s, as illustrated by the data provided in Figure 9.4 for shoreline seawater at St Bees (~ 10 km to the north of Sellafield). Longer time series are showing the peaks in concentrations in the 1970s are shown in Figures 9.5 (northern Irish Sea) and 9.6 (northern North Sea).

Concentrations of caesium-137 in the western English Channel (average activity 0.002 Bq l^{-1}) were, within experimental uncertainties, similar to the background level resulting from global fallout (Figure 9.7).

The caesium-137 data for Scottish waters (Figure 9.8) also show low concentrations (less than 0.01 Bq l^{-1}) throughout the survey area. Nevertheless, the concentration in all the samples analysed here remained slightly elevated above the global fallout level now found in North Atlantic surface waters (approximately 0.0012 Bq l^{-1} in 2002 (Bailly du Bois pers. comm.).

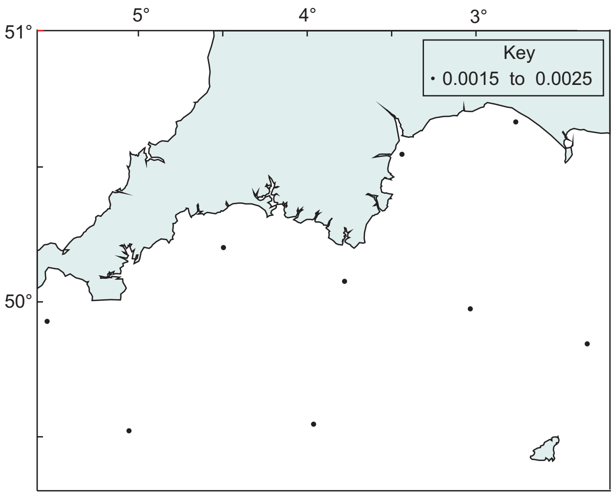

Figure 9.7 Concentrations (Bq l⁻¹) of caesium-137 in filtered seawater from the western English Channel, October-November 2005

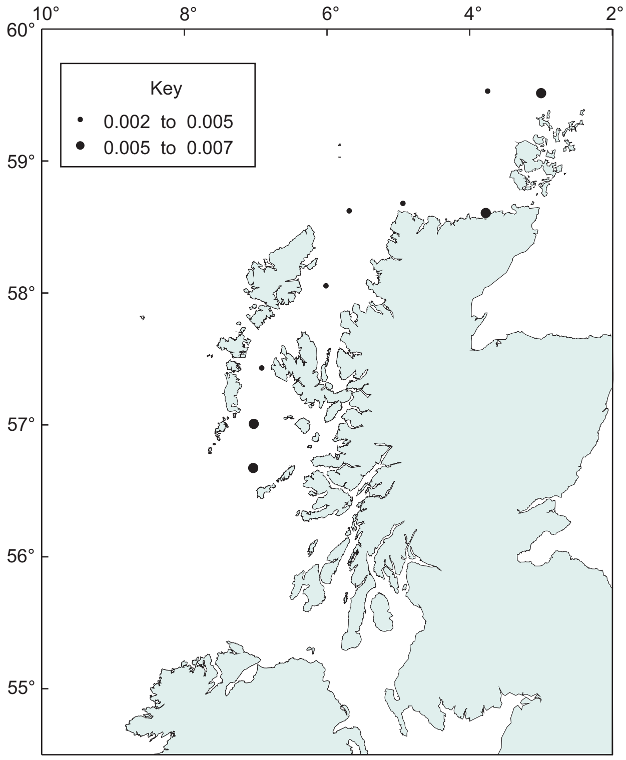

Figure 9.8 Concentrations (Bq l⁻¹) of caesium-137 in filtered seawater from the west and north of Scotland, April-August 2005

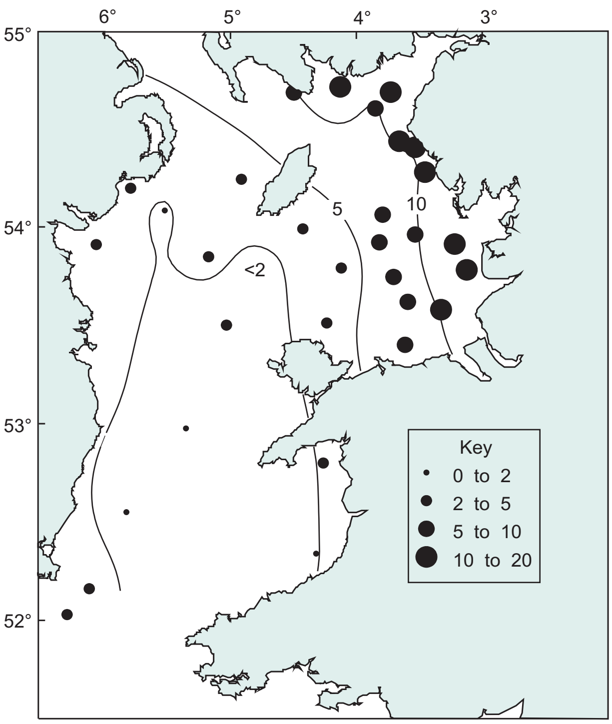

Figure 9.9 Concentrations (Bq l⁻¹) of tritium in surface water from the Irish Sea, June 2005

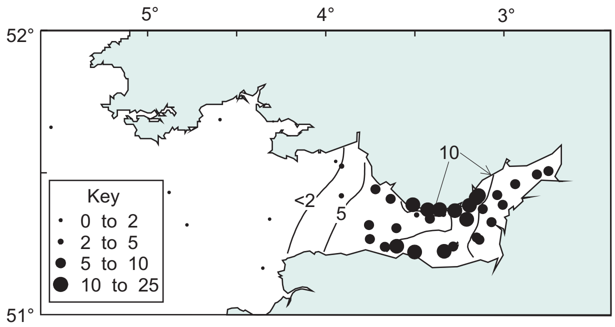

Figure 9.10 Concentrations (Bq l⁻¹) of tritium in surface water from the Bristol Channel, September-October 2005

A full assessment of long-term trends in Northern European seas is provided elsewhere (Povinec *et al.*, 2003).

The concentrations of tritium observed in the Irish Sea (Figure 9.9) were generally higher than those observed in the North Sea (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005) due to the influence of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the combined effects of discharges from Cardiff, Oldbury and Hinkley Point are evident (Figure 9.10). Levels in Scottish waters (Figure 9.11) were below detection.

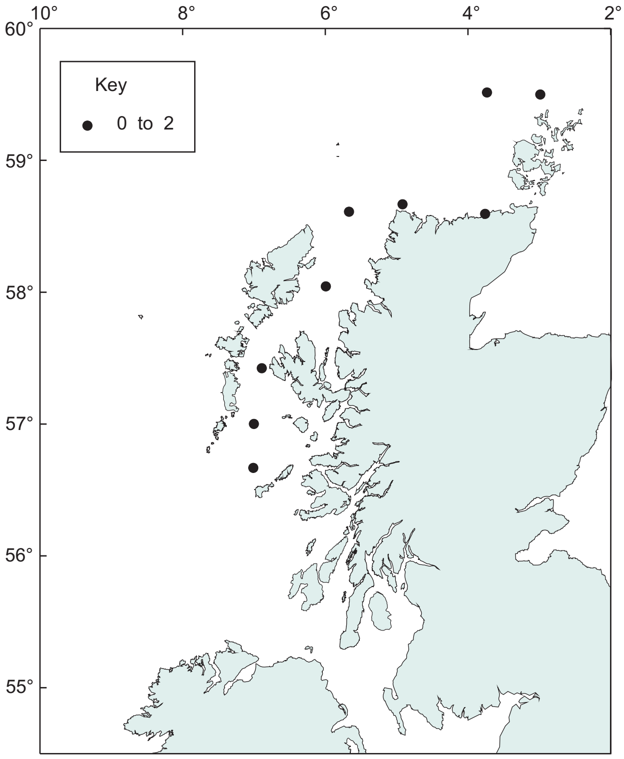

Figure 9.11 Concentrations (Bq l^{-1}) of tritium in surface water from the west and north of Scotland, April-August 2005

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed since 1994. The results of research cruises to study this radionuclide have been published by Leonard *et al*. (1997a and b, 2004) and McCubbin *et al*. (2002). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*. (1999). A full review of the quality status of the north Atlantic has been published by OSPAR (2000b).

Measurements of beta and potassium-40 activity in water from the Clyde in 2005 gave results of less than 1 and less than 10 Bq kg^{-1}, respectively. These concentrations are similar to those for 2004. Caesium-137 was not detected.

Table 9.1 Monitoring of sheep in England, Wales and Scotland

Country	Number of sheep monitored	Number of sheep above action level	Percentage of sheep above action level
England	5551	0	0
Wales	159073	69	0.0434
Scotland	5819	244	4.1932

Table 9.2. Concentrations of radiocaesium in the freshwater environment, 2005

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Rainbow trout	1	<0.21	0.25
Narborough[b]	Rainbow trout	1	<0.05	0.26
Low Wath	Rainbow trout	1	<0.07	0.19
Devoke Water	Brown trout	1	<0.42	83
Devoke Water	Perch	1	<0.41	160
Devoke Water	Water	1	*	0.005
Ennerdale	Brown trout	1	<0.11	13
Ennerdale	Water	1	*	0.003
Gilcrux	Rainbow trout	1	<0.08	0.33
Wast Water	Brown trout	1	<0.07	6.4
Scotland				
Loch Dee	Brown trout	1	<0.14	37
Loch Dee	Water	3	*	0.01

** Not detected by the method used*

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

[b] The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 49, <0.0000088, 0.000037 and 0.000055 Bq kg^{-1}(wet) respectively

Regional/ research

Table 9.3. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs	^{154}Eu
Mackerel	Guernsey	2				<0.08			<0.82		0.23	<0.24
Mackerel	Jersey	1				<0.18			<1.7		0.20	<0.49
Pollack	Jersey	1				<0.05			<0.47		0.17	<0.16
Bass	Guernsey	1				<0.16			<1.7		0.26	<0.45
Bass	Jersey	1				<0.05			<0.55		0.33	<0.15
Edible crabs	Guernsey	1				<0.10			<0.88		<0.08	<0.27
Edible crabs	Jersey	1				<0.13			<1.4		0.11	<0.39
Edible crabs	Alderney	2	<25	<25	77	0.16		0.064	<0.65		<0.06	<0.19
Spiny spider crab	Jersey	1				0.26			<0.96		<0.08	<0.25
Spiny spider crab	Alderney	2				0.70			<0.74		<0.06	<0.19
Lobsters	Guernsey	1				<0.07			<0.66		<0.07	<0.19
Lobsters	Jersey	1				<0.15		0.55	<1.5		<0.12	<0.41
Lobsters	Alderney	1				<0.05			<0.48		<0.04	<0.13
Oysters	Jersey											
	La Rocque	1				<0.05			<0.60		<0.05	<0.15
Limpets	Guernsey	1				<0.17			<1.8		<0.14	<0.43
Limpets	Jersey											
	La Rozel	1				<0.07			<0.64		<0.05	<0.17
Toothed winkle	Alderney	1	<25	26	80	<0.17	<0.094		<1.4		<0.13	<0.42
Scallops	Guernsey	2				<0.08			<0.69		<0.06	<0.23
Scallops	Jersey	2				<0.08			<0.39		<0.03	<0.11
Ormers	Guernsey	1				<0.06			<0.76		<0.05	<0.16
Porphyra	Guernsey											
	Fermain Bay	4				<0.09			<0.94		<0.07	<0.28
Porphyra	Jersey											
	Plemont Bay	4				<0.06			<0.71		<0.05	<0.16
Fucus vesiculosus	Jersey											
	La Rozel	4				<0.11	<0.041	3.0	<0.60		<0.06	<0.21
Fucus vesiculosus	Alderney											
	Quenard Point	2								2.9		
Fucus serratus	Guernsey											
	Fermain Bay	4				<0.13	0.019	1.2	<0.92		<0.08	<0.28
Fucus serratus	Alderney											
	Quenard Point	3				0.20	0.032	2.0	<0.75		<0.05	<0.19
Laminaria digitata	Jersey											
	Verclut	4				<0.06			<0.61		<0.05	<0.22
Mud, sand and stones	Guernsey											
	St. Sampson's Harbour	1				0.36			<1.5		0.86	<0.42
Mud	Jersey											
	St Helier	1				5.9			<3.7		3.0	<1.0
Sand	Alderney											
	Lt. Crabbe Harbour	1				<0.17			<1.8		1.6	<0.46
Seawater	Guernsey	4									<0.002	
Seawater	Jersey	1									0.001	
Seawater	Alderney East	4		4.5							<0.002	

Table 9.3. continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Mackerel	Guernsey	2	<0.21	0.000035	0.00013	0.00025	*	*	100
Mackerel	Jersey	1	<0.25	<0.000025	0.000078	0.00015	*	*	
Pollack	Jersey	1	<0.09			<0.05			100
Bass	Guernsey	1	<0.24	0.000025	0.000066	0.00016	*	*	120
Bass	Jersey	1	<0.14			<0.13			120
Edible crabs	Guernsey	1	<0.14	0.00042	0.0017	0.0032	*	0.00039	61
Edible crabs	Jersey	1	<0.20	0.00026	0.00098	0.0030	*	0.00033	87
Edible crabs	Alderney	2	<0.16	0.00041	0.00083	0.0031	0.000023	0.00055	80
Spiny spider crab	Jersey	1	<0.17			<0.09			110
Spiny spider crab	Alderney	2	<0.17	0.00098	0.0026	0.0039	<0.000015	0.00062	47
Lobsters	Guernsey	1	<0.21			<0.32			96
Lobsters	Jersey	1	<0.20	0.00012	0.00047	0.0023	*	0.00026	88
Lobsters	Alderney	1	<0.14	0.00062	0.0019	0.019	0.000098	0.0030	61
Oysters	Jersey								
	La Rocque	1	<0.16	0.0019	0.0049	0.0052	*	0.00063	65
Limpets	Guernsey	1	<0.23			<0.12			40
Limpets	Jersey								
	La Rozel	1	<0.18	0.0034	0.0085	0.014	0.000045	0.0014	77
Toothed winkle	Alderney	1	<0.22	0.0051	0.015	0.018	0.00011	0.0025	51
Scallops	Guernsey	2	<0.17	0.00071	0.0023	0.0019	*	0.00018	110
Scallops	Jersey	2	<0.06	0.010	0.027	0.012	0.000028	0.0012	72
Ormers	Guernsey	1	<0.17			<0.15			75
Porphyra	Guernsey								
	Fermain Bay	4	<0.17	0.0015	0.0051	0.0058	<0.0000099	0.00064	160
Porphyra	Jersey								
	Plemont Bay	4	<0.10			<0.07			74
Fucus vesiculosus	Jersey								
	La Rozel	4	<0.18	0.0049	0.013	0.0040	0.000081	0.00019	150
Fucus vesiculosus	Alderney								
	Quenard Point	2							
Fucus serratus	Guernsey								
	Fermain Bay	4	<0.17	0.0068	0.026	0.012	0.000071	0.0014	150
Fucus serratus	Alderney								
	Quenard Point	3	<0.17	0.0063	0.019	0.0070	0.000077	0.0012	180
Laminaria digitata	Jersey								
	Verclut	4	<0.14			<0.13			240
Mud, sand and stones	Guernsey								
	St. Sampson's Harbour	1	<0.56	0.068	0.20	0.29	0.00098	0.034	320
Mud	Jersey								
	St Helier	1	<1.2	0.63	1.7	3.1	*	0.30	520
Sand	Alderney								
	Lt. Crabbe Harbour	1	<0.59			<0.67			280

** Not detected by the method used*

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

Regional/ research

Table 9.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2005[c]

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}								
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Aquatic samples										
Cod	4	<0.12	<0.80	<1.3		<1.4	<0.30	<0.13	2.2	<0.75
Herring	3	<0.15	<1.2	<2.9		<1.7	<0.37	<0.17	0.99	<0.89
Lobsters	4	<0.06	<0.28	<0.45	130	<0.62	<0.15	<0.07	0.49	<0.32
Scallops	4	<0.05	<0.20	<0.31		<0.46	<0.11	<0.05	0.27	<0.23
Fucus vesiculosus	4	<0.15	<0.27	<0.51	650	<0.56	<0.30	<0.07	0.80	<0.33
Sediment	1[E]	<0.33	<0.77	<0.34		<1.9	<1.7	<0.28	7.0	<1.1

Material	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
		^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples								
Cod	4	0.00020	0.0012	0.0015	*	*		
Herring	3	0.00021	0.0014	0.0012	*	*		
Lobsters	4			<0.10				160
Scallops	4	0.016	0.088	0.044	*	0.000085		
Fucus vesiculosus	4			<0.25				
Sediment	1[E]			2.1			250	400

Material or selection[b]		No. of sampling observ-ations[d]	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
Terrestrial samples												
Milk		2	<5.6	24	<0.39	<0.28	0.042	<0.84	<0.80	<0.0040	<2.4	<0.68
Milk	max		<6.3	25	<0.43	<0.30	0.052	<0.95	<0.88		<2.8	
Cabbage		1	<4.0	11	<0.20	<0.40	0.11	<0.50	<0.40	<0.026	<2.3	<0.70
Potatoes		1	<5.0	15	0.20	<0.40	0.018	<0.30	<0.30	<0.034	<2.2	<0.80
Strawberries		1	<4.0	13	0.20	<0.30	0.19	<0.40	<0.30		<2.1	<0.60

Material or selection[b]		No. of sampling observ-ations[d]	Mean radioactivity concentration (wet)[a], Bq kg^{-1}						
			^{129}I	Total Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples									
Milk		2	0.024	0.081	<1.3	<0.00010	<0.00010	<0.025	0.00010
Milk	max			0.091					
Cabbage		1	<0.023	0.086	<1.1	<0.00030	0.00020	<0.049	0.00030
Potatoes		1	0.042	0.070	<1.0	<0.00020	<0.00030	<0.044	0.00030
Strawberries		1		0.060	<1.3				

** Not detected by the method used*

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

[b] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments

[c] The gamma dose rate in air at 1m over sand at Douglas[E] was 0.081 μGy h^{-1}

[d] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

[E] Measurements are made on behalf of the Food Standards Agency unless labelled "E". In that case they are made on behalf of the Environment Agency

Table 9.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2005

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{155}Eu
Cod	Kilkeel	4	26	<0.10		<0.24	1.5	<0.17
Cod	North coast	2		<0.05		<0.14	1.8	<0.15
Cod	Portavogie	1		<0.05		<0.14	1.9	<0.16
Whiting	Kilkeel	4		<0.12		<0.31	0.42	<0.31
Haddock	Portavogie	4		<0.13		<0.29	1.1	<0.22
Herring	Ardglass	2		<0.27		<0.60	0.50	<0.57
Spurdog	North coast	4		<0.13		<0.34	1.6	<0.32
Spurdog	Portavogie	4		<0.15		<0.36	1.1	<0.33
Crabs	Kilkeel	4		<0.16		<0.37	<0.29	<0.33
Lobsters	Ballycastle	2		<0.15	53	<0.33	<0.24	<0.21
Lobsters	Kilkeel	4		<0.14	150	<0.31	<0.33	<0.27
Nephrops	Kilkeel	4		<0.17		<0.40	0.91	<0.30
Nephrops	Portavogie	3		<0.12	31	<0.29	1.1	<0.24
Winkles	Ards Peninsula	4		<0.16		<0.38	<0.34	<0.29
Mussels	Carlingford Lough	2		<0.13	18	<0.29	0.46	<0.24
Scallops	Co. Down	2		<0.05		<0.11	0.34	<0.11
Ascophyllum nodosum	Ardglass	1		<0.21		<0.44	0.62	<0.28
Ascophyllum nodosum	Carlingford Lough	1		<0.07		0.40	0.49	<0.21
Fucus spp.	Carlingford Lough	3		<0.13	330	<0.29	0.98	<0.30
Fucus spp.	Portrush	4		<0.07		<0.16	<0.08	<0.17
Fucus vesiculosus	Ardglass	3		<0.20	310	<0.39	0.49	<0.27
Rhodymenia spp.	Strangford Lough	3		<0.12	24	<0.25	0.70	<0.23
Mud	Carlingford Lough	2		<0.81		<3.7	64	<2.6
Mud	Dundrum Bay	2		<0.46		<1.4	6.3	<1.6
Mud	Oldmill Bay	2		<0.63		<2.6	43	<2.2
Mud	Strangford Lough-Nicky's point	2		<0.52		<1.9	34	<2.2
Mud	Ballymacormick	2		<0.43		<1.4	20	<1.5
Mud, sand and stones	Carrichue	2		<0.30		<0.84	2.4	<1.0
Sand	Portrush	2		<0.40		<1.1	0.70	<1.3
Seawater	North of Larne	12			0.018		0.02	

Regional/ research

Table 9.5(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (wet)[a], Bq kg^{-1}				
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
Cod	Kilkeel	4			<0.09		
Cod	North coast	2			<0.19		
Cod	Portavogie	1			<0.23		
Whiting	Kilkeel	4			<0.35		
Haddock	Portavogie	4			<0.14		
Herring	Ardglass	2			<0.65		
Spurdog	North coast	4			<0.34		
Spurdog	Portavogie	4			<0.36		
Crabs	Kilkeel	4			<0.37		
Lobsters	Ballycastle	2			<0.11		
Lobsters	Kilkeel	4			<0.24		
Nephrops	Kilkeel	4			<0.21		
Nephrops	Portavogie	3	0.013	0.076	0.27	*	0.00020
Winkles	Ards Peninsula	4	0.030	0.17	0.19	*	0.00027
Mussels	Carlingford Lough	2			<0.18		
Scallops	Co. Down	2			<0.18		
Ascophyllum nodosum	Ardglass	1			0.37		
Ascophyllum nodosum	Carlingford Lough	1			<0.21		
Fucus spp.	Carlingford Lough	3			<0.26		
Fucus spp.	Portrush	4			<0.16		
Fucus vesiculosus	Ardglass	3			<0.15		
Rhodymenia spp.	Strangford Lough	3	0.046	0.28	0.44	*	0.00093
Mud	Carlingford Lough	2	2.2	13	8.7	*	0.0067
Mud	Dundrum Bay	2			<2.4		
Mud	Oldmill Bay	2	2.7	15	24	*	0.050
Mud	Strangford Lough- Nicky's point	2	1.9	11	12	*	*
Mud	Ballymacormick	2	1.5	8.5	13	*	*
Mud, sand and stones	Carrichue	2	0.020	0.17	0.19	*	*
Sand	Portrush	2			2.1		

** Not detected by the method used*

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

Table 9.5(b). Monitoring of radiation dose rates in Northern Ireland, 2005

Location	Ground type	No. of sampling observa-tions	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Lishally	Mud	1	0.066
Eglington	Shingle	1	0.055
Carrichue House	Mud	1	0.058
Bellerena	Mud	2	0.061
Benone	Sand	2	0.063
Castlerock	Sand	2	0.063
Portstewart	Sand	2	0.060
Portrush, Blue Pool	Sand	1	0.065
Portrush, White Rocks	Sand	1	0.059
Port-Ballintrae	Sand	1	0.061
Giant's Causeway	Sand	1	0.061
Ballycastle	Sand	2	0.061
Cushendun	Sand	1	0.069
Cushendall	Sand and stones	1	0.077
Red Bay	Sand	1	0.074
Carnlough	Sand	1	0.063
Glenarm	Sand	1	0.065
Half Way House	Sand	1	0.063
Ballygally	Sand	1	0.060
Drains Bay	Sand	1	0.060
Larne	Sand	1	0.066
Whitehead	Sand	1	0.070
Carrickfergus	Sand	1	0.068
Belfast Lough	Sand	1	0.067
Helen's Bay	Sand	1	0.071
Groomsport	Sand	1	0.075
Millisle	Sand	1	0.085
Ballywalter	Sand	1	0.070
Ballyhalbert	Sand	1	0.069
Cloughy	Sand	1	0.075
Portaferry	Shingle and stones	1	0.10
Kircubbin	Sand	1	0.090
Greyabbey	Sand	1	0.081
Ards Maltings	Mud	1	0.087
Island Hill	Mud	1	0.085
Nicky's Point	Mud	1	0.088
Strangford	Shingle and stones	1	0.11
Kilclief	Sand	1	0.078
Ardglass	Mud	1	0.091
Killough	Mud	1	0.091
Rocky Beach	Sand	1	0.085
Tyrella	Sand	1	0.085
Dundrum	Mud	1	0.092
Newcastle	Sand	1	0.13
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.096
Greencastle	Sand	1	0.098
Mill Bay	Mud	1	0.11
Rostrevor	Sand	1	0.14
Narrow Water	Mud	1	0.11

Table 9.6. Concentrations of radionuclides in general diet (TDS survey), 2005[a]

Region	Town	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Northern	Alnwick	1	<2.2	31	<0.21	70	<0.045	<0.02	0.030	0.070
Northern	Hessle	1	2.6	40	<0.22	70	<0.048	0.04	0.020	<0.014
Northern	Ormskirk	1	9.8	20	<0.50	70	0.069	<0.05	0.0050	0.021
Central	Bicester	1	<2.5	35	<0.27	80	0.033	<0.05	0.014	0.050
Central	Gorleston	1	<1.8	37	<0.18	61	<0.043	<0.05	0.027	0.046
Central	Leamington Spa	1	10	33	<0.50	90	<0.063	0.04	0.0090	<0.016
Southern	Tonbridge	1	2.1	34	<0.19	70	<0.086	0.03	0.49	0.93
Southern	Wadebridge	1	3.6	30	<0.19	80	0.040	<0.04	0.028	0.060
Southern	Yeovil	1	2.1	35	<0.17	80	0.048	<0.51	0.040	0.011
Wales	Abertillery[b]	1	7.7	36	<0.29	70	0.032	0.05	0.030	0.040
Northern Ireland	Dungannon	1	2.2	31	<0.50	80	0.050	0.06	0.020	0.029
Mean			<4.2	33	<0.29	75	<0.051	<0.085	0.065	<0.12

Region	Town	No. of sampling observations	Mean radioactivity concentration (wet), Bq kg^{-1}					
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Northern	Alnwick	1	0.080	0.00040	<0.023	0.000084	0.00046	0.00070
Northern	Hessle	1	0.031	0.00025	<0.023	<0.00039	0.00042	0.00064
Northern	Ormskirk	1	0.034	0.00059	<0.023	<0.00034	0.00021	0.00049
Central	Bicester	1	0.030	0.0012	<0.024	<0.00035	<0.00044	0.00027
Central	Gorleston	1	0.040	0.00082	<0.023	<0.00014	0.00017	<0.0070
Central	Leamington Spa	1	0.052	0.00045	<0.023	<0.00031	0.00017	0.00083
Southern	Tonbridge	1	0.033	0.00040	0.028	0.000065	0.00040	0.00058
Southern	Wadebridge	1	0.040	<0.00045	<0.023	<0.0010	<0.0012	0.00022
Southern	Yeovil	1	0.043	0.00085	<0.023	0.00017	0.00052	<0.00012
Wales	Abertillery[b]	1	0.027	0.00033	<0.023			0.00098
Northern Ireland	Dungannon	1	0.038	0.00064	0.042	<0.00066	<0.00065	0.00040
Mean			0.041	<0.00058	<0.025	<0.00035	<0.00046	<0.0011

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

[b] *Purchased in Cardiff*

Table 9.7. Concentrations of radionuclides in regional diet in Scotland, 2005

Area	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{3}H	^{35}S	^{40}K	^{90}Sr	^{137}Cs
Dumfries and Galloway (Dumfries)	6	<5.0	<0.43	78	<0.10	<0.05
East Lothian (North Berwick)	6	<5.0	<0.70	81	<0.10	<0.05
Highland (Dingwall)	6	<5.0	<0.50	96	<0.10	<0.07
Renfrewshire (Paisley)	6	<5.0	<0.53	80	<0.10	<0.05

Table 9.8. Estimates of radiation exposure from radionuclides in diet, 2005[a]

Region	Mean[b] exposure, mSv			Maximum exposure, mSv	
	Man-made radionuclides[c]	Naturally occurring radionuclides[d]	All radionuclides	Location	All nuclides
England	0.002	0.28	0.28	Southern, Tonbridge	1.8
Wales	0.001	0.098	0.099	Abertillery	0.099
Northern Ireland	0.002	0.075	0.077	Dungannon	0.077
Scotland	0.002	[e]	[e]	East Lothian, North Berwick	0.003[e]
UK	0.002	0.24	0.24	Southern, Tonbridge	1.8

[a] *Assessments of dose are based on some concentration results at limits of detection.*
Exposures due to potassium-40 content of diet are not included here because they do not vary vary according to the potassium-40 content of diet. Levels of potassium are homeostatically controlled. The average annual dose from potassium-40 in general diet is 0.17mSv, which is in addition to the above figures
[b] *Average of the doses to the most exposed age group at each location*
[c] *Including tritium*
[d] *Including carbon-14*
[e] *Analysis of naturally occurring radionuclides was not undertaken*

Table 9.9. Concentrations of radionuclides in canteen meals, 2005[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (wet), Bq kg^{-1}				
		^{14}C	^{40}K	^{90}Sr	^{137}Cs	Total U
England	4	26	110	<0.055	<0.05	<0.026
Northern Ireland	4	30	100	<0.045	0.06	<0.025
Scotland	1	32	70	<0.30	0.40	<0.025
Wales	4	31	93	<0.055	<0.06	<0.024

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

Table 9.10. Concentrations of radionuclides in milk remote from nuclear sites, 2005

Location	Selection[a]	No. of farms/dairies	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs
Co. Antrim		1	<4.0	18		0.023	0.19
Co. Armagh		1	<4.0	16		0.022	0.085
Cambridgeshire		1	<3.1	17		0.012	0.066
Cheshire		1	<4.0	12		0.019	0.11
Clwyd		1	<4.5	12		0.024	0.074
Cornwall		1	<4.5	15		0.032	0.073
Devon		1	<4.0	20		0.030	0.066
Dorset		1	<4.5	12		0.019	0.091
Co. Down		1	<4.5	16		0.034	0.10
Co. Fermanagh		1	<4.0	14		0.022	0.11
Gloucestershire		2	<4.3	19		0.019	0.066
	max		<4.5	25		0.022	
Guernsey		1	<2.5	14		0.024	0.080
Gwent		1	<3.3	16		0.032	0.066
Gwynedd		1	<4.5	19		0.029	0.075
Hampshire		1	<5.0	13		0.028	0.057
Humberside		1	<4.5	12		0.021	0.065
Kirkcudbrightshire		1	<5.0	<15	<0.50	<0.10	<0.05[c]
Kent		1	<4.5	16		0.020	0.084
Lanarkshire		1	<5.0	<15	<0.50	<0.065	<0.05[c]
Lancashire		1	<4.0	16		0.021	0.086
Leicestershire		1	<4.5	12		0.019	0.084
Lincolnshire		1	<6.0	14		0.014	0.061
Manchester		1	5.5	16		0.021	0.081
Middlesex		1	<4.5	15		0.018	0.076
Midlothian		1	<5.0	<16	<0.50	<0.10	<0.06[c]
North Yorkshire		2	<4.3	17		0.021	0.073
	max		<4.5	20		0.023	0.087
Nairnshire		1	<5.0	<16	<0.50	<0.10	<0.05[c]
Norfolk		1	<4.0	18		0.015	0.072
Renfrewshire		1	<5.0	<15	<0.50	<0.10	<0.05[c]
Suffolk		1	5.0	15		<0.011	0.074
Tyneside		1	<4.5	16		<0.024	0.077
Co. Tyrone		2	<2.6	19		0.025	0.13
	max		<5.0	20		0.027	0.14
Mean Values							
Channel Islands			<2.5	14		0.024	0.080
England			<4.2	16		<0.020	0.075
Northern Ireland			<3.3	18		0.025	0.13
Wales			<3.6	16		0.028	0.072
Scotland			<5.0	<15	<0.50	<0.089	<0.05[c]
United Kingdom			<4.1	<16	<0.50	<0.028	<0.078

[a] *Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima.*
If no 'max' value is given the mean value is the most appropriate for dose assessments
[b] *The number of farms or dairies from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime.*
[c] *^{137}Cs only*

Table 9.11. Concentrations of radionuclides in crops remote from nuclear sites, 2005[a]

Location	Material	No. of samples	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	Total Cs	^{210}Pb	^{210}Po
Berkshire									
Maidenhead	Blackcurrants	1	<5.0	24		0.047	0.090	0.075	0.068
	Lettuce	1	6.0	<3.0		0.10	0.12	0.12	0.076
Carmarthenshire									
Carmarthen	Carrots	1	<5.0	5.0		0.27	0.12	<0.041	0.013
	Spinach	1	<4.0	5.0		0.69	0.14	0.81	0.50
Channel Islands									
Guernsey	Blackberries	1	<4.0	14		0.089	0.052	0.17	0.049
	Lettuce	1	<5.0	<3.0		0.085	0.050	0.077	0.017
Jersey	Potatoes	1	<5.0	14		0.028	0.077		
	Strawberries	1	<5.0	10		0.032	0.046		
Cheshire									
Macclesfield	Cabbage	1	<5.0	7.0		0.60	0.021	0.049	0.056
	Raspberries	1	<5.0	16		0.031	0.086	<0.039	0.024
Cornwall									
Callington	Broccoli	1	<4.0	4.0		0.24	0.086	<0.041	0.016
	Raspberries	1	<4.0	7.0		0.031	0.059	<0.050	0.0073
Penzance	Cabbage	1	<4.0	11		0.048	0.10	<0.059	0.018
	Potatoes	1	<4.0	16		0.027	0.052	<0.048	0.0030
Cumbria									
Kendal	Cabbage	1	<4.0	<3.0		0.63	0.055	0.12	0.059
	Raspberries	1	<5.0	10		0.070	0.020	<0.039	0.024
Dorset									
Poole	Beetroot	1	6.0	13		0.088	0.053	<0.041	0.022
	Cabbage	1	<4.0	6.0		0.17	0.038	0.11	0.039
Dumfriesshire									
Dumfries	Lettuce	1	<5.0	<15	<0.50	<0.10	<0.05[b]		
East Lothian									
North Berwick	Lettuce	1	<5.0	<15	<0.50	<0.10	<0.05[b]		
Hertfordshire									
Letchworth	Cabbage	1	<4.0	5.0		0.061	0.022	0.055	0.019
	Strawberries	1	<4.0	42		0.045	<0.013	<0.028	0.023
Lincolnshire									
Lincoln	Beetroot	1	<4.0	24		0.18	0.27	0.029	0.013
	Kale	1	<4.0	28		1.0	0.079	0.18	0.12
Newport									
Newport	Cabbage	1	<4.0	33		0.098	0.017	0.12	0.20
	Raspberries	1	<4.0	43		0.11	0.014	0.18	0.079
North Yorkshire									
Selby	Cabbage	1	<4.0	27		0.069	0.042	0.092	0.065
	Strawberries	1	<4.0	34		0.24	0.015	0.082	0.041
Nottinghamshire									
Retford	Lettuce	1	<4.0	22		0.091	0.039	<0.033	0.023
	Strawberries	1	<4.0	35		0.062	0.033	0.056	0.017
Renfrewshire									
Paisley	Lettuce	1	<5.0	<15	0.13	<0.10	<0.05[b]		
Ross-shire									
Dingwall	Lettuce	1	<5.0	<15	0.29	<0.10	<0.05[b]		
Shropshire									
Diddlebury	Chard/comfrey	1	<4.0	<3.0		0.40	0.12	0.98	0.47
	Potatoes	1	<6.0	12		0.025	0.038	<0.047	0.0064
Suffolk									
Lowestoft	Cabbage	1	<4.0	29		0.14	0.067	0.091	0.049
	Potatoes	1	<4.0	54		0.031	0.020	<0.026	0.0080
Tyne and Wear									
Sunderland	Cabbage	1	<4.0	8.0		0.15	0.051	0.074	0.044
	Potatoes	1	<5.0	28		0.024	0.10	<0.045	0.0054
Warwickshire									
Stratford upon Avon	Beetroot	1	<4.0	11		0.079	0.043	<0.041	<0.0014
	Spinach	1	<4.0	<3.0		0.27	0.057	0.12	0.061
West Midlands									
Coventry	Gooseberries	1	<4.0	10		0.081	0.033	<0.044	0.034
	Spinach	1	<4.0	9.0		0.47	0.095	0.099	0.13
West Sussex									
Chichester	Cabbage	1	<4.0	13		0.58	0.042	0.21	0.11
	Potatoes	1	<5.0	7.0		0.034	0.061	<0.038	0.0046
Wiltshire									
Salisbury	Lettuce[c]	1	<4.0	6.0		0.25	0.15	0.32	0.23
	Raspberries	1	<4.0	18		0.084	0.041	0.093	0.029
Yorkshire									
Bradford	Potatoes	1	<5.0	16		0.038	0.044	<0.046	0.0067
	Spinach	1	<4.0	11		0.38	0.24	0.52	0.26
Mean Values									
Channel Isles			<4.8	<10		0.059	0.056	0.12	0.033
England			<4.4	<16		0.19	<0.069	<0.11	<0.061
Wales			<4.3	22		0.29	0.071	<0.29	0.15
Scotland			<5.0	<15	<0.36	<0.10	<0.051[b]		
Great Britain			<4.4	<16	<0.36	<0.19	<0.068	<0.13	<0.070

Table 9.11. continued

Location	Material	No. of samples	Mean radioactivity concentration (wet), Bq kg^{-1}						
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Total alpha
Berkshire									
Maidenhead	Blackcurrants	1	0.011	0.0014	<0.032	<0.00010	<0.00020	<0.00020	
	Lettuce	1	0.029	0.014		<0.00020	0.00030	0.00030	
Carmarthenshire									
Carmarthen	Carrots	1	0.086	0.00070		<0.00010	0.00020	0.00050	
	Spinach	1	0.25	0.039		<0.00030	0.00090	0.00050	
Channel Islands									
Guernsey	Blackberries	1	0.014	<0.0013	<0.035	<0.00010	0.00010	0.00050	
	Lettuce	1	0.015	0.0097		<0.00010	0.00020	<0.00020	
Jersey	Potatoes	1				<0.00020	<0.00020	0.00030	
	Strawberries	1				<0.00010	0.00020	0.00060	
Cheshire									
Macclesfield	Cabbage	1	0.044	0.0025		<0.00020	0.00020	0.00020	
	Raspberries	1	0.016	<0.00060	<0.032	0.00010	<0.00010	0.00010	
Cornwall									
Callington	Broccoli	1	0.021	0.0012	<0.033	0.00010	0.00010	0.00030	
	Raspberries	1	0.0090	<0.00080		<0.00020	<0.00020	<0.00020	
Penzance	Cabbage	1	<0.0050	0.0017		<0.00020	<0.00020	<0.00020	
	Potatoes	1	0.011	<0.00090		<0.00020	0.00010	0.00020	
Cumbria									
Kendal	Cabbage	1	0.060	0.0028		<0.00010	0.00020	0.00040	
	Raspberries	1	<0.0030	0.0011		<0.00020	<0.00020	0.00020	
Dorset									
Poole	Beetroot	1	0.038	0.0028		<0.00010	<0.00010	<0.00010	
	Cabbage	1	0.017	<0.0010		<0.00020	<0.00020	0.00040	
Dumfriesshire									
Dumfries	Lettuce	1							0.28
East Lothian									
North Berwick	Lettuce	1							0.60
Hertfordshire									
Letchworth	Cabbage	1	0.0070	0.00030		<0.00020	0.00010	0.00020	
	Strawberries	1	0.015	<0.00060	<0.030	<0.00020	<0.00020	<0.00030	
Lincolnshire									
Lincoln	Beetroot	1	0.073	0.0042		<0.00020	0.00020	<0.00030	
	Kale	1	<0.0050	0.0060	0.061	<0.00020	<0.00020	<0.00040	
Newport									
Newport	Cabbage	1	0.029	<0.00090	<0.034	0.00010	<0.00010	<0.00030	
	Raspberries	1	0.010	<0.0010		<0.00010	0.00010	<0.00030	
North Yorkshire									
Selby	Cabbage	1	0.029	0.0031		<0.00020	<0.00010	0.00030	
	Strawberries	1	0.021	0.0079		<0.00010	<0.00010	<0.00040	
Nottinghamshire									
Retford	Lettuce	1	0.021	0.0036		<0.00020	<0.00020	<0.00040	
	Strawberries	1	0.031	<0.00060		<0.00020	0.00010	0.00040	
Renfrewshire									
Paisley	Lettuce	1							0.29
Ross-shire									
Dingwall	Lettuce	1							<0.34
Shropshire									
Diddlebury	Chard/comfrey	1	0.13	0.0028		<0.00020	<0.00010	0.00020	
	Potatoes	1	0.012	0.0017		<0.00020	<0.00010	0.00030	
Suffolk									
Lowestoft	Cabbage	1	0.026	0.012		<0.00020	0.00010	0.00030	
	Potatoes	1	0.0040	0.0040		<0.00010	0.00020	0.00030	
Tyne and Wear									
Sunderland	Cabbage	1	<0.0070	0.0015		<0.00010	<0.00010	<0.00020	
	Potatoes	1	<0.0020	0.0018	<0.033	<0.00020	<0.00010	<0.00010	
Warwickshire									
Stratford upon Avon	Beetroot	1	0.035	<0.0010	<0.033	<0.00020	0.00010	<0.00020	
	Spinach	1	0.095	0.0070		<0.00010	0.00020	<0.00030	
West Midlands									
Coventry	Gooseberries	1	0.0080	0.0034		<0.00010	0.00010	<0.00030	
	Spinach	1	0.070	0.011		<0.00010	0.00030	<0.00030	
West Sussex									
Chichester	Cabbage	1	0.0090	0.0029		<0.00020	<0.00010	<0.00020	
	Potatoes	1	0.011	0.0011		<0.00020	<0.00020	0.00050	
Wiltshire									
Salisbury	Lettuce[c]	1	0.041	0.064	0.23	<0.00020	0.00070	0.0010	
	Raspberries	1	0.0050	0.0011		<0.00020	<0.00020	0.00020	
Yorkshire									
Bradford	Potatoes	1	0.013	0.0015		<0.00020	<0.00020	<0.00020	
	Spinach	1	0.072	0.0095	0.062	<0.00020	0.00020	<0.00020	
Mean Values									
Channel Isles			0.015	<0.0055	<0.035	<0.00013	<0.00018	<0.00040	
England			<0.028	<0.0050	<0.061	<0.00017	<0.00018	<0.00029	
Wales			0.093	<0.010	<0.034	<0.00015	<0.00033	<0.00040	
Scotland									<0.38
Great Britain			<0.034	<0.0056	<0.058	<0.00017	<0.00019	<0.00030	<0.38

[a] *Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection*
[b] *^{137}Cs only*
[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.044, 0.0038 and 0.048 Bq kg^{-1} respectively*

Table 9.12. Concentrations of radiocaesium in mixed berries, 2005

Sample number	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1} ^{137}Cs
05FSA00120	Blueberries	1	74
05FSA00220	Blackcurrants	1	1700
05FSA00320	Blackberries	1	15
05FSA00420	Blueberries	1	21
05FSA00520	Blackcurrants	1	510
05FSA00620	Blackberries	1	21
05FSA00720	Blueberries	1	170
05FSA00820	Blackcurrants	1	1400
05FSA00920	Blackberries	1	18
05FSA001020	Blueberries	1	44
05FSA001120	Blackcurrants	1	1900
05FSA001220	Blackberries	1	45
05FSA001320	Blueberries	1	77
05FSA001420	Blackcurrants	1	1800
05FSA001520	Blackberries	1	68

Table 9.13. Concentrations of radionuclides in rainwater and air, 2005

Location	Sample	No. of sampling obser-vations	Mean radioactivity concentration,[a] in rainwater and air									
			^{3}H	^{7}Be	^{90}Sr[b]	^{137}Cs	^{210}Pb	^{210}Po	^{239}Pu+^{240}Pu[c]	^{241}Am[c]	Total alpha[b]	Total beta[b]
Ceredigion												
Aberporth	Rainwater	4	0.94	<2.0		<0.065			<0.000030	<0.0000079		
	Air	4		0.0019		$<7.0\ 10^{-7}$			$<3.4\ 10^{-10}$	$<4.1\ 10^{-10}$		
Co. Down												
Conlig	Rainwater	4		1.8		<0.058						
	Air	4		0.0017		$<9.1\ 10^{-7}$						
Dumfries and Galloway												
Eskdalemuir	Rainwater	4	1.3	1.2		<0.022						
	Air	4		0.0015		$<5.4\ 10^{-7}$						
Glasgow												
Glasgow	Air	12				<0.010						<0.002
North Yorkshire												
Dishforth	Rainwater	4		<3.1		<0.083						
	Air	4		0.0012		$<6.5\ 10^{-7}$						
Oxfordshire												
Chilton	Rainwater	4		<2.6	0.0079	<0.089					0.049	0.16
	Air	4		0.0014		$<6.5\ 10^{-7}$						
	Air	13					0.00018	0.0000074				
Shetland												
Lerwick	Rainwater	4		1.7		<0.042						
	Air	4		0.0014		$<5.6\ 10^{-7}$						
Suffolk												
Orfordness	Rainwater	4	0.54	<2.3		<0.086						
	Air	4		0.0019		$<6.2\ 10^{-7}$						

Location	Sample	Mean radioactivity concentration[a] in rainwater and air				
		^{40}K	^{208}Tl	^{210}Pb	^{214}Pb	^{228}Ac
Additional radionuclides detected by gamma spectrometry in some quarters						
Ceredigion						
Aberporth	Rainwater				0.18	
	Air			0.00011		
Co. Down						
Conlig	Air	0.000020		0.00011		
Dumfries and Galloway						
Eskdalemuir	Rainwater			6.4		
	Air	0.000017		0.000075		
North Yorkshire						
Dishforth	Air			0.000080		
Oxfordshire						
Chilton	Air			0.000093		
Shetland						
Lerwick	Air			0.000074		
Suffolk						
Orfordness	Rainwater	5.4	0.081			0.41
	Air			0.00015		

[a] *Bq l^{-1} for rainwater and Bq kg^{-1} for air, 1 kg air occupies 1 m^3 at standard temperature and pressure* [b] *Bulked from 4 quarterly samples* [c] *Separate annual sample for rain, annual bulked sample for air*

Table 9.14. Concentrations of radionuclides in sources of drinking water in Scotland, 2005

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee	1	<1.0	<0.0050	<0.01	<0.010	0.039
Argyll and Bute	Auchengaich	1	<1.0	0.0069		<0.010	0.033
Argyll and Bute	Helensburgh Reservoir	2	<1.0		<0.01	<0.022	0.11
Argyll and Bute	Loch Ascog	2	<1.0		<0.01	<0.010	0.093
Argyll and Bute	Loch Eck	2	<1.1	<0.0050	<0.01	<0.010	0.028
Argyll and Bute	Loch Finlas	2	<1.0		<0.01	<0.025	0.14
Clackmannanshire	Gartmorn	2	<1.0	<0.0050	<0.05	<0.020	0.036
Dumfries and Galloway	Black Esk	2	3.0	<0.050	<0.01	<0.010	0.031
Dumfries and Galloway	Purdomstone	1	5.2		<0.01	0.016	0.68
Dumfries and Galloway	Winterhope	2	10	<0.0050	<0.01	<0.010	0.046
East Lothian	Hopes Reservoir	2	<1.0	<0.0050	<0.01	<0.047	0.20
East Lothian	Thorters Reservoir	2	<1.1	<0.0050	<0.01	<0.020	0.032
East Lothian	Whiteadder	2	<1.0		<0.01	<0.010	0.055
Fife	Holl Reservoir	1	<1.0		<0.05	<0.010	0.035
Highland	Loch Baligill	1	<1.0		<0.01	<0.011	<0.010
Highland	Loch Calder	1	<1.0		<0.01	<0.010	0.016
Highland	Loch Glass	2	<1.0	0.0058	<0.02	<0.010	0.041
Highland	Loch Shurrerey	1	<1.0		<0.01	<0.010	0.052
North Ayrshire	Camphill	2	<1.0	<0.0050	<0.01	<0.010	<0.014
North Ayrshire	Knockendon Reservoir	2	<1.0		<0.01	<0.032	0.22
North Ayrshire	Munnoch Reservoir	2	<1.0	0.0051	<0.01	<0.010	0.031
North Ayrshire	Outerwards	2	<1.0	<0.0050	<0.01	<0.010	<0.015
Orkney Islands	Heldale Water	1	<1.0		<0.01	<0.011	0.035
Perth and Kinross	Castlehill	1	<1.0		<0.01	<0.010	0.022
Scottish Borders	Knowesdean	6	<1.0	<0.0050	<0.01	<0.040	<0.24
Stirling	Loch Katrine	6	<1.0	<0.019	<0.01	<0.015	0.20
West Dunbartonshire	Loch Lomond (Ross Priory)	2	<1.0	<0.0050	<0.01	<0.012	0.35
West Lothian	Morton No 2	1	<1.0		<0.01	<0.010	0.031

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Table 9.15. Concentrations of radionuclides in sources of drinking water in England and Wales, 2005

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l[-1]					
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	^{210}Po
England								
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.050	<0.0010		<0.0010	<0.010
Cambridgeshire	Grafham Water	4	<4.0	0.35	0.0021		<0.0010	<0.010
Cheshire	River Dee, Chester	4	<4.0	0.17	0.0044	<0.0020	0.0010	<0.010
Cornwall	River Fowey	4	<4.0	0.090	0.0019	<0.0020	<0.0012	<0.010
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.080	0.0041		<0.0010	<0.010
County Durham	River Tees, Darlington	4	<4.0	0.065	0.0035	<0.0020	0.0010	<0.010
County Durham	Honey Hill Treatment works	4	<4.0	<0.040	0.0044		0.0013	<0.010
Cumbria	Haweswater Reservoir	4	<4.0	<0.040	0.0032		0.00090	0.014
Cumbria	Ennerdale Lake	4	<4.0	<0.024	0.0048		0.0011	<0.010
Derbyshire	Armfield Water Treatment Plant	4	<4.0	<0.034	<0.0010		0.0011	<0.010
Derbyshire	Matlock, Groundwater	4	<4.0	0.041	<0.0010		<0.0010	<0.010
Devon	River Exe, Exeter	4	<4.0	0.10	0.0033	<0.0024	<0.0010	<0.011
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.17	0.0025	<0.0021	<0.0010	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.37	<0.0031	0.0030	<0.0010	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.090	0.0015	<0.0020	<0.0010	<0.010
Humberside	Littlecoates, Groundwater	4	<4.0	0.098	<0.0010		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.0	0.17	0.0043		<0.0010	<0.010
Kent	Chatham, Deep Groundwater	4	<4.0	0.060	0.0013		<0.0010	<0.010
Lancashire	Corn Close, Groundwater	4	<4.0	0.036	<0.0010		<0.0012	<0.010
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.11	<0.0012	<0.0020	<0.0010	<0.010
Northumbria	Kielder Reservoir	4	<4.0	<0.050	0.0040		<0.0010	<0.010
Oxfordshire	River Thames, Oxford	4	<4.0	0.18	0.0013	<0.0020	<0.0010	<0.010
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.070	<0.0010		<0.0010	<0.010
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.083	0.0017		0.0010	<0.010
Surrey	River Thames, Walton	4	<4.0	0.24	0.0014	<0.0022	<0.0010	<0.010
Surrey	River Thames, Chertsey	4	<4.0	0.22	0.0027	<0.0021	0.0010	<0.010
Yorkshire	Eccup No.1 Washburn Valley Reservoirs, Leeds	1	<4.0	0.12	<0.0016		<0.0013	0.0094
Yorkshire	Chellow Heights, Bradford	2	<4.0	0.050	0.0047		<0.0011	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l[-1]						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.060	<0.050
Cambridgeshire	Grafham Water	4	<0.010	<0.010	<0.010	<0.010	0.019	0.56	0.39
Cheshire	River Dee, Chester	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.24	0.17
Cornwall	River Fowey	4	<0.011	<0.010	<0.010	<0.010	0.046	0.11	0.076
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.11	0.072
County Durham	River Tees, Darlington	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.085	0.057
County Durham	Honey Hill Treatment works	4	<0.010	<0.010	<0.010	<0.010	<0.023	0.074	<0.056
Cumbria	Haweswater Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.054	<0.050
Cumbria	Ennerdale Lake	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.055	<0.050
Derbyshire	Armfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.051	<0.050
Derbyshire	Matlock, Groundwater	4	<0.010	0.031	<0.010	0.017	0.069	0.11	0.076
Devon	River Exe, Exeter	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.12	0.081
Gloucestershire	River Severn, Tewkesbury	4	<0.010	0.019	<0.010	0.011	0.032	0.25	0.17
Greater London	River Lee, Chingford	4	<0.010	<0.010	<0.010	<0.010	0.028	0.55	0.37
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.12	0.087
Humberside	Littlecoates, Groundwater	4	<0.010	<0.010	<0.010	<0.010	0.025	0.18	0.12
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.022	0.27	0.18
Kent	Chatham, Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.078	0.054
Lancashire	Corn Close, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.082	0.058
Norfolk	River Drove, Stoke Ferry	4	<0.010	0.011	<0.010	<0.010	0.025	0.17	0.11
Northumbria	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.059	<0.051
Oxfordshire	River Thames, Oxford	4	<0.010	<0.010	<0.010	<0.010	0.022	0.27	0.18
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	<0.010	<0.010	<0.010	0.020	0.10	0.071
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	<0.010	<0.010	<0.010	0.023	0.20	0.13
Surrey	River Thames, Walton	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.36	0.25
Surrey	River Thames, Chertsey	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.34	0.23
Yorkshire	Eccup No.1 Washburn Valley Reservoirs, Leeds	1	<0.010	<0.010	<0.010	<0.010			
Yorkshire	Chellow Heights, Bradford	2	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050

Table 9.15. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
Wales									
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.020	0.0036			0.0018	<0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.045	0.0030			<0.0010	<0.013
Powys	Elan Valley Reservoir	4	<4.0	<0.050	0.0040			0.00090	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
Wales									
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.052	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.058	<0.050

[1] *Using ^{137}Cs standard*
[2] *Using ^{40}K standard*

Table 9.16. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2005

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{90}Sr	^{137}Cs	^{210}Po	^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Co. Londonderry	R Faughan	4	<1.0	<0.0044	<0.05	<0.010	<0.012	<0.010	<0.010	<0.010	<0.015	0.090
Co. Antrim	Lough Neagh	4	<1.0	<0.0050	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.016	0.096
Co. Down	Silent Valley	4	<1.0	<0.0052	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	0.024	0.043

Table 9.17. Estimates of radiation exposure from radionuclides in drinking water, 2005[a]

Region	Mean[b] exposure, mSv			Maximum exposure, mSv	
	Man-made radionuclides[c]	Naturally occurring radionuclides[d]	All radionuclides	Location	All nuclides
England	<0.001	0.027	0.027	Cumbria, Haweswater Reservoir	0.036
Wales	<0.001	0.029	0.029	Mid-Glamorgan, Llwyn-on Reservoir	0.034
Northern Ireland	0.001	0.027	0.027	Co. Down, Silent Valley	0.027
Scotland	<0.001	[e]	[e]	Dumfries and Galloway, Black Esk	0.002[e]
UK	<0.001	0.027	0.027	Cumbria, Haweswater Reservoir	0.036

[a] *Assessments of dose are based on some concentration results at limits of detection.*
Exposures due to potassium-40 content of water are not included here because they do not vary vary according to the potassium-40 content of water. Levels of potassium are homeostatically controlled.
[b] *Average of the doses to the most exposed age group at each location*
[c] *Including tritium*
[d] *Including carbon-14*
[e] *Analysis of naturally occurring radionuclides was not undertaken*

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Table 9.18. Concentrations of radionuclides in seawater, 2005

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}											
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Dounreay (Sandside Bay)	4	<1.0		<0.10			<0.28	<0.10	<0.10	<0.18	<0.10		
Dounreay (Brims Ness)	3	<1.0		<0.10			<0.35	<0.10	<0.10	<0.24	<0.10		
Rosyth	2	<1.0		<0.10			<0.37	<0.10	<0.10	<0.25	<0.10		
Torness	2	<1.5		<0.10			<0.23	<0.10	<0.10	<0.14	<0.10		
Hartlepool (North Gare)	2			<0.32			<2.6	<0.31	<0.25	<1.3	<0.63	<2.1	15
Hartlepool (North Gare)	2[F]	<2.0											
Sizewell	2			<0.38			<2.9	<0.35	<0.30	<1.3	<0.41	<3.2	23
Aldeburgh	2[F]	<1.5											
Bradwell	2			<0.39			<3.0	<0.38	<0.32	<1.5	<0.48	<2.6	13
Dungeness (inlet)	2[F]	47											
Dungeness south	2			<0.37			<3.0	<0.37	<0.32	<1.5	<0.47	<2.8	15
Winfrith (Lulworth Cove)	2			<0.32			<2.3	<0.29	<0.25	<1.2	<0.45	<2.8	15
Alderney	4[F]	4.5						*	<0.002				
Jersey	1[F]							*	0.001				
Guernsey	4[F]							*	<0.002				
Devonport (Millbrook Lake)	2	<4.0	<4.0	<0.42									
Devonport (Tor Point South)	2	<4.0	<4.0	<0.31									
Hinkley	2			<0.33	<0.020		<2.3	<0.30	<0.24	<1.2	<0.63	<2.4	14
Berkeley and Oldbury	1			<0.52			<3.6	<0.46	<0.41	<1.7	<0.54	<1.0	4.9
Cardiff (Orchard Ledges)[a]	2	<4.6	<4.0										
Cardiff (Orchard Ledges East)	2[F]	10											
Holyhead	4[F]	4.6						*	0.06				
Wylfa (Cemaes Bay)	2			<0.32			<2.3	<0.32	<0.26	<1.3	<0.63	<1.6	9.6
Wylfa (Cemlyn Bay)	2			<0.31			<2.3	<0.29	<0.24	<1.2	<0.45	<2.6	14
Llandudno	1[F]							*	0.07				
Menai Straits	1[F]					0.022							
Prestatyn	1[F]							*	0.11				
New Brighton	1[F]							*	0.09				
Ainsdale	1[F]							*	0.15				
Rossall	1[F]							*	0.14				
Heysham (inlet)	1			<0.46			<3.6	<0.46	<0.42	<1.7	<0.52	<1.6	13
Heysham (inlet)	2[F]	24											
Half Moon Bay	1[F]							*	0.21				
Silecroft	1[F]							*	0.14				
Seascale (Particulate)	2			<0.14	<0.010		<0.84	<0.11	<0.12	<0.43	<0.15	0.21	<0.23
Seascale (Filtrate)	2			<0.30	<0.079	<1.4	<2.4	<0.30	<0.27	<1.3	<0.65	<2.2	16
St. Bees	12[F]	19						*	0.14				
St. Bees (Particulate)	2			<0.14	<0.030		<0.84	<0.11	<0.12	<0.43	<0.15	0.17	<0.14
St. Bees (Filtrate)	2			<0.29	<0.025	<0.30	<2.3	<0.30	<0.28	<1.1	<0.41	<1.3	4.7
Whitehaven	1[F]							*	0.12				
Maryport	1[F]							*	0.14				
Silloth	1[F]							*	0.21				
Seafield	4	7.5		<0.10			<0.25	<0.10	<0.14	<0.18	<0.10		
Southerness[b]	4	5.9		<0.10			<0.23	<0.10	<0.11	<0.16	<0.0011		
Auchencairn	4	5.3		<0.10			<0.37	<0.10	<0.13	<0.25	<0.10		
Ross Bay	1[F]							*	0.09				
Isle of Whithorn	1[F]							*	0.05				
Drummore	1[F]							*	0.04				
Knock Bay	4	<2.1		<0.10			<0.30	<0.10	<0.10	<0.21	<0.10		
Knock Bay	4[F]	<2.7						*	0.03				
Hunterston	2	8.9		<0.10			<0.65	<0.10	<0.10	<0.36	<0.10		
North of Larne	12					0.018		*	0.02				
Faslane (Carnban)	2	2.3		<0.10			<0.28	<0.10	<0.10	<0.19	<0.10		

** Not detected by the method used*
[a] The concentration of ^{3}H as tritiated water was 12 Bq l^{-1}
[b] The concentrations of ^{238}Pu and $^{239+240}Pu$ were <0.00016 and <0.0013 Bq l^{-1} respectively
[F] Measurements are made on behalf of the environment agencies unless labelled "F". In that case they are made on behalf of the Food Standards Agency

10. RESEARCH IN SUPPORT OF THE MONITORING PROGRAMMES

The Food Standards Agency and the Environment Agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

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

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002c). A review of research funded by the Food Standards Agency was published in 2004 (Food Standards Agency, 2004).

A list of related projects completed in 2005 is presented in Table 10.1. Those sponsored by the Environment Agency and the Food Standards Agency are also listed on the Internet (www.environment-agency.gov.uk, www.food.gov.uk, respectively). Copies of the final reports for each of the projects funded by the Food Standards Agency are available from the Emergency Planning, Radiation and Incidents Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by the Scottish Environment Protection Agency and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.environment-agency.com. A charge may be made to cover costs. Table 10.1 also provides information on projects that are currently underway. The results of these projects will be made available in due course. A short summary of the key points from specific monitoring projects that have recently been completed is given here.

Development of a Framework for Assessing the Suitability of Controlled Landfills to Accept Disposals of Solid Low-Level Radioactive Waste - UKRSR03

This study, completed in 2006, was undertaken to establish a framework for assessing the suitability of controlled landfills to accept disposals of solid low-level radioactive waste (Special Precautions Burial (SPB)) (SNIFFER, 2006). The disposal of radioactive waste alongside other wastes at landfill sites is a disposal route aimed at non-nuclear users rather than at the nuclear industry, and it is restricted to relatively low activity wastes.

The framework comprises the overall process for determining the suitability of landfill sites for accepting certain types of low-level radioactive waste. The framework comprises four principal stages:

- initial screening for potentially suitable sites
- development of the assessment context and methodology
- calculation of specific doses and radiological capacity
- authorisation decision and conditions

The framework has been developed to ensure that, as far as possible, a consistent approach is used for all the assessments undertaken. The report is available to download from the SNIFFER website (www.sniffer.org.uk).

UK recovery handbook for radiation incidents: 2005 - C05032

Following an incident dispersing radioactive material in the environment, there will be an initial emergency phase where urgent measures, such as sheltering and evacuation are required to protect individuals from short-term, relatively high risks such as sheltering or evacuation. This is followed by a recovery phase, which ends when all those affected have resumed 'normal lifestyles'. This study provides a handbook to guide decision makers through the available recovery options following such a hypothetical incident and is part of the UK risk mitigation procedures (Mobbs *et al*., 2005). It considers agricultural food production, domestic food production, gathering of free foods, inhabited areas and drinking water sources. The report is available from the HPA website (www.hpa.org.uk).

Assessment of organically bound tritium (OBT) in the environment (Phase 2) - R01034

This project continued the study of the effects of discharges of organic tritium from Cardiff into the Severn Estuary (Croudace and Warwick, 2005). The main findings from a programme running from January 2002 – December 2003 were:

- concentrations of tritium in intertidal sediments to the southern side of the estuary were negligible confirming that there was limited transport of tritium labelled sediments across the estuary
- levels of tritium generally declined although there was a very small increase in concentrations near to the discharge point following the commissioning of a new water treatment works
- a saltmarsh core confirmed earlier findings that tritium was preserved at depth in the marsh at Peterstone. The data also suggest that tritiated species in the marsh are not readily biodegraded. The current situation regarding tritium in the Severn Estuary is considered in Section 7.

Table 10.1. Extramural projects

Topic	Reference	Further details	Target completion date
Assessing the suitability of controlled landfills to accept radioactive waste	UKRSR03	S	Complete
Assessment of organically bound tritium (OBT) in the environment	R01034	F	Complete
Recovery handbook - response to nuclear incidents	C05032	F, E, S	Complete
Options for disposal of North Sea decommissioning NORM waste	SC030160	E	Complete
Modelling of ^{3}H and ^{14}C uptake by crops and chemicals	R01063	F	Complete
Soil and herbage survey	UKRSR01 and SC000027	E, S	Nov-06
Transfer of radionuclides into sewage sludge	SC020150	E	Mar-07
Total diet studies	R03024	F	Mar-07
Availability of technetium-99 to seafood from contaminated sediments	R01062	F	Mar-08
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-09

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

11. REFERENCES

Bailly du Bois, P., Personal communication.

Baxter, A.J., Camplin, W.C. and Steele, A.K., 1992. Radiocaesium in the seas of northern Europe: 1975 – 79. Fish. Res. Data Rep., MAFF Direct. Fish. Res., Lowestoft, **(28)**: 1 – 166.

Baxter, A.J. and Camplin, W.C., 1994. The use of caesium-137 to measure dispersion from discharge pipelines at nuclear sites in the UK. Proc. Instn. Civ. Engrs. Wat., Marit. And Energy, **(106)**: 281 – 288.

BNFL, 2002. Discharges and monitoring of the environment in the UK. Annual Report 2001. BNFL, Warrington.

Brenk, H.D., Onishi, Y., Simmonds, J.R. and Subbaratnam, T., (unpublished). A practical methodology for the assessment of individual and collective radiation doses from radionuclides in the environment. International Atomic Energy Authority draft working document no. 1987 – 05 – 06, Vienna.

Bryan, S.E., Hill, R., McDonald, P. and Wilson, R.C., 2006. Sea to land transfer of anthropogenic radionuclides to the North Wales Coast. Westlakes Scientific Consulting, Moor Row.

Byrom, J., Robinson, C.A., Simmonds, J.R., Walters, C.B. and Taylor, R.R., 1995. Food consumption rates for use in generalised radiological dose assessments. J. Rad. Prot., **15(4)**: 335 – 342.

Camplin, W.C., Grzechnik, M. and Smedley, C., 2005. Methods for assessment of total dose in the Radioactivity in Food and the Environment report. NDAWG/3/2005. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Camplin, W.C., Rollo, S. and Hunt, G.J., 2000. Surveillance related assessments of sea-to-land transfer. In Proceedings of the Second RADREM - TESC Workshop held in London 21 January 1999. Edited by Ould-Dada, Z. DETR/RADREM/00.001. DETR, London.

Carpenter, R., 2005. The determination of Technetium-99 in seaweed and sediment samples collected from the Menai Strait. RD1472. Harwell Scientifics, Harwell.

Codex Alimentarius Commission, 2004. Report of the 36th Session of the Codex Committee on Food Additives and Contaminants, Rotterdam, The Netherlands, 22 – 26 March 2004. CODEX, Rome.

Commission of the European Communities, 1989. Council regulation (Euratom) No 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feeding stuffs following a nuclear accident or any other case of radiological emergency. OJ 1**1(L371)**, amended by Council Regulation 2218/89 OJ **1(L211)**.

Commission of the European Communities, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L206: 7 – 50.

Commission of the European Communities, 1996. Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. OJ **39(L159)**: 1 – 114.

Commission of the European Communities, 1998. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. OJ **L330**: 32 – 54.

Commission of the European Communities, 1999a. Council Directive 1999/2/EC of the European Parliament and of the Council of 22 February 1999 on the approximation of the laws of Member States concerning foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 16.

11. References

COMMISSION OF THE EUROPEAN COMMUNITIES, 1999b. Council Directive 1999/3/EC of the European Parliament and of the Council of 22 February 1999 on the establishment of a Community list of foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 24.

COMMISSION OF THE EUROPEAN COMMUNITIES, 2000a. Commission recommendation on the application of Article 36 of the Euratom Treaty concerning the monitoring of the levels of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole. OJ 27th July 2000. 2000/473/Euratom.

COMMISSION OF THE EUROPEAN COMMUNITIES, 2000b. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L327 22/12/2000 1 – 73.

COMMISSION OF THE EUROPEAN COMMUNITIES, 2002. MARINA II. Update of the MARINA Project on the radiological exposure of the European Community from radioactivity in North European marine waters. Radiation Protection 132. CEC, Luxembourg.

COMMISSION OF THE EUROPEAN COMMUNITIES, 2004. Environmental risk from ionising contaminants: assessment and management. ERICA. Sixth Framework Programme EURATOM Contract F16R-CT-2003 – 508847. CEC, Luxembourg.

COMMISSION OF THE EUROPEAN COMMUNITIES, 2005. Thematic Strategy on the Protection and Conservation of the Marine Environment. COM (2005) 504. CEC, Brussels.

COPELAND BOROUGH COUNCIL *ET AL.*, 1999. The radiological implications of contaminated feral pigeons found at Sellafield and Seascale. CBC, DoH, Environment Agency, HSE, MAFF and NRPB, Penrith.
Copeland Borough Council et al., 1999. The radiological implications of contaminated feral pigeons found at Sellafield and Seascale. CBC, DoH, Environment Agency, HSE, MAFF and NRPB, Penrith.

COPPLESTONE, D., BIELBY, S., JONES, S.R., PATTEN, D., DANIEL, P. AND GIZE, I., 2001. Impact assessment of ionising radiation on wildlife. Project P3 – 085. EA R&D Publication 128. Environment Agency, Bristol.

CROUDACE, I.W. AND WARWICK, P.E., 2005. Organically-bound tritium (OBT) dispersion and accumulation in Severn Estuary sediments (R01034) - Extension to study. National Oceanographic Centre, Southampton.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS, SCOTTISH EXECUTIVE AND WELSH ASSEMBLY GOVERNMENT, 2002. Safeguarding our seas. A strategy for the conservation and sustainable development of our marine environment. Defra, London.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS, DEPARTMENT OF THE ENVIRONMENT, NORTHERN IRELAND, NATIONAL ASSEMBLY FOR WALES AND SCOTTISH EXECUTIVE, 2002. UK strategy for radioactive discharges 2001 – 2020. Department for Environment, Food and Rural Affairs, London.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS, 2004a. National report on compliance with the obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Defra, London.

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS, 2004b. Contribution of aerial radioactive discharges to radionuclide concentrations in the marine environment. DEFRA/RAS/04.002. Defra, London.

Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005. Charting Progress. an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005a. 1: Marine Environment Quality. Report 1 of 5 contribuiting to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005b. 5: Integrated Regional Assessment. Report 5 of 5 contributing to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005c. The United Kingdom's second national report on compliance with the obligations of the joint convention on the safety of spent fuel management and on the safety of radioactive waste management. Defra, London.

Department for Environment, Food and Rural Affairs, 2005d. Water Environment Reports Submitted to the European Commission. News Release 142/05. Defra, London.

Department for Environment, Food and Rural Affairs, 2005e. Consultation on draft Magnox decision. Defra, London.

Department for Environment, Food and Rural Affairs, 2006. Consultation on draft radioactively contaminated land exposure assessment (RCLEA) summary, technical report and methodology. Defra, London.

Department for Environment, Food and Rural Affairs and Department of Health, 2006. Drigg review decision document. Defra and Department of Health, Bristol and London.

Department of the Environment, Transport and the Regions, 2000. Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. DETR, London.

Department of the Environment, Transport and the Regions, 2001. Monitoring of radioactivity in the UK environment. An annotated bibliography of current programmes. DETR/RAS/00.009. DETR, London.

Dounreay Particle Advisory Group, 2006. 3rd Interim Report. SEPA, Stirling.

DSTL Radiological Protection Services, 2005. Marine environmental radioactivity surveys at nuclear submarine berths 2004. The Stationery Office, London.

Environment Agency, 2002a. Radioactivity in the environment. Report for 2001. Environment Agency, Lancaster.

Environment Agency, 2002b. Review of Windscale discharges begins. News Doc 166 – 02. Environment Agency, Bristol and London.

Environment Agency, 2002c. Radioactive Waste Regulation. Summary of Research 1996 – 2001. R&D Publication 129. Environment Agency, Bristol and London.

Environment Agency, 2004a. Environment Agency cuts Sellafield radioactive discharge limits further with new authorisation. News 110 – 04tf. Environment Agency, Bristol and London.

Environment Agency, 2004b. Environment Agency issues reduced radioactive waste permit to Imperial College London. News 210/04. Environment Agency, Bristol and London.

Environment Agency, 2004c. Environment Agency proposes new reduced limits on Imperial College radioactive waste. News Doc 48/04. Environment Agency, Bristol and London.

Environment Agency, 2004d. Public consultation to vary radioactive waste disposal authorisations. News Doc 10/04. Environment Agency, Bristol and London.

Environment Agency, 2004e. Agency Issues Enforcement Notice on Amersham News TC162/04 MW. Environment Agency, Bristol and London.

Environment Agency, 2005a. Water Framework Directive - Characterisation of impacts from radioactive substances. Technical Report: MAPG/TR/2004/004. Environment Agency, Bristol and London.

Environment Agency, 2005b. Environment Agency requires improvement at Sellafield. News 041 – 05js. Environment Agency, Bristol and London.

Environment Agency, 2005c. Environment Agency measurement of technetium-99 in samples from the Menai Strait. Environment Agency, Bristol and London.

Environment Agency, 2005d. Environment Agency consults public on Windscale proposals. News 021 – 05js. Environment Agency, Bristol and London.

Environment Agency, 2005e. Public consultations on Winfrith radioactive waste disposal. News Doc 144/05. Environment Agency, Bristol and London.

Environment Agency, 2005f. Enforcement notice served on Devonport Dockyard. News Doc 122/05. Environment Agency, Bristol and London.

Environment Agency, 2006a. Decision on the application made by United Kingdom Atomic Energy Authority to dispose of radioactive wastes from its Winfrith site. BW2536, February 2006. Environment Agency, Bristol and London.

Environment Agency, 2006b. Decision on the application made by Waste Management Technology Limited to dispose of radioactive wastes from its facilities on the Winfrith site. BV3502, February 2006. Environment Agency, Bristol and London.

Environment Agency, 2006c. Explanatory Document for the future disposal of radioactive waste at British Energy Generation Limited's nuclear sites. Environment Agency, Bristol and London.

Environment Agency, 2006d. All clear for Hinkley Point following Environment Agency monitoring checks. News Doc 070/06. Environment Agency, Bristol and London.

Environment Agency 2006e. Nuclear, consultation, AWE, Aldermaston, Burghfield. News Doc DF/78/06. Environment Agency, Bristol and London.

Environment Agency, 2006f. Decision document. Future regulation of disposals of radioactive waste on/from the Low-Level Waste Repository at Drigg, Cumbria operated by British Nuclear Group Sellafield Ltd. Environment Agency, Bristol and London.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2004. Radioactivity in Food and the Environment, 2003. RIFE-9. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency. Bristol, Belfast, London and Stirling.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005. Radioactivity in Food and the Environment, 2004. RIFE-10. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, Bristol, Belfast, London and Stirling.

Environment and Heritage Service, 2004. Report of the Chief Alkali Inspector for the years 2002 and 2003. Environment and Heritage Service, Belfast.

Food Standards Agency and Scottish Environment Protection Agency, 2000. Radioactivity in Food and the Environment, 1999. RIFE-5. Food Standards Agency and Scottish Environment Protection Agency, London and Stirling

Food Standards Agency, 2001a. Consultative Exercise on Dose Assessment, 3 and 4 October 2000. FSA/0022/0501.500. Food Standards Agency, London.

Food Standards Agency, 2001b. Radiological survey of foodstuffs from the Cardiff area. Food Survey Information Sheet 18/01. www.food.gov.uk/science/surveillance/fsis-2001/radsurvcardiff.

Food Standards Agency and Scottish Environment Protection Agency, 2002. Radioactivity in Food and the Environment, 2001. RIFE-7. Food Standards Agency and Scottish Environment Protection Agency, London and Stirling.

Food Standards Agency, 2002. Survey for irradiated foods - herbs and spices, dietary supplements and prawns and shrimps. Food Survey Information Sheet, Number 25/02. June 2002. Food Standards Agency, London.

Food Standards Agency, 2003. Analysis of farmed salmon for technetium-99 and other radionuclides. Food Survey Information Sheet Number 39/03. Food Standards Agency, London.

Food Standards Agency, 2004. Review of FSA research programmes on radiological protection. Research review report for the period 1998 – 2003. Food Standards Agency, London. http://www.food.gov.uk/science/research/researchinfo/radiologicalresearch/radioactivityenvironment/r01programme/radioprogsreview

Food Standards Agency, 2006a. Irradiated food supplements: enforcement exercise. Food Standards Agency, London.

Food Standards Agency, 2006b. Post-Chernobyl Monitoring and Controls: Report of Cumbrian De-Restriction Surveys 2004 and 2005. Food Standards Agency, London.

Food Standards Agency, 2006c. Post-Chernobyl Monitoring and Controls. Report of Scottish De-Restriction Surveys 2005. Food Standards Agency, London.

Food Standards Agency, 2006d. Post-Chernobyl Monitoring and Controls. Report of Welsh Experimental Surveys 2005, Food Standards Agency, London.

Harrison, J.D. and Phipps, A., 2001. Invited editorial: gut transfer and doses from environmental technetium. J. Radiol. Prot., 21: (9 – 11).

Harrison, J.D., Khursheed, A and Lambert, B.E., 2002. Uncertainties in dose coefficients for intakes of tritiated water and organically bound forms of tritium by members of the public. Radiation Protection Dosimetry, 98, 299 – 311.

Harvey, M.P., Titley, J.G. and Simmonds, J.R., 2000. Generalised derived limits for radioisotopes of polonium, lead, radium and uranium. Docs. NRPB 11(2). NRPB, Chilton.

11. References

Health and Safety Executive, 2005a. HSE revokes the nuclear site licence for ICI's Triga reactor and ends the licensees' period of responsibility. http://www.hse.gov.uk/nuclear/triga.htm

Health and Safety Executive, 2005b. HM Nuclear Installations Inspectorate, AWE Aldermaston and Burghfield, Quarterly Report for 1 January to 31 March 2005. http://www.hse.gov.uk/nuclear/llc/2005/awe1.htm#inspect

Her Majesty's Inspectorate of Pollution, 1995. Routine measurement of gamma ray air kerma rate in the environment. Technical Guidance Note (Monitoring) M5. HMSO, London.

Hodgson, A. Scott, J.E., Fell, T.P. and Harrison, J.D., 2005. Radiation doses from the consumption of Cardiff Bay flounder containing organically bound tritium (OBT). Project SC020042/SR. Environment Agency, Bristol.

Hunt, G.J., 1984. Simple models for prediction of external radiation exposure from aquatic pathways. Radiat. Prot. Dosim., **8**: 215 – 224.

Hunt, G.J., 1998. Transfer across the human gut of environmental plutonium, americium, cobalt, caesium and technetium: studies with cockles (*Cerostoderma edule*) from the Irish Sea. J. Radiol. Prot., **18(2)**: 101 – 109.

Hunt, G.J. and Allington, D.J., 1993. Absorption of environmental polonium-210 by the human gut. J. Radiol. Prot., **13(2)**:119 – 126.

Hunt, G.J., Hewitt, C.J. and Shepherd, J.G., 1982. The identification of critical groups and its application to fish and shellfish consumers in the coastal area of the north-east Irish Sea. Health Physics **43 (6)** 875 – 889.

Hunt, G.J., Leonard, D.R.P. and Lovett, M.B., 1986. Transfer of environmental plutonium and americium across the human gut. Sci. Total Environ., **53**: 89 – 109.

Hunt, G.J., Young, A.K. and Bonfield, R.A., 2001. Transfer across the human gut of environmental technetium in lobsters (*Homarus gammarus* L.) from the Irish Sea. J. Radiol. Prot., **21**: 21 – 29.

Hunt, G.J. and Rumney, H.S., 2004. The human gut transfer of environmental polonium-210. Proc. Int. Conf. on widening the radiation protection world, 23 – 28 May 2004, Madrid. IRPA, Fontenay-aux-Roses.

Hunt, G.J and Rumney, H.S., 2005. The human alimentary tract transfer of environmental polonium-210. Proceedings of the Seventh International Symposium of the Society for Radiological Protection, 12th-17th June 2005, Cardiff. SRP, London.

International Atomic Energy Agency, 1996. International basic safety standards for protection against ionising radiation and for the safety of radiation sources. Saf. Ser. No. 115. IAEA Vienna.

International Atomic Energy Agency, 1997. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. INF CIRC/546. IAEA, Vienna.

International Commission on Radiological Protection, 1991. 1990 Recommendations of the International Commission on Radiological Protection. Annal. ICRP 21(1 – 3). Pergamon Press, Oxford, 201pp. (ICRP Publ. (**60**)).

International Commission on Radiological Protection, 1993. Principles for intervention for protection of the public in a radiological emergency. Annal. ICRP 22(4). Pergamon Press, Oxford, 30pp. (ICRP Publ. (**63**)).

International Commission on Radiological Protection, 1994. Age-dependent doses to members of the public from intake of radionuclides: Part 2 Ingestion dose coefficients. Annal ICRP 23(3/4). Pergamon Press, Oxford, 167pp. (ICRP Publ. (**67**)).

International Commission on Radiological Protection, 1996a. Age-dependent doses to members of the public from intake of radionuclides: Part 5 Compilation of ingestion and inhalation dose coefficients. Annal. ICRP 26(1). Elsevier Science, Oxford, 91pp. (ICRP Publ. (**72**)).

International Commission on Radiological Protection, 1996b. Conversion coefficients for use in radiological protection against external radiation. Annal ICRP 26(3/4). Elsevier Science, Oxford (ICRP Publ. (**74**)).

International Commission on Radiological Protection, 2001. Doses to the embryo and fetus from intakes of radionuclides by the mother. Annal ICRP 31(1 – 3). Elsevier Science, Oxford. (ICRP Publ.(**88**)).

International Organisation for Standardisation, 2005. General requirements for the competence of testing and calibration laboratories. ISO 17025.

Joint Research Centre of the European Commission, 2005. Environmental Radioactivity in the European Community 1996 – 2000. Radiation Protection No. **141**. EUR. CEC, Luxembourg.

Jones, K.A., Simmonds, J., Jones, A., Harvey, M., Kamaljit, S. Bexon, A., Smith, B.D., Aldridge. J.N., Gurbutt. P.A. and Hill, M., 2003. Distinguishing between impacts of current and historic radioactive discharges to sea from UK nuclear sites. RW/8/6/82. Defra, London.

Kershaw, P.J. and Baxter, A.J., 1995. The transfer of reprocessing wastes from north-west Europe to the Arctic. Deep-Sea Res. II, **43(6)**: 1413 – 1448.

Kershaw, P.J., McCubbin, D. and Leonard, K.S., 1999. Continuing contamination of north Atlantic and Arctic waters by Sellafield radionuclides. Sci. Tot. Env., **237/238**: 119 – 132.

Knowles, J.F., Smith, D.L. and Winpenny K., 1998. A comparative study of the uptake, clearance and metabolism of technetium in lobster (*Homarus gammarus*) and edible crab (*Cancer pagurus*). Radiat. Prot. Dosim., **75**: 125 – 129.

Kocher, D.C. and Eckerman, K.F., 1987. Electron dose-rate conversion factors for external exposure of the skin from uniformly deposited activity on the body surface. Hlth. Phys., **53**: 135 – 141.

Leonard, D.R.P., Camplin, W.C. and Tipple, J.R., 1990. The variability of radiocaesium concentrations in freshwater fish caught in the UK following the Chernobyl nuclear reactor accident: an assessment of potential doses to critical group consumers. pp. 247 – 256. In: 'Proc. Int. Symp. on Environmental Contamination Following a Major Nuclear Accident'. IAEA, Vienna, IAEA-SM-306/**15**.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997a. A summary report of the distribution of Technetium-99 in UK Coastal Waters. Radioprotection, **32**: 109 – 114.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997b. Distribution of technetium-99 in UK coastal waters. Mar. Pollut. Bull., **34(8)**: 628 – 636.

Leonard, K.S., McCubbin, D., McMahon, C.A., Mitchell, P.I. and Bonfield, R., 1998. 137Cs/90Sr ratios in the Irish Sea and adjacent waters: a source term for the Arctic. Radiat. Prot. Dosim., **75(1 – 4)**: 207 – 212.

11. References

Leonard, K.S., McCubbin, D., Blowers, P. and Taylor, B.R., 1999. Dissolved plutonium and americium in surface waters of the Irish Sea, 1973 – 96. J. Environ. Rad., **44**: 129 – 158.

Leonard, K.S., McCubbin, D. and Bailey, T.A., 2001. Organic forms of tritium in foodchains. Project R01023/C0814. RL 6/01. Cefas, Lowestoft.

Leonard, K.S., McCubbin, D., McDonald, P., Service, M., Bonfield, R, and Conney, S. 2004. Accumulation of technetium-99 in the Irish Sea? Sci. Tot. Env., 322: 255 – 270.

Mayall, A., Cabianca, T., Attwood, C., Fayers, C.A., Smith, J.G., Penfold, J., Steadman, D., Martin, G., Morris, T.P. and Simmonds, J.R., 1997. PC-CREAM. Installing and using the PC system for assessing the radiological impact of routine releases. EUR 17791 EN. European Commission, Luxembourg.

McCubbin, D., Leonard, K.S., Bailey, T.A., Williams, J. and Tossell, P., 2001. Incorporation of organic tritium (3H) by marine organisms and sediment in the Severn Estuary/Bristol Channel (UK). Mar. Pollut. Bull., 42 (10): 852 – 863.

McCubbin, D., Leonard, K.S., Brown, J., Kershaw, P.J., Bonfield, R.A. and Peak, T., 2002. Further studies of the distribution of 99Tc and 137Cs in UK and European coastal waters. Cont. Shelf. Res. 22/10: 1417 – 1445.

McKay, W.A., Barr H.M., Halliwell C.M., Spencer D., Adsley I. and Perks C.A., 1995. Site specific background dose rates in coastal areas. DoE/HMIP/RR/94/037. Her Majesty's Inspectorate of Pollution, London.

Ministry of Agriculture, Fisheries and Food, 1994. The British Diet: Finding the facts. Food Surveillance Paper No. 40. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food, 1995. Terrestrial radioactivity monitoring programme (TRAMP) report for 1994. Radioactivity in food and agricultural products in England and Wales. MAFF, London, TRAMP/9, 223pp.

Ministry of Agriculture, Fisheries and Food, 1996. Pesticides Safety Directorate's Handbook. Appendix IC. MAFF, London.

Ministry of Agriculture, Fisheries and Food, 1998. National Food Survey 1997. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998. Radioactivity in Food and the Environment, 1997. RIFE-3. MAFF and Scottish Environment Protection Agency, London and Stirling.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999. Radioactivity in Food and the Environment, 1998. RIFE-4. MAFF and Scottish Environment Protection Agency, London and Stirling.

Mobbs, S., Barraclough, I., Napier, i., Casey, A., Poynter, R. and Harvey, M., 1998. A review of the use and disposal of gaseous tritium light devices. Environment Agency, Lancaster.

Mobbs, S., Nisbet, A., Brown, J., Mercer, J., Mortimer, K., Roberts, G. and Hesketh, N., 2005. UK recovery handbook for radiation incidents: 2005. HPA-RPD-002. HPA, Chilton.

Mondon, K.J., and Walters, C.B., 1990. Measurements of radiocaesium, radiostrontium and plutonium in whole diets following deposition of radioactivity in the UK originating from the Chernobyl power plant accident. Food Addit. Contam., **7(6)**: 837 – 848.

National Dose Assessment Working Group, 2004. Principles for the assessment of total restrospective public doses. Environment Agency, Food Standards Agency, NRPB, NII, Chilton.

National Radiological Protection Board, 1990. Gut transfer factors. Docs. NRPB **1(2)**. NRPB, Chilton, 26pp.

National Radiological Protection Board, 2005. Guidance on the application of dose coefficients for the embryo and fetus from intakes of radionuclides by the mother. Docs NRPB 16(2). NRPB, Chilton, 41pp.

Northern Ireland Assembly, 2003. Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland).

Nuclear Decommissioning Authority, 2006. Strategy. NDA, Moor Row, Cumbria.

Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985. Review of the continued suitability of the dumping site for radioactive waste in the North-East Atlantic. OECD, Paris, 448pp.

OSPAR, 1998. SINTRA Statement. Summary Record OSPAR 98/14/1, Annex 45. OSPAR, London.

OSPAR, 2000a. Convention for the protection of the marine environment of the North-East Atlantic. OSPAR, London.

OSPAR, 2000b. Quality Status Report 2000. OSPAR, London.

OSPAR, 2002. Discharges of radioactive substances into the maritime area by non-nuclear industry. Radioactive Substances Series. Publication 161. OSPAR, London.

OSPAR, 2005. Summary Record of the meeting of the Radioactive Substances Committee (RSC), Valencia: 25 – 28 January 2005. RSC 05/13/1-E. OSPAR, London.

OSPAR, 2006. Agreement on a monitoring programme for concentrations of radioactive substances in the marine environment. Annex 14, ref 9.8c, Malahide (Ireland): 27 June-1 July 2005. OSPAR, London.

Ould-Dada, Z., 2000. Sea-to-Land transfer of radionuclides. How much do we know. Proceedings of the second RADREM-TESC Workshop held in London on 21 January 1999. DETR/RADREM/00.001 DETR, London.

Peattie, M.E., Buss, D.H., Lindsay, D.G. and Smart G.Q., 1983. Reorganisation of the British Total Diet Study for monitoring Food Constituents from 1981. Food Chem. Toxicol., 21: 503 – 507.

Povinec, P.P., Bailly Du Bois, P., Kershaw, P.J., Nies, H. and Scotto, P. 2003. Temporal and spatial trends in the distribution of 137Cs in surface waters of Northern European Seas - a record of 40 years of investigations. Deep Sea Res. II, 50: 2785 – 2801.

Preston, A., Mitchell, N.T. and Jefferies, D.F. 1974. Experience gained in applying the ICRP Critical Group concept to the assessment of public radiation exposure in control of liquid waste disposal. Proc. Symp. IAEA Portoroz, IAEA-SM-184/10, 131 – 146.

Rollo, S.F.N., Camplin, W.C., Allington, D.J. and Young, A.K., 1992. Natural radionuclides in the UK marine environment. In: 'Proceedings of the Fifth International Symposium on Natural Radiation Environment, Saltzburg, September 22 – 28, 1991'. Radiat. Prot. Dosim., **45(1/4)**: 203 – 210.

Rollo, S.F.N., Camplin, W.C., Duckett, L., Lovett, M.B. and Young, A.K., 1994. Airborne radioactivity in the Ribble Estuary. pp277 – 280. In: 'Proc. IRPA Regional Congress on Radiological Protection, 6 – 10 June 1994, Portsmouth, UK'. Nuclear Technology Publishing.

Rowe, J., James, A. and Allott, R., 2001. Potential for bio-accumulation of organically bound tritium in the environment: review of monitoring data. NCAS/TR/2000/026. Environment Agency, Lancaster.

Rowe, J.E., Allott, R. and Morris, C., 2005. Response to questionnaire on the implementation of Article 35 of the Euratom Treaty - Environment Agency and Food Standards Agency Monitoring Programmes. MAPG/TR/2005/003. Environment Agency and Food Standards Agency, Bristol and London.

RWE NUKEM, 2006. Investigation/hot spot removal at Dalgety Bay. TR/89191/001. RWE NUKEM, Rosyth.

Scotland and Northern Ireland Forum for Environmental Research, 2005. Identification and assessment of alternative disposal options for radioactive oilfield wastes. Summary Guidance. Project UKRSR07. SNIFFER, Edinburgh.

Scotland and Northern Ireland Forum for Environmental Research, 2006. Development of a framework for assessing the suitability of controlled landfills to accept disposals of solid low-level radioactive waste. UKRSR03. SNIFFER, Edinburgh.

Scottish Environment Protection Agency, 2005. Review of regulatory approach to offshore oil and gas industry radioactive waste issues. SEPA, Stirling.

Scottish Environment Protection Agency, 2006a. Application by British Energy Generation Limited for variation of authorisation to dispose of combustible radioactive waste under the Radioactive Substances Act pertaining to Hunterston B Power Station. Consultation document. SEPA, Stirling.

Scottish Environment Protection Agency, 2006b. Application by British Energy Generation Limited for the variation of authorisation to dispose of solid combustible and liquid combustible radioactive waste under the Radioactive Substances Act pertaining to Torness Power Station. Consultation document. SEPA, Stirling.

Scottish Environment Protection Agency, 2006c. Consultation on proposals to vary Scotoil authorisation. News release 21/5/6. SEPA, Sturling.

Scottish Environment Protection Agency, 2006d. Aberdeen beach radioactivity declared not harmful by export team. News release 28/2/6. SEPA, Stirling.

Scottish Environment Protection Agency, 2006e. Radium contamination at Dalgety Bay, Fife. SEPA, Stirling.

Scottish Executive, 2000. Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000. Scottish Executive, Edinburgh.

Scottish Executive, 2005. Consultation on proposed Statutory Guidance from the Scottish Ministers to the Scottish Environment Protection Agency on the UK Strategy for Radioactive Discharges. Scottish Executive, Edinburgh.

Simmonds, J.R., Lawson, G. and Mayall, A., 1995. Radiation Protection 72; Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. Report EUR 15760 EN. Office for Official Publications of the European Community, Luxembourg.

Smith, B.D., 2002. Continuity of data for key marine environmental indicators. Project EG 1/4/67/ C1414. RL 2/02. Cefas, Lowestoft.

Smith, B.D. and Jeffs, T.M., 1999. Transfer of radioactivity from fishmeal in animal feeding stuffs to man. RL 8/99. Cefas, Lowestoft.

Smith, K.R., and Jones, A.L. 2003. Generalised habit data for radiological assessments. NRPB-W41. NRPB, Chilton.

Smith, J.T., Comans, R.N.J., Beresford, N.A., Wright, S.M., Howard, B.J. and Camplin, W.C., 2000. Chernobyl's legacy in food and water. Nature, **405**: 7141.

Smith, D.L., Smith, B.D., Joyce, A.E. and McMeekan, I.T., 2002. An assessment of aquatic radiation exposure pathways in Northern Ireland. SR(02)14. RL 20/02. Scotland and Northern Ireland Forum for Environmental Research, Edinburgh.

Smith, B.D., Hunt, G.J. and Camplin, W.C., 2004. The impact of liquid radioactive waste discharges from Sellafield to the Irish Sea in recent years. Proc. Int. Conf. on Widening the radiation protection world, 23 – 28 May 2004, Madrid. IRPA, Fontenay-aux-Roses.

Smith, K.R., Mobbs, S.F. and Cooper, J.R., 2006. Dose criteria for the designation of radioactivity contaminated land. RCE-2. Health Protection Agency, Chilton

Stephen, P., 2006. Personal communication. July 2006. Health and Safety Executive, Bootle.

Swift, D.J., 2001. Cardiff radiological survey of selected foodstuffs. Project C1003. RL 11/01. Cefas, Lowestoft.

Swift, D.J. and Nicholson, M.D., 2001. Variability in the edible fraction content of 60Co, 99Tc, 110mAg, 137Cs and 241Am between individual crabs and lobsters from Sellafield (north eastern Irish Sea). J. Environ. Radioact., **54**, 311 – 326.

United Kingdom - Parliament, 1965. Nuclear Installations Act, 1965. HMSO, London.

United Kingdom - Parliament, 1985. Food and Environment Protection Act, 1985. HMSO, London.

United Kingdom - Parliament, 1993. Radioactive Substances Act, 1993. HMSO, London.

United Kingdom - Parliament, 1995a. Environment Act, 1995. HMSO, London.

United Kingdom - Parliament, 1995b. Review of Radioactive Waste Management Policy. HMSO, London, 55pp. (Cm 2919).

United Kingdom - Parliament, 1999. The Ionising Radiations Regulations 1999. Stat. Inst. 1999/3232. HMSO, London, 67pp.

United Kingdon - Parliament, 2003. Water resources, England and Wales. The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003. Stat. Inst. 2003 No 3242. HMSO, London.

11. References

WATSON, S.J., JONES, A.L., OATWAY, W.B. AND HUGHES, J.S., 2005. Ionising radiation exposure of the UK population: 2005 Review. HPA-RPD-001. Health Protection Agency, Chilton.

WELSH ASSEMBLY GOVERNMENT, 2006. Publication of report on radiation and North Wales Coastal Land. Welsh Assemby Government, Cardiff.

WORLD HEALTH ORGANISATION, 2004. Guidelines for drinking water quality. 3rd Edition. WHO, Geneva.

WILLIAMS. J.L., RUSS, R.M., MCCUBBIN, D. AND KNOWLES, J.F. 2001. An overview of tritium behaviour in the Severn estuary (UK). J. Rad. Prot., 21: 337 – 344.

YOUNG, A.K., MCCUBBIN, D. AND CAMPLIN, W.C., 2002. Natural radionuclides in seafood. Project R03010/C0808. RL 17/02. Cefas, Lowestoft.

APPENDIX 1. DISPOSALS OF RADIOACTIVE WASTE*

Table A1.1. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2005

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005 TBq[a]	Discharges during 2005 % of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Tritium[c]	78	0.031	<1
	Uranium	0.02	$2.00\ 10^{-4}$	1.0
	Uranium daughters	0.02	$4.00\ 10^{-4}$	2.0
	Non-uranic alpha	0.003	$1.20\ 10^{-5}$	<1
	Technetium-99	0.1	$1.70\ 10^{-4}$	<1
Sellafield[d] (sea pipelines)	Alpha	1	0.248	25
	Beta	220	42.9	20
	Tritium	$2\ 10^{4}$	1570	7.9
	Carbon-14	21	5.26	25
	Cobalt-60	3.6	0.663	18
	Strontium-90	48	12.7	26
	Zirconium-95+Niobium-95	3.8	0.162	4.3
	Technetium-99	20	6.7	34
	Ruthenium-106	63	1.85	2.9
	Iodine-129	2.0	0.298	15
	Caesium-134	1.6	0.164	10
	Caesium-137	34	5.86	17
	Cerium-144	4.0	0.542	14
	Neptunium-237	1.0	0.05	5.0
	Plutonium alpha	0.7	0.203	29
	Plutonium-241	25	5.5	22
	Americium-241	0.3	0.0337	11
	Curium-243+244	0.069	0.0043	6.2
	Uranium[i]	2000	369	18
Sellafield (factory sewer)	Alpha	$3\ 10^{-4}$	$1.16\ 10^{-4}$	39
	Beta	0.0061	$2.86\ 10^{-4}$	4.7
	Tritium	0.068	0.0138	20
Springfields	Alpha	0.55	0.25	45
	Beta	140	103	74
	Technetium-99	0.6	0.063	11
	Thorium-230	0.4	0.085	21
	Thorium-232	0.015	$3.30\ 10^{-4}$	2.2
	Neptunium-237	0.04	0.00178	4.5
	Other transuranic radionuclides	0.02	0.00248	12
	Uranium	0.1	0.036	36
Research establishments				
Dounreay PFR liquid metal disposal plant	Alpha[4]	0.02	$2.83\ 10^{-4}$	1.4
	Beta[l]	0.11	0.00481	4.4
	Tritium	1.4	0.0103	<1
	Sodium-22	1.8	0.127	7.1
	Caesium-137	0.066	0.00393	6.0
Dounreay Other facilities	Alpha	0.09	$4.56\ 10^{-4}$	<1
	Beta	0.62	0.0011	<1
	Tritium	5.5	0.0891	1.6
	Strontium-90	0.77	0.102	13
	Caesium-137	1.0	0.017	1.7
Harwell (pipeline)	Alpha	$5\ 10^{-5}$	$1.09\ 10^{-5}$	22
	Beta	0.0033	$2.35\ 10^{-4}$	7.1
	Tritium	0.3	0.00408	1.4
	Cobalt-60	$1.2\ 10^{-4}$	$4.38\ 10^{-6}$	3.6
	Caesium-137	$5.4\ 10^{-4}$	$4.38\ 10^{-5}$	8.1

* *As reported to SEPA and the Environment Agency*

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005 TBq[a]	% of annual limit[b]
Harwell (Lydebank Brook)	Alpha	10^{-4}	$7.64\ 10^{-6}$	7.6
	Beta	$6\ 10^{-4}$	$7.56\ 10^{-5}$	13
	Tritium	0.08	0.00932	12
Winfrith (inner pipeline)	Alpha	0.3	$2.76\ 10^{-4}$	<1
	Tritium	650	8.54	1.3
	Cobalt-60	10	$5.06\ 10^{-4}$	<1
	Zinc-65	6	$2.94\ 10^{-4}$	<1
	Other radionuclides	80	0.0111	<1
Winfrith (outer pipeline)	Alpha	0.004	$2.57\ 10^{-5}$	<1
	Tritium	1	0.00389	<1
	Other radionuclides	0.01	$5.82\ 10^{-5}$	<1
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	$4\ 10^{-5}$	Nil	Nil
	Other radioactivity	10^{-5}	Nil	Nil
Imperial Chemical Industries plc Billingham[q]	Tritium	Nil	Nil	Nil
	Beta/gamma	Nil	Nil	Nil
	Thorium	Nil	Nil	Nil
Scottish Universities Environmental Research Centre East Kilbride	Total activity	0.00169	Nil	Nil
Nuclear power stations				
Berkeley	Tritium	2	$5.90\ 10^{-4}$	<1
	Caesium-137	0.2	0.00671	3.4
	Other radionuclides	0.4	0.00473	1.2
Bradwell	Tritium	7	0.317	4.5
	Caesium-137	0.7	0.288	41
	Other radionuclides	0.7	0.351	50
Chapelcross	Alpha	0.1	$1.04\ 10^{-5}$	<1
	Beta[l]	25	0.0049	<1
	Tritium	5.5	0.0333	<1
Dungeness 'A' Station	Tritium	8	1.21	15
	Caesium-137	1.1	0.119	11
	Other radionuclides	0.8	0.0829	10
Dungeness 'B' Station	Tritium	650	273	42
	Sulphur-35	2	0.300	15
	Cobalt-60	0.03	0.00339	11
	Other radionuclides	0.25	0.0294	12
Hartlepool	Tritium	1200	242	20
	Sulphur-35	3	0.262	8.7
	Cobalt-60	0.03	0.00101	3.4
	Other radionuclides	0.3	0.00365	1.2
Heysham Station 1	Tritium	1200	288	24
	Sulphur-35	2.8	0.194	6.9
	Cobalt-60	0.03	$1.94\ 10^{-4}$	<1
	Other radionuclides	0.3	0.0146	4.8
Heysham Station 2	Tritium	1200	326	27
	Sulphur-35	2.3	0.129	5.6
	Cobalt-60	0.03	$1.21\ 10^{-4}$	<1
	Other radionuclides	0.3	0.0142	4.7

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005	
			TBq[a]	% of annual limit[b]
Hinkley Point 'A' Station	Tritium	1.8	0.379	21
	Caesium-137	1	0.193	19
	Other radionuclides	0.7	0.156	22
Hinkley Point 'B' Station	Tritium	620	358	58
	Sulphur-35	5	0.667	13
	Cobalt-60	0.033	$1.57\ 10^{-4}$	<1
	Other radionuclides	0.235	0.0171	7.3
Hunterston 'A' Station	Alpha	0.04	$1.30\ 10^{-4}$	<1
	Beta	0.6	0.0472	7.9
	Tritium	0.7	$4.78\ 10^{-4}$	<1
	Plutonium-241	1.0	$1.50\ 10^{-4}$	<1
Hunterston 'B' Station	Alpha	0.001	$1.13\ 10^{-4}$	11
	Beta	0.45	0.0101	2.2
	Tritium	800	394	49
	Sulphur-35	10	0.610	6.1
	Cobalt-60	0.03	$8.6\ 10^{-4}$	2.9
Oldbury	Tritium	1	0.317	32
	Caesium-137	0.7	0.420	60
	Other radionuclides	0.7	0.181	26
Sizewell 'A' Station	Tritium	11	0.260	2.4
	Caesium-137	1	0.651	65
	Other radionuclides	0.7	0.413	59
Sizewell 'B' Station	Tritium	80	30.9	39
	Other radionuclides	0.2	0.0284	14
Torness	Alpha	0.001	$1.92\ 10^{-5}$	1.9
	Beta[2,3,6]	0.45	0.0029	<1
	Tritium	800	381	48
	Sulphur-35	10	0.0313	<1
	Cobalt-60	0.03	$1.76\ 10^{-4}$	<1
Trawsfynydd	Other radionuclides[5]	0.17	0.00332	2.0
	Tritium	0.5	0.0164	3.3
	Strontium-90	0.05	$7.60\ 10^{-4}$	1.5
	Caesium-137	0.03	0.00122	4.1
Wylfa[f]	Tritium	15	8.52	57
	Other radionuclides	0.11	0.0277	25
Defence establishments				
Aldermaston (River Thames)[g]	Alpha	$6\ 10^{-5}$	$6.75\ 10^{-6}$	11
	Tritium	0.05	0.00773	15
	Plutonium-241	$2.4\ 10^{-4}$	$2.70\ 10^{-5}$	11
	Other radionuclides	$6\ 10^{-5}$	$3.59\ 10^{-6}$	6.0
Aldermaston (Silchester)	Alpha	$4\ 10^{-5}$	$1.30\ 10^{-6}$	3.2
	Beta/gamma	$1.2\ 10^{-4}$	$7.66\ 10^{-6}$	6.4
	Tritium	0.05	$7.96\ 10^{-4}$	1.6
Aldermaston (to stream)	Tritium	0.01	$1.16\ 10^{-3}$	12

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005	
			TBq[a]	% of annual limit[b]
Barrow[l]	Tritium	0.012	Nil	Nil
	Other gamma emitting radionuclides	3.5 10^{-6}	Nil	Nil
Derby[m]	Alpha[n]	0.002	7.67 10^{-5}	3.8
	Alpha[o]	3 10^{-7}	1.30 10^{-8}	4.3
	Beta[o]	3 10^{-4}	4.89 10^{-7}	<1
Devonport[p,f] (sewer)	Beta		2.18 10^{-5}	
	Tritium		1.27 10^{-5}	
	Cobalt-60		8.30 10^{-7}	
Devonport[k] (sewer)	Tritium	0.002	1.63 10^{-4}	8.2
	Cobalt-60	3.5 10^{-4}	1.11 10^{-5}	3.2
	Other radionuclides	6.5 10^{-4}	2.83 10^{-4}	44
Devonport[k] (pipeline)	Tritium	0.7	0.155	22
	Carbon-14	0.0017	5.04 10^{-4}	30
	Cobalt-60	8 10^{-4}	8.40 10^{-5}	11
	Other radionuclides	3 10^{-4}	9.99 10^{-5}	33
Faslane	Alpha	2 10^{-4}	1.88 10^{-6}	<1
	Beta[3,6]	5 10^{-4}	1.29 10^{-5}	2.6
	Tritium	1	0.115	12
	Cobalt-60	5 10^{-4}	3.06 10^{-6}	<1
Rosyth[j]	Alpha	5 10^{-7}	9.10 10^{-8}	18
	Beta[3,6]	4.8 10^{-4}	6.52 10^{-5}	14
	Tritium	0.012	4.79 10^{-3}	40
	Cobalt-60	0.0025	1.36 10^{-4}	5.5
Radiochemical production				
Amersham (GE Healthcare)	Alpha	3 10^{-4}	1.04 10^{-14}	<1
	Beta >0.4 MeV	0.06	0.00113	1.9
	Tritium	0.141	9.55 10^{-4}	<1
	Iodine-125	0.004	5.73 10^{-5}	1.4
	Caesium-137	0.005	1.51 10^{-5}	<1
	Other radionuclides	0.215	0.00756	3.5
Cardiff (GE Healthcare)	Tritium	130	40.4	31
	Carbon-14	0.91	0.274	30
	Phosphorus-32/33	8.5 10^{-5}	7.41 10^{-8}	<1
	Iodine-125	3 10^{-4}	1.44 10^{-5}	4.8
	Others	1.2 10^{-4}	Nil	Nil

Table A1.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005	
			TBq[a]	% of annual limit[b]
Industrial and landfill sites				
Drigg (sea pipeline)[e]	Alpha	0.1	$5.99\ 10^{-5}$	<1
	Beta	0.3	$7.40\ 10^{-4}$	<1
	Tritium	120	0.162	<1
Drigg (stream[h])	Alpha	$9\ 10^{4}$	55.8	<1
	Beta	$1.2\ 10^{6}$	521	<1
	Tritium	$6\ 10^{8}$	$1.88\ 10^{4}$	<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] *The limit for tritium is derived from a limit on activity concentration in Rivacre Brook of 111 Bq ml^{-1} and a flow rate of 90 $m^3\ h^{-1}$*
[d] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[e] *Discharge authorisations at Drigg were revised with effect from 1 May 2006*
[f] *The current limits are expressed as an activity concentration of 2 MBq m^{-3} with no more than 800 m^3 discharged per year*
[g] *Discharge ceased from 15 March 2005*
[h] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)*
[i] *The limit and discharge data are expressed in kg*
[j] *Discharges were made by Rosyth Royal Dockyard Ltd*
[k] *Discharges were made by Devonport Royal Dockyard Ltd*
[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[n] *Discharge limit is for Nuclear Fuel Production Plant*
[o] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[p] *Discharges were made by the Ministry of Defence*
[q] *The authorisation was revoked on 25 November 2005*
[1] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[2] *Excluding sulphur-35*
[3] *Excluding cobalt-60*
[4] *All alpha emitting radionuclides taken together*
[5] *Including strontium*
[6] *Excluding tritium*

Table A1.2 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2005

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005 TBq	Discharges during 2005 % of annual limit[b]
Nuclear fuels production and reprocessing				
Capenhurst (BNGSL)	Tritium	1600	0.00124	<1
	Uranium[c]		$1\ 10^{-6}$	
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$4.44\ 10^{-7}$	18
Sellafield[d]	Alpha	$8.8\ 10^{-4}$	$6.13\ 10^{-5}$	7.0
	Beta	0.042	$6.88\ 10^{-4}$	1.6
	Tritium	1100	93.2	8.5
	Carbon-14	3.3	0.911	28
	Krypton-85	$4.4\ 10^{5}$	$4.98\ 10^{4}$	11
	Strontium-90	$7.1\ 10^{-4}$	$5.2\ 10^{-5}$	7.3
	Ruthenium-106	0.028	0.00154	5.5
	Antimony-125	0.0023	$3.84\ 10^{-4}$	17
	Iodine-129	0.07	0.00105	15
	Iodine-131	0.055	0.00102	1.9
	Caesium-137	0.0058	$6.13\ 10^{-4}$	11
	Plutonium (alpha)	$1.9\ 10^{-4}$	$3.19\ 10^{-5}$	17
	Plutonium-241	0.003	$3.31\ 10^{-4}$	11
	Americium-241 and curium-242	$1.2\ 10^{-4}$	$2.73\ 10^{-5}$	23
Springfields	Uranium	0.0053	$6.50\ 10^{-4}$	12
Springfields (Nexia Solutions)	Tritium	10^{-4}	$4.10\ 10^{-5}$	41
	Carbon-14	10^{-5}	$5.7\ 10^{-8}$	<1
	Other alpha radionuclides	10^{-6}	Nil	Nil
	Other beta radionuclides	10^{-5}	$1.76\ 10^{-8}$	<1
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$9.84\ 10^{-6}$	1.0
	Beta[f,g]	0.045	$2.41\ 10^{-4}$	<1
	Tritium	2	0.299	15
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$8.56\ 10^{-5}$	2.0
	Ruthenium-106	0.0039	$9.23\ 10^{-6}$	<1
	Iodine-129	0.0011	$1.33\ 10^{-4}$	12
	Iodine-131	$1.5\ 10^{-4}$	$6.57\ 10^{-5}$	44
	Caesium-134	$8.4\ 10^{-4}$	$1.14\ 10^{-6}$	<1
	Caesium-137	0.007	$5.46\ 10^{-5}$	<1
	Cerium-144	0.007	$6.71\ 10^{-6}$	<1
	Plutonium-241	0.0033	$1.20\ 10^{-5}$	<1
	Curium-242	$2.7\ 10^{-4}$	$1.07\ 10^{-7}$	<1
	Curium-244[h]	$5.4\ 10^{-5}$	$2.52\ 10^{-7}$	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	$2.61\ 10^{-9}$	<1
	Beta	0.0015	$1.02\ 10^{-8}$	<1
	Tritium	4.5	$5.97\ 10^{-4}$	<1
	Krypton-85	$4\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$3.90\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$3.03\ 10^{-6}$	5.9
	Tritium	10.5	0.245	2.3
	Krypton-85	4	Nil	Nil
Dounreay (PFR minor sources)	Alpha[i]	$6\ 10^{-8}$	$4.40\ 10^{-10}$	<1
	Beta[f]	$5\ 10^{-7}$	$1.42\ 10^{-9}$	<1
	Tritium	0.2	0.114	57

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005 TBq	% of annual limit[b]
Dounreay (East minor sources)	Alpha[i]	1.37 10^{-5}	7.74 10^{-8}	<1
	Beta[f,g]	3.71 10^{-4}	3.84 10^{-7}	<1
	Krypton-85[j]	1	Nil	Nil
Dounreay (West minor sources)	Alpha[i]	3 10^{-7}	1.34 10^{-9}	<1
	Beta[f,g]	7.5 10^{-5}	5.20 10^{-9}	<1
	Tritium	0.01	3.29 10^{-4}	3.3
Harwell (AEA Technology)	Alpha	7 10^{-7}	Nil	Nil
	Beta	3 10^{-5}	Nil	Nil
	Tritium	2 10^{-4}	Nil	Nil
Harwell (UKAEA)	Alpha	8 10^{-7}	5.5 10^{-8}	6.9
	Beta	2 10^{-5}	1.6 10^{-6}	8.0
	Tritium	15	0.61	4.1
	Krypton-85	2	0.0015	<1
	Radon-220	100	9.8	9.8
	Radon-222	3	0.27	9.0
	Iodines	0.01	Nil	Nil
	Other radionuclides	0.1	Nil	Nil
Windscale	Alpha	1.2 10^{-5}	9.73 10^{-8}	<1
	Beta	5 10^{-4}	1.75 10^{-6}	<1
	Tritium	2.3	0.005	<1
	Krypton-85	14	0.062	<1
	Iodine-131	0.0012	1.33 10^{-6}	<1
Winfrith (AEA Technology)	Alpha	2 10^{-7}	Nil	Nil
	Beta	2.5 10^{-5}	9.32 10^{-6}	37
	Tritium	10	2.58	26
Winfrith (UKAEA)	Alpha	2 10^{-6}	4.50 10^{-10}	<1
	Beta	2.5 10^{-5}	1.26 10^{-7}	<1
	Tritium	5	0.099	2.0
	Carbon-14	0.3	2.86 10^{-4}	<1
	Krypton-85	150	Nil	Nil
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	3 10^{-4}	6.22 10^{-5}	21
	Argon-41	1.7	0.250	15
Imperial Chemical Industries plc Billingham	Tritium, argon-41, krypton-85 and xenon-133	2.3	Nil	Nil
	Thorium	3 10^{-5}	Nil	Nil
Scottish Universities Environmental Research Centre East Kilbride	Beta	5 10^{-7}	Nil	Nil
	Tritium	0.05	Nil	Nil

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005	
			TBq	% of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	3 10^{-5}	5.60 10^{-7}	1.9
	Tritium	0.075	0.00342	4.6
	Carbon-14	0.011	1.90 10^{-4}	1.7
Bradwell	Beta	6 10^{-4}	1.35 10^{-5}	2.3
	Tritium	1.5	0.0216	1.4
	Carbon-14	0.6	0.00245	<1
	Sulphur-35	0.02	1.6 10^{-5}	<1
Chapelcross	Tritium	5000	300	6
	Sulphur-35	0.05	2.30 10^{-5}	<1
	Argon-41	4500	Nil	Nil
Dungeness 'A' Station	Beta[q]	5.5 10^{-4}	1.79 10^{-4}	33
	Tritium	2.6	0.499	19
	Carbon-14	5	1.91	38
	Sulphur-35	0.15	0.0363	24
	Argon-41	1700	1020	60
Dungeness 'B' Station	Beta[q]	0.001	5.14 10^{-6}	<1
	Tritium	15	5.91	39
	Carbon-14	5	0.704	14
	Sulphur-35	0.45	0.0455	10
	Argon-41	150	15.2	10
	Iodine-131	0.005	1.74 10^{-6}	<1
Hartlepool	Beta[q]	0.001	3.93 10^{-6}	<1
	Tritium	6	1.32	22
	Carbon-14	5	1.33	27
	Sulphur-35	0.16	0.0327	20
	Argon-41	60	4.31	7.2
	Iodine-131	0.005	2.51 10^{-5}	<1
Heysham Station 1	Beta[q]	0.001	7.62 10^{-6}	<1
	Tritium	6	1.35	23
	Carbon-14	4	1.09	27
	Sulphur-35	0.12	0.0138	11
	Argon-41	60	3.10	5.2
	Iodine-131	0.005	1.11 10^{-4}	2.0
Heysham Station 2	Beta[q]	0.001	1.02 10^{-5}	1.0
	Tritium	15	1.06	7.1
	Carbon-14	3	1.55	52
	Sulphur-35	0.3	0.017	5.7
	Argon-41	85	13.4	16
	Iodine-131	0.005	5.15 10^{-5}	1.0
Hinkley Point 'A' Station	Beta	1.5 10^{-4}	7.60 10^{-7}	<1
	Tritium	1.5	0.154	10.3
	Carbon-14	0.6	7.60 10^{-4}	<1
Hinkley Point 'B' Station	Beta[q]	0.001	2.81 10^{-5}	2.8
	Tritium	30	3.04	10
	Carbon-14	8	1.58	20
	Sulphur-35	0.4	0.190	47
	Argon-41	300	10.8	3.6
	Iodine-131	0.005	4.25 10^{-6}	<1

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005	
			TBq	% of annual limit[b]
Hunterston 'A' Station	Beta[q]	6 10^{-5}	2.12 10^{-7}	<1
	Tritium	0.02	0.00154	7.7
	Carbon-14	0.002	1.11 10^{-4}	5.5
Hunterston 'B' Station	Beta[q]	0.002	3.85 10^{-5}	1.9
	Tritium	20	3.97	20
	Carbon-14	3	1.64	55
	Sulphur-35	0.8	0.0291	3.6
	Argon-41	220	20.2	9.2
Oldbury	Beta	10^{-4}	3.50 10^{-5}	35
	Tritium	9	2.24	25
	Carbon-14	4	1.15	29
	Sulphur-35	0.45	0.0765	17
	Argon-41	500	24.5	4.9
Sizewell 'A' Station	Beta	8.5 10^{-4}	2.22 10^{-4}	26
	Tritium	3.5	1.72	49
	Carbon-14	2	1.22	61
	Sulphur-35	0.35	0.156	45
	Argon-41	3000	1990	66
Sizewell 'B' Station[a]	Noble gases	300	3.43	1.1
	Halogens	0.003	1.54 10^{-6}	<1
	Beta[q]	0.01	3.76 10^{-5}	<1
	Tritium	8	0.76	9.5
	Carbon-14	0.6	0.209	35
Torness	Beta[q]	0.002	3.12 10^{-6}	<1
	Tritium	20	2.15	11
	Carbon-14	3	0.569	19
	Sulphur-35	0.8	0.014	1.8
	Argon-41	220	4.81	2.2
Trawsfynydd	Beta	5 10^{-5}	3.10 10^{-7}	<1
	Tritium	0.75	0.0606	8.1
	Carbon-14	0.01	0.00316	32
Wylfa	Beta	7 10^{-4}	3.21 10^{-5}	4.6
	Tritium	18	2.42	13
	Carbon-14	2.3	1.25	54
	Sulphur-35	0.45	0.183	41
	Argon-41	100	19.9	20
Defence establishments				
Aldermaston[a,m]	Alpha	4.5 10^{-7}	6.33 10^{-8}	14
	Tritium	170	1.41 10^{-8}	<1
	Krypton-85	1	Nil	Nil
	Plutonium-241	1.68 10^{-6}	2.11 10^{-7}	13
	Other beta and gamma emitters	5 10^{-6}	1.09 10^{-7}	2.2
Barrow[l]	Tritium	3.2 10^{-6}	Nil	Nil
	Argon-41	0.048	Nil	Nil
Burghfield[a,m]	Tritium	0.05	4.82 10^{-9}	<1
	Uranium	2 10^{-8}	4.60 10^{-10}	2.3
Coulport	Tritium	0.05	0.00519	10
Derby[n,rs]	Uranium	5 10^{-6}	6.78 10^{-7}	14
Derby (Neptune)	Alpha[q]	2.4 10^{-8}	2.04 10^{-10}	<1
	Beta[q]	1.8 10^{-6}	4.92 10^{-8}	2.7

Table A1.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2005 TBq	% of annual limit[b]
Devonport[o]	Beta/gamma[q]	$3\ 10^{-7}$	$3.14\ 10^{-8}$	10
	Tritium	0.004	$2.85\ 10^{-4}$	7.1
	Carbon-14	0.043	0.00898	21
	Argon-41	0.015	$6.80\ 10^{-6}$	<1
Dounreay (Vulcan)	Alpha[q]	10^{-6}	$4.68\ 10^{-11}$	<1
	Beta[q]	10^{-4}	$1.20\ 10^{-6}$	1.2
	Noble gases	0.027	$3.81\ 10^{-4}$	1.4
	Iodine-131	$3.7\ 10^{-4}$	$2.60\ 10^{-5}$	7.0
Rosyth[p]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$2.25\ 10^{-6}$	$1.56\ 10^{-7}$	6.9
	Beta >0.4 MeV	0.0202	$6.04\ 10^{-5}$	<1
	Radionuclides T½<2hr	0.01	$5.33\ 10^{-4}$	5.3
	Tritium	2	$1.08\ 10^{-6}$	<1
	Sulphur-35	0.035	0.004	11
	Selenium-75	0.0015	$2.18\ 10^{-4}$	15
	Iodine-125	0.02	0.00141	7.1
	Iodine-131	0.001	$4.93\ 10^{-4}$	49
	Radon-222	10	3.18	32
	Other noble gases	50	17.6	35
	Other	0.016	$6.25\ 10^{-4}$	3.9
Cardiff (GE Healthcare)	Soluble tritium	156	48.7	31
	Insoluble tritium	600	244	41
	Carbon-14	2.38	1.24	52
	Phosphorus-32/33	$5\ 10^{-6}$	$8.00\ 10^{-7}$	16
	Iodine-125	$1.8\ 10^{-4}$	$3.74\ 10^{-5}$	21
	Other radionuclides	0.001	Nil	Nil

[a] *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*
[d] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*
[e] *Excluding curium-242 and 244*
[f] *Excluding tritium*
[g] *Excluding krypton-85*
[h] *Data includes any curium-243 present*
[i] *Excluding radon and daughter products*
[j] *Krypton-85 discharges are calculated monthly*
[k] *Combined data for Berkeley Power Station and Berkeley Technology Centre*
[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by AWE plc*
[n] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Discharges were made by Rosyth Royal Dockyard Ltd*
[q] *Particulate activity*
[r] *Annual limits on beta and alpha derived from monthly and weekly notification levels*

Table A1.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2005

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2005	
			TBq	% of limit
Drigg[d]	Tritium	10	0.980	9.8
	Carbon-14	0.05	0.0120	24
	Cobalt-60	2	0.220	11
	Iodine-129	0.05	$6.40\ 10^{-4}$	1.3
	Radium-226 plus thorium-232	0.03	0.003	10
	Uranium	0.3	0.053	18
	Other alpha[a]	0.3	0.080	27
	Others[a,b]	15	3.6	24
Dounreay[c]	Alpha		$5.87\ 10^{-3}$	
	Beta/gamma		0.0262	

[a] *With half-lives greater than three months*
[b] *Other beta emitting radionuclides but including iron-55 and cobalt-60*
[c] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits*
[d] *Discharge authorisations at Drigg were revised with effect from 1 May 2006*

APPENDIX 2. MODELLING OF CONCENTRATIONS OF RADIONUCLIDES IN FOODSTUFFS AND AIR

A2.1 Foodstuffs

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

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

$C_m = F_m Ca\, Q_f$ and

$C_f = F_f\, Ca\, Q_f$ where

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

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

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

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

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

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

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

Table A2.1 Data for food chain model

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

Table A2.2 Predicted concentrations of radionuclides from food chain model used in assessments of exposures

Foodstuff	Location	Radioactivity concentration (wet weight), Bq kg^{-1}			
		^{99}Tc	^{106}Ru	^{144}Ce	^{241}Pu
Milk	Sellafield	[a]	2.69 10^{-4}	[b]	5.74 10^{-6}
	Ravenglass	[a]	3.21 10^{-4}	3.67 10^{-3}	9.33 10^{-6}
	Drigg	[a]	6.28 10^{-4}	5.20 10^{-3}	1.43 10^{-5}
	Isle of Man	[a]	3.99 10^{-4}	3.81 10^{-3}	8.49 10^{-6}
Beef	Sellafield	[a]	2.69 10^{-1}	[b]	5.74 10^{-4}
	Ravenglass	[a]	3.21 10^{-1}	1.84 10^{-1}	9.33 10^{-4}
Lamb	Sellafield	[a]	3.10 10^{-1}	[b]	2.65 10^{-4}
	Ravenglass	6.53 10^{-2}	3.71 10^{-1}	2.12 10^{-1}	4.31 10^{-4}
	Drigg	[a]	7.25 10^{-1}	3.00 10^{-1}	6.60 10^{-4}
Beef offal	Sellafield	[a]	2.69 10^{-1}	[b]	1.15 10^{-1}
	Ravenglass	[a]	3.21 10^{-1}	[a]	[a]
Lamb offal	Sellafield	[a]	3.10 10^{-1}	[b]	1.99 10^{-2}
	Ravenglass	[a]	3.71 10^{-1}	[a]	3.23 10^{-2}
	Drigg	[a]	7.25 10^{-1}	[a]	[a]

[a] *Positive result used, or LoD result used because modelling result greater than LoD*
[b] *No grass or LGV or sample LOD dta available*

A2.2 Air

For some sites, discharges to air can lead to significant doses. Doses may arise from radionuclides transferred from the plume to food crops and animal products, inhalation of radionuclides in the plume itself and external doses from radionuclides in the plume.

An assessment of doses from non-food pathways arising from discharges to air has been made around the operating Magnox power stations Dungeness A, Oldbury, Sizewell A and Wylfa, from Sellafield and GE Health Care at Amersham and at Cardiff. For the power stations, discharges of argon-41 to air are significant whilst the reactors are operating. Argon-41 is a noble gas with a short radioactive half-life of about 1.8 h. It does not become incorporated into food produce, but people working or living within the plume may be exposed to external radiation from argon-41 as it disperses downwind of the discharge point. Inhalation of other radionuclides downwind of the discharge point has also been assessed.

Average annual concentrations of radionuclides in the air at nearest habitations were calculated using a Gaussian plume model, PC CREAM (Mayall *et al*., 1997), and the reported discharges of radionuclides to air. Site-specific meteorological data were used in the assessments. The key modelling assumptions (i.e. discharge height, habitations) are shown in Table A2.3.

External radiation doses from radionuclides in the plume and from deposited activity were calculated taking into account occupancy indoors and outdoors and location factors to allow for building shielding. During the time people are assumed to be indoors, the standard assumption that the dose from radionuclides in the plume will be reduced by 80 per cent (i.e. shielding factor of 0.2) has been made. Internal radiation doses from inhalation of discharged radionuclides was assessed using breathing rates. Doses were initially assessed for three age groups: infants (1 y), children (10 y) and adults. Adults and infants are assumed to have year-round occupancy at the nearest habitation, whilst children are assumed to spend time away at school. The inhalation and occupancy rates assumed in this assessment are shown in Table A2.4. The dose to the fetal age group was taken to be the same as that for an adult. The predicted concentrations of radioactivity in air are given in Tables A2.5 and A2.6.

Table A2.3 Air concentration modelling assumptions

Nuclear site	Stack height, m	Exposure location	Distance to exposure location, m	Bearing to exposure location
Amersham	20	Dwelling	250	
Cardiff	20	Dwelling	400	270°
Dungeness	17	Dwelling	300	70°
Oldbury	20	Farm	700	90°
Sizewell	18	Dwelling	300	180°
Sellafield	93	Farm	1200	900°
Wylfa	17	Farm	500	110°

Table A2.4 Inhalation and occupancy data for dose assessment of discharges to air

Age group, y	Inhalation rates, $m^3 h^{-1}$	Occupancy at exposure location, $h\ y^{-1}$	Fraction of time indoors
Amersham, Cardiff, Dungeness and Sizewell (dwellings)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.7
Oldbury, Sellafield and Wylfa (farm locations)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.5

Table A2.5 Predicted concentrations of radionuclides in air at highest exposure locations in the vicinity of Magnox power stations and Cardiff

Site	Radioactivity concentration in air, $Bq\ m^{-3}$								
	Tritium	^{14}C	^{32}P	^{35}S	^{41}Ar	^{60}Co	^{85}Kr	^{125}I	^{131}I
Cardiff	6.9	0.12	$7.5\ 10^{-8}$					$3.5\ 10^{-6}$	
Dungeness	1.2	0.50		$1.6\ 10^{-2}$	$2.0\ 10^{2}$	$3.5\ 10^{-5}$			$3.3\ 10^{-7}$
Oldbury	0.13	$6.8\ 10^{-2}$		$4.5\ 10^{-3}$	1.4	$2.1\ 10^{-6}$			
Sizewell	0.11	$9.3\ 10^{-2}$		$1.0\ 10^{-2}$	$1.3\ 10^{2}$	$1.7\ 10^{-5}$	0.22		$3.1\ 10^{-5}$
Wylfa	$8.5\ 10^{-2}$	$4.6\ 10^{-2}$		$6.7\ 10^{-3}$	0.72	$1.2\ 10^{-6}$			

Table A2.6 Predicted concentrations of radionuclides in air at most exposed location in vicinity of Amersham and Sellafield

Radionuclide	Radioactivity concentration in air, $Bq\ m^{-3}$	
	Amersham	Sellafield
Tritium	$7.1\ 10^{-8}$	0.17
Carbon-14		$1.8\ 10^{-3}$
Sulphur-35	$2.6\ 10^{-4}$	
Cobalt-60		
Selenium-75	$1.4\ 10^{-5}$	
Krypton-85		$9.9\ 10^{1}$
Strontium-90	$4.0\ 10^{-6}$	$8.8\ 10^{-8}$
Ruthenium-106		$2.6\ 10^{-6}$
Antimony-125		$7.5\ 10^{-7}$
Iodine-125	$9.3\ 10^{-5}$	
Iodine-129		$1.9\ 10^{-5}$
Xenon-133	1.2	
Iodine-131	$3.2\ 10^{-5}$	$1.8\ 10^{-6}$
Caesium-137	$4.1\ 10^{-5}$	$8.0\ 10^{-7}$
Radon-222	0.21	
Plutonium-239		$5.5\ 10^{-8}$
Plutonium-241		$5.9\ 10^{-8}$
Americium-241	$1.0\ 10^{-8}$	$4.7\ 10^{-8}$

APPENDIX 3. ABBREVIATIONS AND GLOSSARY

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Ltd
CAC	Codex Alimentarius Commission
CCFAC	The Codex Committee on Food Additives and Contaminants
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries and Aquaculture Science
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DPAG	Dounreay Particles Advisory Group
DRDL	Devonport Royal Dockyard Ltd
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EHS	Environment and Heritage Service
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FSA	Food Standards Agency
GDL	Generalised Derived Limit
GE	General Electric
HALES	High Active Liquor Evaporation and Storage
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Staionery Office
HPA	Health Protection Agency
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
LCBL	Lifecycle baseline
LLW	Low-Level Waste
LLWR	Low-Level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries and Food
MoD	Ministry of Defence
MoD(N)	Ministry of Defence (Navy)
MRL	Minimum reporting level
ND	Not detected
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval reactor test establishment
NSL	Nexia Solutions Limited
NTWP	Near Team Work Plan
OBT	Organically bound tritium

OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
RIFE	Radioactivity in Food and the Environment
RRMPOL	Rolls Royce Marine Power Operations Ltd
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Ltd
SIXEP	Site Exchange Effluent Plant
SL	Scientifics Ltd
SRP	Society for Radiological Protection
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally Occurring Radioactive Material
TPP	Tetraphenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WMTL	Waste Management Technology Limited
YP	Ystradyfodwg and Pontpridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J/kg.
Becquerel	One radioactive transformation per second.
Committed effective	The sum of the committed equivalent doses for all organs and tissues in dose the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the Sievert (Sv).
Critical group	Those who receive the largest dose from artificially-produced radionuclides due to their habits, diet and where they spend their time.
Direct shine	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.
Dose	Shortened form of ‘effective dose’ or ‘absorbed dose’.
Dose limits	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv/y for the UK.
Dose rates	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv).
Environmental materials	Include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.

Equivalent dose	The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the Sievert (Sv).
External dose	Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.
Fragments	'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.
Generalised derived limit	A convenient reference level against which the results of environmental monitoring can be compared. GDLs are calculated using deliberately cautious assumptions and are based on the assumption that the level of environmental contamination is uniform over the year. GDLs relate the concentrations of a single radionuclide in a single environmental material to the dose limit for members of the public.
Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the foodchain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the disintegration of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
TNORM	Naturally occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take. account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01.
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation.

Appendices

APPENDIX 4. CONSUMPTION, INHALATION, HANDLING AND OCCUPANCY RATES

This appendix gives the consumption, handling and occupancy rate data used in the routine assessment of exposures from terrestrial consumption and aquatic pathways. Further data are presented in Appendix 7 for the assesment of total dose integrated across pathways. Consumption rates for terrestrial foods are based on Byrom *et al*. (1995) and are given in Table A4.1. These are derived from national statistics and are taken to apply at each site. Site-specific data for aquatic pathways based on local surveys are given in Table A4.2. Occupancy over intertidal areas and rates of handling from local surveys have been reassessed to take account of a change in the factor used to determine the range of rates within the critical group. Previously, when using the 'cut-off' method to define the critical group (Hunt *et al*., 1982; Preston, *et al*., 1974), a factor of 1.5 was used to describe the ratio of the maximum to the minimum rate within the group. The factor has now changed to 3 to make the selection process consistent with that used for consumption pathways. From 2002, sites in England and Wales with new local surveys were adjusted to adopt the new factor. From 2003, all sites in Scotland were adjusted. Data used for routine assessments of external and inhalation pathways from gaseous discharges are given in Appendix 2.

Table A4.1 Consumption rates for terrestrial foods

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

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

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

Site (Year of last survey)	Group[a]	Rates
Aldermaston (2002)	A	1 kg y^{-1} pike
		320 h y^{-1} over riverbank
	B	1.2 kg y^{-1} crayfish
Amersham (2004)		1 kg y^{-1} pike
		630 h y^{-1} over riverbank
Berkeley and Oldbury (2001)		18 kg y^{-1} salmonids and other fish
		2.3 kg y^{-1} shrimps
		520 h y^{-1} over mud
Bradwell	A (1999)	44 kg y^{-1} fish
		3.1 kg y^{-1} crabs and lobsters
		6.5 kg y^{-1} Pacific oysters and winkles
		2900 h y^{-1} over mud
	B (NA)	300 h y^{-1} over sediment

Table A4.2. continued

Site	Group[a]	Rates
Capenhurst (NA)	10 year old children	500 h y^{-1} over sediment
		5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		20 l y^{-1} water by inadvertent ingestion
Cardiff	A (2003)	24 kg y^{-1} fish
		3.8 kg y^{-1} prawns and lobster
		500 h y^{-1} over mud
	B (NA)	500 h y^{-1} over bank of the River Taff
		2.5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		34 l y^{-1} water by inadvertent ingestion
	C (2003)	5.6 kg y^{-1} wildfowl
Channel Islands (1997)		62 kg y^{-1} fish
		30 kg y^{-1} crabs, spider crabs and lobsters
		30 kg y^{-1} scallops and whelks
		1400 h y^{-1} over mud and sand
Chapelcross (2005)	A	31 kg y^{-1} salmonids
		950 h y^{-1} over mud
	B	450 h y^{-1} over salt marsh
		19 kg y^{-1} wildfowl
	C	390 h y^{-1} handling nets
		610 h y^{-1} handling sediment
Culham (NA)		600 l y^{-1} water
Derby (NA)		600 l y^{-1} water
Devonport (2004)	A	32 kg y^{-1} fish
		3.5 kg y^{-1} crabs, prawns and shrimps
		1.7 kg y^{-1} scallops
		980 h y^{-1} over sediment and shale
	B	2000 h y^{-1} over mud
Dounreay (2003)	A	1500 h y^{-1} handling fishing gear
	B	30 kg y^{-1} fish
		8.9 kg y^{-1} crab and lobster
		0.5 kg y^{-1} mussels and winkles
	C	410 h y^{-1} over rock and sand
	D	8 h y^{-1} in a Geo
Drigg (NA)		35 l y^{-1} water
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (2005)	A	51 kg y^{-1} fish
		9.3 kg y^{-1} crabs and shrimps
		17 kg y^{-1} king scallops
		1500 h y^{-1} over mud and sand
	B (Rye Harbour houseboats)	2000 h y^{-1} over mud
Faslane (2000)	A	200 h y^{-1} over mud
	B	9.9 kg y^{-1} fish
		690 h y^{-1} over mud and sand
Hartlepool (2002)		32 kg y^{-1} fish
		15 kg y^{-1} crab and lobster
		12 kg y^{-1} winkles and whelks
		910 h y^{-1} over mud
Harwell (1991)		1 kg y^{-1} pike
		650 h y^{-1} over river bank
Heysham (2001)		36 kg y^{-1} fish
		18 kg y^{-1} shrimps
		19 kg y^{-1} cockles, whelks and mussels
		1200 h y^{-1} over mud and sand

Table A4.2. continued

Site	Group[a]	Rates
Hinkley Point (2000)		43 kg y^{-1} fish 9.8 kg y^{-1} shrimps and prawns 1.8 kg y^{-1} whelks 960 h y^{-1} over mud
Holy Loch (1989)		730 h y^{-1} over mud
Hunterston (2001)	A	29 kg y^{-1} fish 22 kg y^{-1} Nephrops and squat lobsters 2 kg y^{-1} queen scallops
	B	1200 h y^{-1} over mud and sand
Landfill		1.5 l y^{-1} water
Rosyth (2005)	A	31 kg y^{-1} fish 28 kg y^{-1} crabs and lobsters
	B	14 kg y^{-1} winkles and mussels 730 h y^{-1} over sediments
Sellafield	A (Sellafield fishing community) (2005)	41 kg y^{-1} cod (60%) and other fish (40%) 20 kg y^{-1} crab (60%), lobster (20%) and *Nephrops* (20%) 33 kg y^{-1} winkles (60%) and other molluscs (40%) 790 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (2003)	730 h y^{-1} handling nets and pots
	C (Bait digging and mollusc collecting) (2003)	1000 h y^{-1} handling sediment
	D (Whitehaven commercial) (1998)	40 kg y^{-1} plaice and cod 9.7 kg y^{-1} Nephrops 15 kg y^{-1} whelks
	E (Morecambe Bay)	See Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod 29 kg y^{-1} shrimps 23 kg y^{-1} whelks
	G (Dumfries and Galloway) (2002)	43 kg y^{-1} fish 20 kg y^{-1} Nephrops, crab and lobster 11 kg y^{-1} whelks and king scallop 700 h y^{-1} over mud and sand
	H (Laverbread) (1972)	47 kg y^{-1} laverbread
	I (Trout) (NA)	6.8 kg y^{-1} rainbow trout
	J (Typical fish consumer) (NA)	15 kg y^{-1} cod and plaice
	K (Isle of Man) (NA)	100 kg y^{-1} fish 20 kg y^{-1} crustaceans 20 kg y^{-1} molluscs
	L (Northern Ireland) (2000)	99 kg y^{-1} haddock and other fish 34 kg y^{-1} Nephrops and crabs 7.7 kg y^{-1} mussels and other molluscs 1100 h y^{-1} over mud and sand
	M (North Wales) (NA)	100 kg y^{-1} fish 20 kg y^{-1} crustaceans 20 kg y^{-1} molluscs 300 h y^{-1} over mud and sand
	N (Sellafield fishing community 2001-2005) (2005)	41 kg y^{-1} fish 12 kg y^{-1} crabs 5.9 kg y^{-1} lobsters 3.3 kg y^{-1} Nephrops 15 kg y^{-1} winkles 14 kg y^{-1} other molluscs 950 h y^{-1} over mud and sand
	O (Ravenglass recreational use) (NA)	300 h y^{-1} over mud and sand 1.5 10^{-3} kg y^{-1} mud and sand by inadvertent ingestion 2.76 10^{-5} kg y^{-1} mud and sand by resuspension and inhalation
	P (Typical beach user) (NA)	30 h y^{-1} over sand
	Q (Ravenglass nature warden) (2003)	400 h y^{-1} over salt marsh 2.0 10^{-3} kg y^{-1} mud by inadvertent ingestion 3.7 10^{-5} kg y^{-1} mud by resuspension and inhalation

Table A4.2. continued

Site	Group[a]	Rates
Sizewell (2005)		23 kg y^{-1} fish 11 kg y^{-1} crab and lobster 5.1 kg y^{-1} Pacific oysters and mussels 720 h y^{-1} over mud
Springfields	A (2000)	42 kg y^{-1} fish 15 kg y^{-1} shrimps 10 kg y^{-1} cockles and mussels
	B (2000)	860 h y^{-1} handling nets
	C (Ribble Estuary houseboats) (2001-2005) (NA)	1800 h y^{-1} over mud 0.012 kg y^{-1} mud by inadvertent ingestion 2.2 10^{-4} kg y^{-1} mud by resuspension and inhalation
	D (10 year old children) (NA)	30 h y^{-1} over mud 3 10^{-4} kg y^{-1} mud by inadvertent ingestion 1.9 10^{-6} kg y^{-1} mud by resuspension and inhalation
	E (Anglers) (NA)	840 h y^{-1} over mud
Torness (2001)	A	41 kg y^{-1} fish 17 kg y^{-1} Nephrops, crab and lobster 5.9 kg y^{-1} mussels 360 h y^{-1} over sand
	B	1500 h y^{-1} handling fishing gear
Trawsfynydd (2005)		1.3 kg y^{-1} brown trout 60 kg y^{-1} rainbow trout 450 h y^{-1} over lake shore
Upland lake (NA)		37 kg y^{-1} fish
Winfrith (2003)		40 kg y^{-1} fish 15 kg y^{-1} crabs and lobsters 14 kg y^{-1} scallops and whelks 300 h y^{-1} over sand and stones
Wylfa (2004)		22 kg y^{-1} fish 6.5 kg y^{-1} crabs and lobsters 1.5 kg y^{-1} molluscs 270 h y^{-1} over sand and stones

[a] Where more than one group exists at a site the groups are denoted A, B, etc. Year of habits survey is given where appropriate
NA Not appropriate.
Data sources include Environment Agency (2002a) and Smith and Jones (2003).

APPENDIX 5. DOSIMETRIC DATA

The dose coefficients used in assessments in this report are provided in Table A5.1 for ease of reference. For adults and postnatal children they are based on generic data contained in International Commission on Radiological Protection Publication 72 (International Commission on Radiological Protection, 1996a). Doses for prenatal children have been obtained primarily from ICRP 88 (International Commission on Radiological Protection, 2001) and National Radiological Protection Board (2005). For a few radionuclides where prenatal dose coefficients are unavailable the relevant adult dose coefficient has been used.

In the case of tritium, polonium, plutonium and americium radionuclides, dose coefficients have been adjusted according to specific research work of relevance to assessments in this report.

A5.1 Polonium

The current ICRP advice is that a gut uptake factor of 0.5 is appropriate for dietary intakes of polonium by adults (International Commission on Radiological Protection, 1994). A study involving the consumption of crabmeat containing natural levels of polonium-210 has suggested that the factor could be as high as 0.8 (Hunt and Allington, 1993). More recently, similar experiments with mussels and cockles suggested a factor in the range 0.30 to 0.61 and 0.15 to 0.57 respectively, close to the ICRP value of 0.5 (Hunt and Rumney, 2004 and 2005). Further experiments are planned and until the outcome of these is assessed, estimates of the exposures due to polonium intake have been calculated using the conservative assumption that a factor of 0.8 applies to all seafood except molluscs where specific data suggests 0.5 is more appropriate. We have retained a factor of 0.5 for other food.

A5.2 Plutonium and americium

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

A5.3 Technetium-99

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

A5.4 Tritium

Harrison *et al*. (2002) reviewed dose coefficients for tritium associated with organic material. They gave estimates of uncertainty on central estimates of dose coefficients but did not suggest revision of the current ICRP value for organically-bound tritium. The HPA has recently published a study of the uptake and retention of tritium in rats fed with fish from Cardiff Bay (Hodgson *et al*., 2005). This suggests that an increase in the dose coefficient from the ICRP value of $4.2\ 10^{-11}$ Sv Bq^{-1} (adults) (ICRP, 1996a) to $6.0\ 10^{-11}$ Sv Bq^{-1} may be warranted in some circumstances. The effect of applying the higher value is considered for all age groups in the assessment of seafood collected near the Cardiff site (Section 7).

Table A5.1. Dosimetric data

Radionuclide	Half Life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology (Sv.Bq^{-1})			
				Adults	10 yr.	1 yr.	Fetus
H-3	1.24E+01	5.68E-03	0.00E+00	1.8E-11	2.3E-11	4.8E-11	3.1E-11
H-3 (f)				4.2E-11	5.7E-11	1.2E-10	6.3E-11
H-3 (h)				6.0E-11	8.0E-11	2.0E-10	9.0E-11
C-14	5.73E+03	4.95E-02	0.00E+00	5.8E-10	8.0E-10	1.6E-09	8.0E-10
P-32	3.91E-02	6.95E-01	0.00E+00	2.4E-09	5.3E-09	1.9E-08	2.5E-08
S-35 (g)	2.39E-01	4.88E-02	0.00E+00	7.7E-10	1.6E-09	5.4E-09	1.6E-09
Ca-45	4.46E-01	7.72E-02	0.00E+00	7.1E-10	1.8E-09	4.9E-09	8.7E-09
Cr-51	7.59E-02	0.00E+00	3.20E-01	3.8E-11	7.8E-11	2.3E-10	3.8E-11
Mn-54	8.56E-01	4.22E-03	8.36E-01	7.1E-10	1.3E-09	3.1E-09	7.1E-10
Fe-55	2.70E+00	4.20E-03	1.69E-03	3.3E-10	1.1E-09	2.4E-09	8.1E-11
Co-57	7.42E-01	1.86E-02	1.25E-01	2.1E-10	5.8E-10	1.6E-09	1.1E-10
Co-58	1.94E-01	3.41E-02	9.98E-01	7.4E-10	1.7E-09	4.4E-09	5.8E-10
Co-60	5.27E+00	9.66E-02	2.50E+00	3.4E-09	1.1E-08	2.7E-08	1.9E-09
Zn-65	6.67E-01	6.87E-03	5.85E-01	3.9E-09	6.4E-09	1.6E-08	4.1E-09
Se-75	3.28E-01	1.45E-02	3.95E-01	2.6E-09	6.0E-09	1.3E-08	2.7E-09
Sr-90†	2.91E+01	1.13E+00	3.16E-03	3.1E-08	6.6E-08	9.3E-08	4.6E-08
Zr-95†	1.75E-01	1.61E-01	1.51E+00	1.5E-09	3.0E-09	8.8E-09	7.6E-10
Nb-95	9.62E-02	4.44E-02	7.66E-01	5.8E-10	1.1E-09	3.2E-09	3.7E-10
Tc-99	2.13E+05	1.01E-01	0.00E+00	6.4E-10	1.3E-09	4.8E-09	4.6E-10
Ru-103†	1.07E-01	7.48E-02	4.69E-01	7.3E-10	1.5E-09	4.6E-09	2.7E-10
Ru-106†	1.01E+00	1.42E+00	2.05E-01	7.0E-09	1.5E-08	4.9E-08	3.8E-10
Ag-110m†	6.84E-01	8.70E-02	2.74E+00	2.8E-09	5.2E-09	1.4E-08	2.1E-09
Sb-124	1.65E-01	1.94E-01	1.69E+00	2.5E-09	5.2E-09	1.6E-08	1.0E-09
Sb-125	2.77E+00	1.01E-01	4.31E-01	1.1E-09	2.1E-09	6.1E-09	4.7E-10
Te-125m	1.60E-01	1.09E-01	3.55E-02	8.7E-10	1.9E-09	6.3E-09	8.7E-10
I-125	1.65E-01	1.94E-02	4.21E-02	1.5E-08	3.1E-08	5.7E-08	9.1E-09
I-129	1.57E+07	6.38E-02	2.46E-02	1.1E-07	1.9E-07	2.2E-07	4.4E-08
I-131†	2.20E-02	1.94E-01	3.81E-01	2.2E-08	5.2E-08	1.8E-07	2.3E-08
Cs-134	2.06E+00	1.63E-01	1.55E+00	1.9E-08	1.4E-08	1.6E-08	8.7E-09
Cs-137†	3.00E+01	2.49E-01	5.65E-01	1.3E-08	1.0E-08	1.2E-08	5.7E-09
Ba-140†	3.49E-02	8.49E-01	2.50E+00	4.6E-09	1.0E-08	3.1E-08	3.5E-09
Ce-144†	7.78E-01	1.28E+00	5.28E-02	5.2E-09	1.1E-08	3.9E-08	3.1E-11
Pm-147	2.62E+00	6.20E-02	4.37E-06	2.6E-10	5.7E-10	1.9E-09	2.6E-10
Eu-154	8.80E+00	2.92E-01	1.24E+00	2.0E-09	4.1E-09	1.2E-08	2.0E-09
Eu-155	4.96E+00	6.34E-02	6.06E-02	3.2E-10	6.8E-10	2.2E-09	3.2E-10
Pb-210†	2.23E+01	4.28E-01	4.81E-03	6.9E-07	1.9E-06	3.6E-06	1.4E-07
Bi-210	1.37E-02	3.89E-01	0.00E+00	1.3E-09	2.9E-09	9.7E-09	6.6E-12
Po-210(c)	3.79E-01	0.00E+00	0.00E+00	1.2E-06	2.6E-06	8.8E-06	1.3E-07
Po-210(d)				1.9E-06	4.2E-06	1.4E-05	2.1E-07
Ra-226†	1.60E+03	9.56E-01	1.77E+00	2.8E-07	8.0E-07	9.6E-07	3.2E-07
Th-228†	1.91E+00	9.13E-01	1.57E+00	1.4E-07	4.3E-07	1.1E-06	2.4E-07
Th-230	7.70E+04	1.46E-02	1.55E-03	2.1E-07	2.4E-07	4.1E-07	8.6E-09
Th-232	1.41E+10	1.25E-02	1.33E-03	2.3E-07	2.9E-07	4.5E-07	9.4E-09
Th-234†	6.60E-02	8.82E-01	2.10E-02	3.4E-09	7.4E-09	2.5E-08	1.5E-11
U-234	2.44E+05	1.32E-02	1.73E-03	4.9E-08	7.4E-08	1.3E-07	1.5E-08
U-235†	7.04E+08	2.15E-01	1.82E-01	4.7E-08	7.1E-08	1.3E-07	1.4E-08
U-238†	4.47E+09	8.92E-01	2.24E-02	4.8E-08	7.5E-08	1.5E-07	1.3E-08
Np-237†	2.14E+06	2.67E-01	2.38E-01	1.1E-07	1.1E-07	2.1E-07	3.6E-09
Pu-238(a)	8.77E+01	1.06E-02	1.81E-03	2.3E-07	2.4E-07	4.0E-07	9.0E-09
Pu-238(b)				9.2E-08	9.6E-08	1.6E-07	3.6E-09
Pu-239(a)	2.41E+04	6.74E-03	8.07E-04	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-239(b)				1.0E-07	1.1E-07	1.7E-07	3.8E-09
Pu-α(e)	2.41E+04	6.74E-03	8.07E-04	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-240(a)	6.54E+03	1.06E-02	1.73E-03	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-240(b)				1.0E-07	1.1E-07	1.7E-07	3.8E-09
Pu-241(a)	1.44E+01	5.25E-03	2.55E-06	4.8E-09	5.1E-09	5.7E-09	1.1E-10
Pu-241(b)				1.9E-09	2.0E-09	2.3E-09	4.4E-11
Am-241(a)	4.32E+02	5.21E-02	3.25E-02	2.0E-07	2.2E-07	3.7E-07	2.7E-09
Am-241(b)				8.0E-08	8.8E-08	1.5E-07	1.1E-09
Cm-242	4.46E-01	9.59E-03	1.83E-03	1.2E-08	2.4E-08	7.6E-08	4.7E-10
Cm-243	2.85E+01	1.38E-01	1.35E-01	1.5E-07	1.6E-07	3.3E-07	1.5E-07
Cm-244	1.81E+01	8.59E-03	1.70E-03	1.2E-07	1.4E-07	2.9E-07	2.2E-09

Table A5.1. continued

Radionuclide	Dose per unit intake by inhalation using ICRP-60 methodology (Sv.Bq^{-1})			
	Adults	10 yr.	1 yr.	Fetus
H-3	4.5E-11	8.2E-11	2.7E-10	2.6E-12
H-3(f)	4.1E-11	5.5E-11	1.1E-10	6.3E-11
C-14	2.0E-09	2.8E-09	6.6E-09	6.6E-11
P-32	3.4E-09	5.3E-09	1.5E-08	6.5E-09
S-35(g)	1.4E-09	2.0E-09	4.5E-09	1.5E-11
Ca-45	2.7E-09	3.9E-09	8.8E-09	1.7E-09
Cr-51	3.7E-11	6.6E-11	2.1E-10	3.7E-11
Mn-54	1.5E-09	2.4E-09	6.2E-09	1.5E-09
Fe-55	3.8E-10	6.2E-10	1.4E-09	6.6E-11
Co-57	5.5E-10	8.5E-10	2.2E-09	6.1E-11
Co-58	1.6E-09	2.4E-09	6.5E-09	2.5E-10
Co-60	1.0E-08	1.5E-08	3.4E-08	1.2E-09
Zn-65	1.6E-09	2.4E-09	6.5E-09	7.4E-10
Se-75	1.0E-09	2.5E-09	6.0E-09	1.1E-09
Sr-90†	3.8E-08	5.4E-08	1.2E-07	1.0E-08
Zr-95†	6.3E-09	9.0E-09	2.1E-08	4.6E-10
Nb-95	1.5E-09	2.2E-09	5.2E-09	1.6E-10
Tc-99	4.0E-09	5.7E-09	1.3E-08	8.3E-11
Ru-103†	2.4E-09	3.5E-09	8.4E-09	1.1E-10
Ru-106†	2.8E-08	4.1E-08	1.1E-07	4.1E-10
Ag-110m†	7.6E-09	1.2E-08	2.8E-08	1.5E-09
Sb-124	6.4E-09	9.6E-09	2.4E-08	4.4E-10
Sb-125	4.8E-09	6.8E-09	1.6E-08	2.6E-10
Te-125m	3.4E-09	4.8E-09	1.1E-08	3.4E-09
I-125	5.1E-09	1.1E-08	2.3E-08	3.1E-09
I-129	3.6E-08	6.7E-08	8.6E-08	1.5E-08
I-131†	7.4E-09	1.9E-08	7.2E-08	8.1E-09
Cs-134	6.6E-09	5.3E-09	7.3E-09	3.0E-09
Cs-137†	4.6E-09	3.7E-09	5.4E-09	2.0E-09
Ba-140†	6.2E-09	9.6E-09	2.6E-08	1.4E-09
Ce-144†	3.6E-08	5.5E-08	1.6E-07	4.2E-10
Pm-147	5.0E-09	7.0E-09	1.8E-08	5.0E-09
Eu-154	5.3E-08	6.5E-08	1.5E-07	5.3E-08
Eu-155	6.9E-09	9.2E-09	2.3E-08	6.9E-09
Pb-210†	1.2E-06	1.6E-06	4.0E-06	6.1E-08
Bi-210	9.3E-08	1.3E-07	3.0E-07	9.1E-12
Po-210	3.3E-06	4.6E-06	1.1E-05	1.9E-08
Ra-226†	3.5E-06	4.9E-06	1.1E-05	9.9E-08
Th-228†	4.3E-05	5.9E-05	1.4E-04	2.5E-07
Th-230	1.4E-05	1.6E-05	3.5E-05	2.6E-08
Th-232	2.5E-05	2.6E-05	5.0E-05	2.8E-08
Th-234†	7.7E-09	1.1E-08	3.1E-08	6.7E-12
U-234	3.5E-06	4.8E-06	1.1E-05	4.9E-08
U-235†	3.1E-06	4.3E-06	1.0E-05	4.5E-08
U-238†	2.9E-06	4.0E-06	9.4E-06	4.4E-08
Np-237†	2.3E-05	2.2E-05	4.0E-05	4.3E-07
Pu-238	4.6E-05	4.4E-05	7.4E-05	1.1E-06
Pu-239	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-α(e)	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-240	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-241	9.0E-07	8.3E-07	9.7E-07	1.4E-08
Am-241	4.2E-05	4.0E-05	6.9E-05	3.2E-07
Cm-242	5.2E-06	7.3E-06	1.8E-05	5.1E-08
Cm-243	3.1E-05	3.1E-05	6.1E-05	3.1E-05
Cm-244	2.7E-05	2.7E-05	5.7E+00	2.6E-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) *Pu-239 data used*
(f) *Organically bound tritium*
(g) *Organically bound sulphur*
(h) *Organically bound tritium for seafood near the Cardiff site*

APPENDIX 6. ESTIMATES OF CONCENTRATIONS OF NATURAL RADIONUCLIDES

6.1 Aquatic foodstuffs

Table A6.1 gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis carried out by Cefas (Young *et al*., 2002 and unpublished studies). Data for lead-210 and polonium-210 are from a detailed study and are quoted as medians with minimum and maximum values given in brackets. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background.

Table A6.1 Concentrations of radionuclides in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (wet))									
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	23	27			23					
Lead-210	0.042	0.02	0.24	0.080	1.2	1.5	1.6	0.94	0.39	1.5
	(0.0030-0.55)	(0.013-2.4)	(0.043-0.76)	(0.02-0.79)	(0.18-6.8)	(0.69-2.6)	(0.68-6.8)	(0.59-1.3)	(0.18-0.61)	(0.68-4.9)
Polonium-210	0.82	9.1	19	5.3	17	13	42	18	6.5	8.4
	(0.18-4.4)	(1.1-35)	(4.1-35)	(1.9-10)	(1.2-69)	(6.1-25)	(19-69)	(11-36)	(1.2-11)	(5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

6.2 Terrestrial foodstuffs

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

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

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

APPENDIX 7. ASSESSMENT OF TOTAL DOSE INTEGRATED ACROSS PATHWAYS

7.1 Introduction

This appendix describes the methods, data and results used to assess total dose to the public near nuclear sites from all exposure pathways. The approach uses dietary and occupancy data collected from integrated habit surveys carried out around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gathers data on people's occupancy close to each site and local food intake rates. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Hartlepool, Hunterston, Rosyth, Sellafield, Sizewell, Trawsfynydd, Winfrith and Wylfa. Further sites will be added in future RIFE reports as new integrated surveys are undertaken.

7.2 Objectives

The Environment Agencies are required to ensure that doses to the public do not exceed 1 mSv/y from all routine man made sources, except certain medical ones. Doses to the public are assessed and compared with the dose limit. For nuclear sites the dose assessment takes into account exposure to radionuclides in food and the environment and direct radiation. The assessment makes use of the monitoring results reported elsewhere in this report. The monitoring and habits data used in the assessment are provided for each site on the CD accompanying this report.

7.3 Methods and data

The calculation method relies on the application of data from site-specific habits surveys (Camplin *et al*., 2005). This is possible because recent surveys have considered the habits of individuals in an integrated way, i.e. information for each individual has been recorded for all of the pathways of interest. Using the habits survey data, the people who are regarded as having the potential to receive the highest doses are identified for each major pathway at each site. Doses to the public from direct radiation are included in the assessment of total dose using information provided by the HSE who are responsible for regulating dose from direct radiation to the public (see Table A7.1).

The methodology may be summarised in four steps;

1) Starting with the first pathway, individuals are selected from the habit data based on the 'cut-off' method whereby all those who have habits within a factor of three of the maximum observed for the pathway are selected as members of the potential critical group for that pathway (Hunt *et al*., 1982; Preston *et al*., 1974).

2) Habit profiles for a particular pathway (for example fish consumers) are calculated for adults by averaging the habit data selected by the cut-off method. The profile includes averages of all the other habits identified in the integrated habit survey. Habit profiles for children and infants are derived from the adult profiles using scaling factors.

3) Steps 1) and 2) are repeated for each pathway, thereby deriving a profile for each pathway and a series of potential critical groups.

4) Once all pathway profiles have been determined, doses are calculated for each profile using the environmental and food data. Doses from direct radiation are included via those profiled groups who spend time near to the nuclear site (Stephen, 2006). The group with the highest dose near each site becomes the critical group.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2005 data are given in files on the CD accompanying this report. Care should be taken in using these data in other circumstances because the profiles leading to the highest doses may change if the measured or forecast concentrations and dose rates change. Doses are calculated for each potential critical group using the same concentration and dose rate information used in the routine assessments earlier in this report. Pathways related to gaseous discharges, which are not included in the routine monitoring programmes (in particular inhalation and plume shine), were assessed using dispersion modelling within the PC CREAM assessment code (Mayall *et al*., 1997). A similar approach is used for the routine assessments and is described in Appendix 2.

Table A7.1. Individual radiation exposures - direct radiation pathway, 2005

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.080
Sellafield	0.0038[b]
Springfields	<0.030
Research establishments	
Dounreay	<0.010
Harwell	0.022
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	0.089
Bradwell	<0.067
Chapelcross	Bgd[a,c]
Dungeness	0.54
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	<0.0021
Hunterston	0.083
Oldbury	<0.0049
Sizewell	<0.026
Torness	<0.020
Trawsfynydd	0.019
Wylfa	0.0086
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Radiochemical production	
Amersham	0.24
Cardiff (Amersham plc)	Bgd[a]
Industrial and landfill sites	
Drigg	0.084

[a] *Doses not significantly different from natural background*
[b] *Sum of doses to Sellafield (0.002mSv) and Windscale (0.0018mSv)*
[c] *2004 data used due to unavailability of 2005 data*

7.4 Results of the assessment of total dose

The results of the assessment are summarized in Table A7.2 for each site. The data are presented in three parts. The group receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in the upper half of the tables, part A; those for liquid discharges in the middle part, part B. Occasionally the group receiving the highest dose from all pathways is different from that in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented.

In all cases, doses estimated for 2005 were less than the limit of 1mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most important groups for liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose was at Sellafield though 46% was due to the legacy of discharges of naturally occurring radionuclides from a phosphate processing works in Whitehaven. These broad results and the numerical values of dose are similar to those found in routine assessments earlier in this report, taking into account the additional effect of direct radiation where it is prominent.

Table A7.2. Individual radiation exposures integrated across pathways, 2005

Site	Critical group[a]	Exposure, mSv Total	Dominant contributions[b]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1 y	<0.005	Milk, ^{3}H, ^{137}Cs, ^{234}U
Amersham	Local adult inhabitants (0 - 0.25km)	0.24	Direct radiation
Cardiff	Milk consumers aged 1 y	<0.005	Milk, ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{125}I, ^{137}Cs
Chapelcross	Milk consumers aged 1 y	0.023	Milk, ^{3}H, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Adult green vegetable consumers	<0.005	Domestic fruit, green vegetables, root vegetables, ^{137}Cs
Dounreay	Adult domestic fruit consumers	0.043	Domestic fruit, green vegetables, potatoes, ^{129}I
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Hunterston	Prenatal children of mushroom consumers	0.090	Direct radation
Rosyth	-	-	
Sellafield	Milk consumers aged 1 y	0.019	Milk, ^{60}Co, ^{90}Sr, ^{134}Cs
Sizewell	Prenatal children of wild fruit and nut consumers	0.086	Direct radiation, plume related pathways
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.021	Direct radiation
Winfrith	Adult green vegetable consumers	<0.005	Domestic fruit, honey, milk, green vegetables, potatoes, ^{14}C, ^{137}Cs
Wylfa	Local adult inhabitants (0 - 0.25km)	0.010	Direct radiation
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose rate from riverbank
Amersham	Adult occupants over sediment	<0.005	Gamma dose rate over sand/stone
Cardiff	Prenatal children of fish consumers	0.023	Fish, ^{3}H
Chapelcross	Adult occupants over sediment	0.012	Gamma dose rate over sand/mud
Devonport	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Dounreay	'Other' vegetable consumers aged 1 y	0.028	Domestic fruit, green vegetables, potatoes, ^{129}I
Dungeness	Adult occupants over sediment	0.007	Gamma dose rate over sediment
Hartlepool	Prenatal children of mollusc consumers	<0.005	Direct radiation, mollusca, ^{14}C
Hunterston	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield	Adult mollusc consumers[c]	0.41	Mollusca, ^{210}Po, ^{241}Am
Sizewell	Adult occupants over sediment	0.012	Direct radiation, gamma dose rate over sediment, plume related pathways
Trawsfynydd	Adult occupants over sediment	0.008	Gamma dose rate over sand/stone, direct radiation
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult occupants over sediment	<0.005	Gamma dose rate over sediment, direct radiation
C Combined releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose rate from riverbank
Amersham	Local adult inhabitants (0 - 0.25km)	0.24	Direct radiation
Cardiff	Prenatal children of fish consumers	0.023	Fish, ^{3}H
Chapelcross	Milk consumers aged 1 y	0.023	Milk, ^{3}H, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Dounreay	Adult domestic fruit consumers	0.043	Domestic fruit, green vegetables, potatoes, ^{129}I
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Hunterston	Prenatal children of mushroom consumers	0.090	Direct radiation
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield	Adult mollusc consumers[c]	0.41	Mollusca, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of wild fruit and nut consumers	0.086	Direct radiation, plume related pathways
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.021	Direct radiation
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Local adult inhabitants (0.25 - 0.5km)	0.010	Direct radiation

[a] *Selected on the basis of providing the highest dose from the pathways associated with the sources as defined in A, B or C*
[b] *Pathways and radionuclides that contribute more than 10% of the total dose. Some radionuclides are reported as being at the limits of detection*
[c] *The doses from man-made and naturally occurring radionuclides were 0.22 and 0.19 mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven*

APPENDIX 8. CONCENTRATIONS OF RADIONUCLIDES IN SEDIMENT FROM CUMBRIA, 2005

In the UK, Defra, Department of the Environment for Northern Ireland, Scottish Executive and National Assembly for Wales issue licences to operators for the disposal of dredge material under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom - Parliament, 1985). The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant foodchain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA has published a system of assessment which can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003). This has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2005, specific assessments of the disposal of dredge material from Maryport and Silloth were carried out. At both locations, the harbour sediments contain artificial radionuclides due to discharges from BNFL Sellafield and from other widespread sources such as weapon test fallout. Samples of the material were taken and analysed and the results are given in Table A8.1. The assessments showed that the impact of the radioactivity associated with the disposal operation was very low and exposures were below 0.010 mSv.

Table A8.1. Concentrations of radionuclides in sediment from Cumbria, 2005

	Location Radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb) (1)	^{232}Th (via ^{228}Ac) (1)	^{238}U (via ^{234}Th) (1)	^{241}Am
Maryport Harbour						
Senhouse Dock	28	561	27	35	58	930
Elizabeth Dock Approach	18	385	21	25	48	572
Elizabeth Dock	37	930	27	33	47	882
Silloth						
A	9.4	661	23	33	49	581
B	9.9	531	23	24	49	508

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

Appendices