RIFE - 14

Radioactivity in Food and the Environment, 2008

Environment Agency

FOOD STANDARDS AGENCY

NIEA Northern Ireland Environment Agency
www.ni-environment.gov.uk

SEPA Scottish Environment Protection Agency

2009

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SCOTTISH ENVIRONMENT PROTECTION AGENCY

Radioactivity in Food and the Environment, 2008

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November 2009

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Preface

The Environment Agency, the Food Standards Agency, the Northern Ireland Environment Agency and the Scottish Environment Protection Agency (SEPA) work together on the radiological monitoring of food and the environment. Their monitoring programmes are independent of and used as a check on the site operators' monitoring programmes. The Food Standards Agency is responsible for food safety in the UK whilst the Environment Agency, the Northern Ireland Environment Agency and SEPA (together referred to as the 'environment agencies' in this report), are responsible for environmental protection and regulation in England and Wales, Northern Ireland and Scotland, respectively.

Our report gives a detailed assessment of radioactivity in food and the environment in the UK and the public's exposure to radiation during 2008. Radioactivity in the environment comes from several sources, including natural radiation, residues from the Chernobyl accident and atmospheric testing, plus radioactive discharges and emissions from nuclear and non-nuclear sites (authorised premises). The report focuses on key information that shows that food is safe and the public's exposure to ionising radiation around the 39 nuclear sites around the UK is within legal limits.

At many sites, radionuclide concentrations were low and, in some cases so low, they could not be detected with the methods used. These low concentrations continue to decrease at many sites as a result of changes in discharges to the environment. For example, concentrations of tritium in seafood around Cardiff continued to fall in 2008 from the highest levels seen in 2001. This is as a result of reductions in discharges of tritium in liquid wastes that concentrate in the environment. Having previously met the target set in the UK National Discharges Strategy for 2006, discharges of technetium-99 from Sellafield were again reduced.

This year the UK Government, in conjunction with the Devolved Administrations, has published its revised UK Strategy for Radioactive Discharges. The scope of the strategy is now wider and includes aerial as well as liquid discharges from both decommissioning and operational activities and from the non-nuclear as well as the nuclear industry. It also provides a framework for discharge reductions across sectors and describes how the UK will implement the agreements of the OSPAR Convention. The revised discharges strategy shows the progress that has been made in reducing emissions since the original strategy was published in 2002 and describes sectoral outcomes which are expected to be achieved by 2020 and 2030. Regulators and the nuclear and non-nuclear industry will now consider the revised Strategy when they take operational decisions.

As older power stations have closed down and treatment plants opened, this has had an effect on reducing radionuclide discharges and levels in the environment. Before 2008, nine of the eleven Magnox power stations (the first generation of nuclear power stations in the UK) had been permanently closed. This left Oldbury and Wylfa of the Magnox reactors and the eight British Energy nuclear power stations operating at the start of 2008. In late 2006 Dungeness A and Sizewell A were closed.

At certain sites the environment agencies and the Food Standards Agency undertook or required sites to undertake detailed investigations. For instance, monitoring and removal of particles containing radioactivity has continued on beaches around Dounreay, Chapelcross and Dalgety Bay in Scotland. Seabed investigations have also taken place in the Dounreay area. The Food Standards Agency has recently published a review of the Food and Environment Protection Act (FEPA) Order at Dounreay, which has been in place since 1997. This concluded that the Order should remain in place to facilitate the remediation of the area. At Sellafield in England, the Environment Agency has also required the site to monitor for particles containing enhanced levels of radioactivity. The site is also preparing to investigate particle distributions offshore from Sellafield in 2010. Particles found to date on beaches at Sellafield have been removed and analysed. The Health Protection Agency will undertake a detailed assessment of the risks from the particles found so far around Sellafield in 2010. This assessment will provide more advice on any risks that these particles might present to the public. The findings of this assessment will be covered in a future edition of this report.

This report summarises the results from several large-scale radiological monitoring programmes run by the UK Government and Devolved Administrations. The results clearly show that discharges from nuclear licensed sites do not pose a significant risk to public health and that all doses are within legal limits.

Technical summary

We have divided the technical summary into sections to highlight the main topics within the report. These 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 exposure to radiation from sediments, etc.
- Site incidents and non-routine surveys
- Radiation exposures and radioactivity concentrations at other UK locations not associated with nuclear sites

Radiation exposure around nuclear sites

This report uses the results of monitoring of radioactivity in food and the environment near nuclear sites to make an assessment of doses to the public. Monitoring results are supplemented by modelling when appropriate. The assessments use radionuclide concentrations, dose rates and information on the habits of people living near the sites. Changes in doses occur from year to year. The changes are mostly caused by variations in radionuclide concentrations and dose rates. However, in some years doses are affected by changes in people's habits, in particular the food they eat, shown in habits surveys.

Figure S.1 and Table S.1 show the assessed doses due to the effects of waste discharges for those groups most exposed to radiation near all major nuclear licensed sites in the UK. In 2008, radiation doses to adults and children living around nuclear sites remained well below the national and European limit, which is 1 millisievert (mSv, a measure of dose) per year.

A group of people in Cumbria that consumed a large amount of fish and shellfish received the highest dose of radiation due to discharges. Their dose was estimated to be 0.62 mSv in 2008. This was due to the effects of current and past liquid discharges from Sellafield and from past liquid discharges from a phosphate processing plant at Whitehaven. Sellafield discharges were estimated to have contributed 0.23 mSv to this dose in 2008, similar to the contribution to dose in 2007 of 0.24 mSv (this contribution includes a dose from external radiation). Most of the dose at Sellafield was due to the accumulation of caesium-137, plutonium isotopes and americium-241 in seafood and the environment from past liquid discharges. Doses from technetium-99 have been falling for several years as a result of decreasing discharges from Sellafield. In 2008, technetium-99 in seafood contributed 0.003mSv (about 1 per cent) to the 0.23 mSv dose, a reduction from 0.004 mSv (about 2 per cent) of 0.24 mSv in 2007.

Most liquid radioactive discharges from Sellafield have fallen in recent years. Concentrations of some radionuclides in fish and shellfish have also reduced or are largely unchanged. Some people in the area have consumed more fish and shellfish since 2000, which has led to an increase in doses, but this trend was not seen in 2008.

As well as the radiation from Sellafield discharges, the people who consumed seafood also received 0.39 mSv from the legacy of past discharges from a phosphate processing works at Whitehaven. This was a practice that generated what is sometimes known as 'technologically enhanced naturally-occurring radioactive material' (TNORM). Where discharges of TNORM occur this can lead to an increase in the concentration of naturally occurring radionuclides. Near the closed plant at Whitehaven, levels have fallen in recent years so it is difficult to distinguish the increases from the range of normal concentrations expected from natural sources. However, using an approach based on average concentrations of natural sources, small increases of some radionuclides are observed. The dose increased from 0.28 mSv in 2007 to 0.39 mSv in 2008. This was due to small increases in polonium-210 concentrations in seafood, which may partly be caused by normal variations in radionuclide levels, but also by the decay of radium-226 and lead-210 in past discharges that produce polonium-210. Altogether, the group who consumed the seafood received a dose from radiation exposure of 0.62 mSv in 2008, which is well within the EU and UK limit for members of the public of 1 mSv per year. Doses to people who had consumed crops grown on land fertilised by seaweed from around Sellafield were also assessed. Their estimated dose for 2008 was 0.009 mSv (0.012 mSv in 2007). Doses to people using the local beaches and other intertidal areas were less than 0.046 mSv. Doses due to gaseous discharges from Sellafield were much lower than those from liquid discharges, at 0.027 mSv in 2008, and similar to the dose of 0.023 mSv in 2007. The majority of this dose was from consumption of milk. This assessment of dose from gaseous discharges was supplemented by modelling air concentrations.

In terms of radiation exposure from waste discharges, the second group of people most affected were those living on houseboats in the Ribble Estuary. In 2008, their dose was 0.13 mSv. Most of this exposure was due to external dose from radionuclides from Sellafield in intertidal sediments. Their dose in 2007 was 0.073 mSv. The increase in 2008 was largely due to increases in gamma dose rates in the estuary.

The next group most affected in terms of exposure to radiation from waste discharges were those people on the Dumfries and Galloway coast who consumed seafood. It was estimated

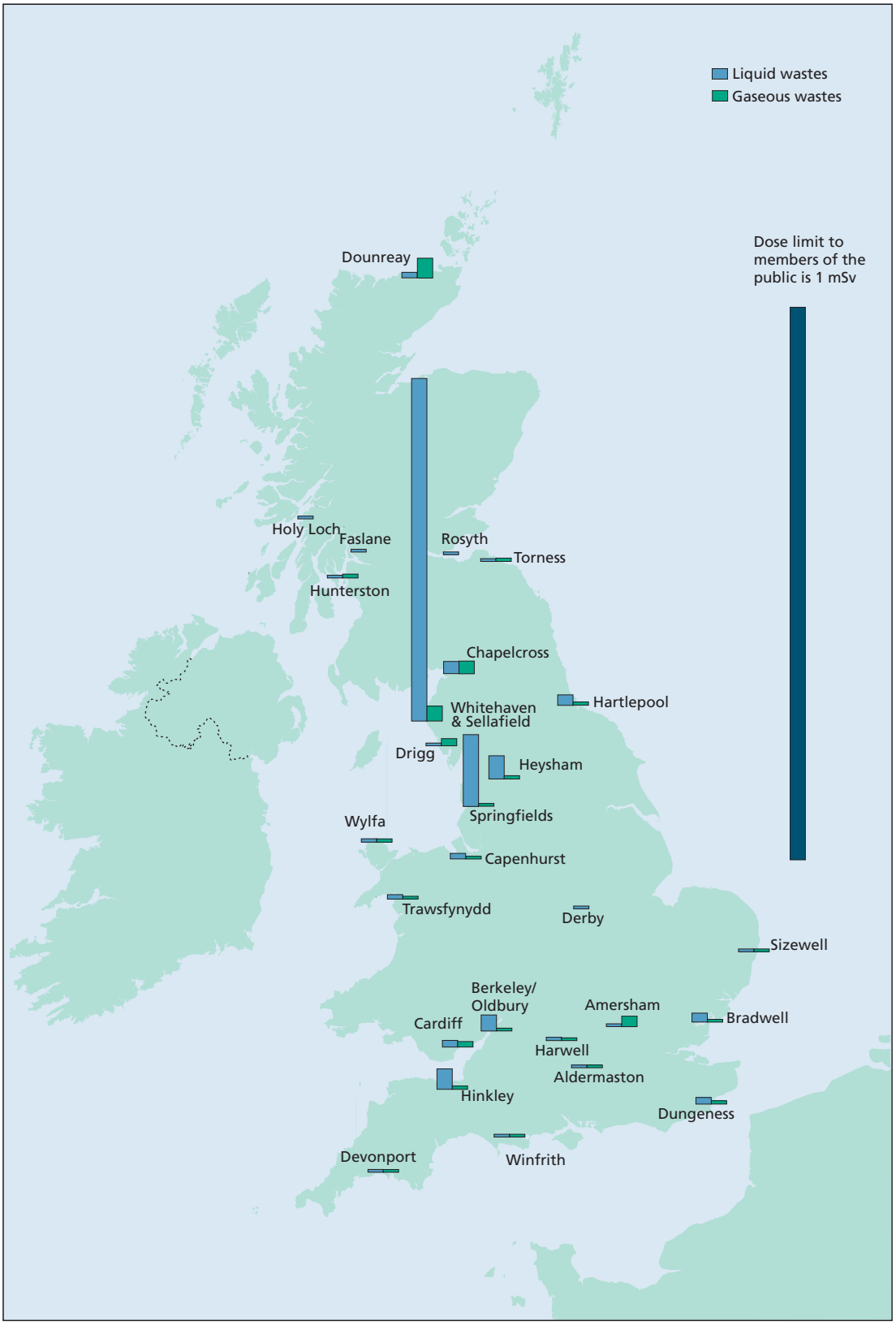


Figure S1. Radiation exposures in the UK due to radioactive waste disharges, 2008 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S1. Radiation doses due to discharges of radioactive waste in the United Kingdom, 2008

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	0.010	Ext
	Terrestrial foods[i]	G	<0.005	^{234}U
Springfields	External (skin) to fishermen	L	0.066[f]	Beta
	Fish and shellfish consumption	L	0.017	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site	G	<0.005[h]	^{14}C
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{230}Th
	Occupancy of houseboats	L	0.13	Ext
	External in intertidal areas (farmers and wildfowlers)	L	0.033	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2004-2008 surveys) (excluding naturally occurring radionuclides)[k]	L	0.23	$^{239/240}$Pu ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2004-2008 surveys) (including naturally occurring radionuclides)[l]	L	0.62	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2008 surveys) (excluding naturally occurring radionuclides)[k]	L	0.23	$^{239/240}$Pu ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.027	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.014	^{90}Sr
	External in intertidal areas (Ravenglass)[a]	L	0.046	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)	L	0.13	Ext
	External (skin) to bait diggers	L	0.026[f]	Beta
	Handling of fishing gear	L	0.049[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield	L	0.009	^{99}Tc
Research establishments				
Culham	Water consumption[n]	L	<0.005	
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ^{241}Am
	Terrestrial foods	G	0.036	^{90}Sr ^{137}Cs
Harwell	Fish consumption and external to anglers	L	0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{3}H ^{222}Rn
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.029	Ext ^{137}Cs
	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	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{3}H ^{14}C
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.022	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.023	^{14}C
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext ^{241}Am
	Occupancy of houseboats	L	0.012	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{137}Cs
Hartlepool	External in intertidal areas	L	0.019	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.042	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{14}C
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.037	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{14}C
Hunterston	Fish and shellfish consumption	L	0.005	^{241}Am Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.007	^{35}S ^{90}Sr
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{35}S ^{137}Cs

Summary Table S1. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear power production *continued*				
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{110m}Ag ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{35}S ^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.008	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.006	Ext ^{14}C
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{14}C ^{35}S
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005[h]	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005[h]	^{137}Cs
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, external and inhalation near site[o]	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{134}Cs
Holy Loch	External in intertidal areas	L	<0.005	Ext
Rosyth	Fish and shellfish consumption	L	<0.005	
	Shellfish consumption and external in intertidal areas	L	<0.005	Ext
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.019	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[o]	L	0.012	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.010	^{14}C
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	
Industrial and landfill				
Drigg	Terrestrial foods[i]	G	0.013	^{90}Sr
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.39	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.62	^{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 Appendix 1). 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 Appendix 1)*
[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*

that they received 0.047 mSv in 2008, a decrease from 0.060 mSv in 2007. Most of this dose was due to americium-241 and plutonium in shellfish, originating from Sellafield. This was the group most exposed to the effects of Sellafield discharges in Scotland.

Relatively high concentrations of tritium have previously been found in food and the environment near GE Healthcare at Cardiff, where radiochemicals for life sciences are produced. In 2008, the most exposed group, with an estimated dose of 0.012 mSv, were unborn children of women who had eaten seafood. Their dose in 2007 was 0.014 mSv. The dose was due to eating fish from the Severn Estuary that contained tritium and carbon-14, and also due to external radiation (0.006 mSv) that is not derived from operations at the Maynard Centre. The dose to adults was similar to that of unborn children at 0.010 mSv. Doses at this site have been steadily falling since 2000 in line with lower discharges.

The dose estimates above apply to discharges from nuclear and other sites. The public is also exposed to another source of radiation near some of these facilities. This is radiation that comes directly from operations on the sites and is known as 'direct radiation' or 'direct shine'. This source of exposure has been significant around some of the Magnox power stations when they are operating. The Health and Safety Executive (the regulatory authority) has provided estimates of direct radiation doses at sites in the UK, using information from the site operators.

In 2003, a method of assessing the total dose to the public from radiation around the UK's nuclear sites was introduced. This included an estimate of exposure from direct radiation. In 2008, *total doses* to the public were assessed at 24 nuclear site locations. The results are shown in Figure S.2 and Table S.2. In 2008, the *total doses* at these sites were all less than the annual EU and UK limit of 1 mSv, with direct radiation doses at Dungeness A and Sizewell A much lower than before closure of the site at the end of 2006.

Habits surveys near nuclear sites

In 2008, the regular programmes of habits surveys around nuclear sites continued. These give site-specific information on diets and occupancy habits of people near nuclear sites. In 2008, surveys were carried out at Capenhurst, Hartlepool and Sellafield in England, and at Dounreay in Scotland. The findings were used to strengthen and update monitoring programmes and to improve the assessment of doses to members of the public near nuclear sites.

Radioactivity concentrations in samples collected around nuclear sites

This section summarises any changes in concentrations of radioactivity in food or the environment, given in becquerels per kilogramme (Bq kg^{-1}) or becquerels per litre (Bq l^{-1}).

A revised UK Radioactive Discharge Strategy was published in 2009, extending and strengthening the scope of the earlier one published in 2002. Both describe how the UK will implement the agreements of the meetings of the Oslo and Paris Convention (OSPAR) on radioactive discharges to the North-East Atlantic marine area, overseen by the OSPAR Commission. One of the aims of the UK strategy is to progressively and substantially reduce the amount of liquid radioactive discharges and the associated regulatory 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 the future. In 2008, the Environment Agency and the Scottish Environment Protection Agency (SEPA) issued new authorisations, with strengthened conditions and reduced limits on disposing of radioactive waste, for 10 sites (Aldermaston, Amersham, Barrow, Capenhurst, Derby, Drigg, Rosyth, Sellafield, Windscale and Winfrith).

Reductions in discharges, either by reducing discharge limits or through initiatives taken by the operator, can reduce concentrations in food and environmental samples near the site. Discharges from GE Healthcare at Cardiff have continued to fall over the past decade. This has led to a downward trend in concentrations of tritium in fish and molluscs. Similarly, lower discharges of technetium-99 from Sellafield have meant a fall in technetium-99 in local food and the environment since the peaks seen in 1997. There were no major variations in concentrations of radioactivity in 2008 compared to those in 2007.

In 2008, the highest concentration of tritium in seafood from near Cardiff was 3,800 Bq kg^{-1} in sole, an increase from 2,400 Bq kg^{-1} in 2007. However, the levels in other seafoods decreased or remained the same as 2007 levels. The 2008 concentrations were less than 10 per cent of the levels seen in 2000, when tritium concentrations in flounder were 54,000 Bq kg^{-1}. Tritium concentrations in seafood at some other coastal locations around the UK ranged up to 140 Bq kg^{-1}, which is above the expected background tritium concentration of 1 Bq kg^{-1}. The increase was due to discharges of tritium but with a relatively small proportion accumulating as organically bound tritium. The degree of this bioaccumulation was of little significance and much lower than the concentrations found near Cardiff.

During 2008, discharges of technetium-99 from Sellafield continued at the lower level seen since new abatement technology was successfully introduced. Discharges are expected to remain low in the future. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and in the North Sea. Concentrations of technetium-99 have shown a continued reduction from their most recent peak in 2003, with a further decrease in 2008 compared with 2007. Technetium-99 has been found in seaweed, and our monitoring has shown a small-scale transfer of technetium-99 from sea to land when seaweed was used as a soil conditioner.

Marine sediment samples are a useful indicator of trends in the environment. People who spend time on beaches can be exposed to radiation through the radionuclide content of the sediments. Near Sellafield, the environmental concentrations

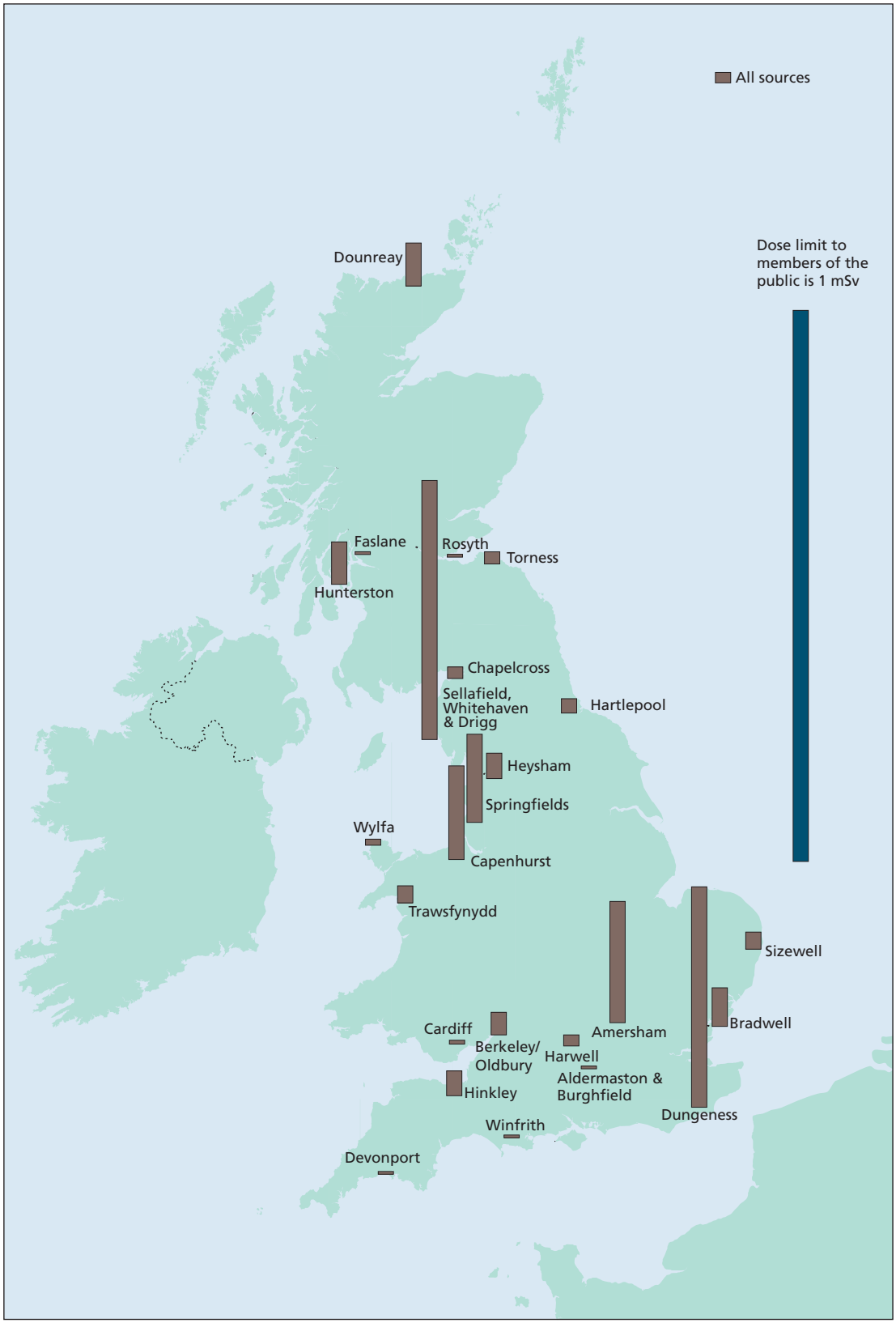


Figure S2. Total radiation exposures in the UK due to radioactive waste disharges and direct radiation, 2008 (Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S2. Radiation doses due to all sources at major UK sites, 2008[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.17	Direct radiation
Springfields	0.16	Gamma dose rate over sediment
Sellafield[d]	0.47	Molluscs, ^{210}Po, ^{241}Am
Research establishments		
Dounreay	0.078	Game meat, ^{137}Cs
Harwell	0.020	Direct radiation
Winfrith	<0.005	Gamma dose rate over sediment
Nuclear power stations		
Berkeley and Oldbury	0.041	Direct radiation
Bradwell	0.070	Direct radiation
Chapelcross	0.021	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Dungeness	0.40	Direct radiation
Hartlepool	0.026	Direct radiation, gamma dose rate over sediment
Heysham	0.046	Gamma dose rate over sediment
Hinkley Point	0.045	Gamma dose rate over sediment
Hunterston	0.077	Direct radiation
Sizewell	0.031	Direct radiation
Torness	0.022	Direct radiation
Trawsfynydd	0.031	Direct radiation
Wylfa	0.011	Direct radiation
Defence establishment		
Aldermaston and Burghfield	<0.005	Gamma dose rate over sand
Derby	Not assessed by this method	
Devonport	<0.005	Gamma dose rate over sediment
Faslane	<0.005	Gamma dose rate over mud, fish, ^{134}Cs
Holy Loch	Not assessed by this method	
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.007	Gamma dose rate over sediment, fish, ^{3}H
Industrial and landfill		
Drigg[d]	0.47	Molluscs, ^{210}Po, ^{241}Am
Whitehaven[d]	0.47	Molluscs, ^{210}Po, ^{241}Am

[a] *Includes the effects of waste discharges and direct radiation from the site. May also include the far-field effects of discharges of liquid waste from Sellafield*

[b] *Committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv*

[c] *Pathways and radionuclides that contribute more than 10% of the total dose. Some radionuclides are reported as being at the limits of detection*

[d] *The doses from man-made and naturally occurring radionuclides were 0.18 and 0.29 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the Drigg site into the same area*

of most radionuclides have declined substantially over the last 20 years. In recent years, concentrations of caesium-137, plutonium isotopes and americium-241 in some mud samples from the Ravenglass estuary near Sellafield have been gradually increasing, but this was not seen in 2008. These trends are unlikely to be associated with changes in discharges. Concentrations of americium-241 will have increased due to radioactive 'in-growth' from the decay of the parent radionuclide plutonium-241 in the environment. Higher activity concentrations can occur in sediments as a result of their containing radioactivity from discharges in earlier decades and then being remobilised, or due to the differences in their particle size. The changes are small and are not seen in fish and shellfish samples from Cumbria.

Dose rates from around nuclear sites

Sediments in intertidal areas can make a significant contribution to the total exposure of members of the public. For this reason, external doses are recorded by measuring dose rates. These 'external doses' are included in the assessment of doses to the public where they are higher than background levels.

There were no major changes in external dose rates in intertidal areas in 2008 compared with 2007. At most locations, the external dose rates were close to background levels. Levels were higher in some estuaries near Sellafield (up to twice the background rate) and in the Ribble Estuary. Some modest increases in dose rates were seen in the Ribble Estuary between 2007 and 2008 and these had an effect on the doses received by the critical group.

Nuclear site incidents and non-routine surveys

During 2008, as a result of an ongoing programme of monitoring radioactive items were detected on beaches on the Cumbrian coastline, where 302 particles and contaminated pebbles/stones from Sellafield were removed.

At Chapelcross three particles were removed, whilst further fragments of irradiated nuclear fuel (particles) were recovered near Dounreay, where fishing restrictions under the Food and Environment Protection Act 1985 are still in force. In all of these cases, the risks posed by these particles were negligible.

'Special' (or *ad hoc*) sampling was needed on five other occasions. This was because of concerns about site operations or because of higher than normal discharges that triggered reporting procedures. These were at Chapelcross, Devonport, twice at Sellafield and at Wylfa. The incident at Devonport involved an unauthorised release of liquid radioactive waste into the Tamar Estuary. This occurred after a hose transferring reactor coolant from HMS *Trafalgar* to a shoreside tank was ruptured, releasing liquid contaminated with tritium and cobalt-60. Although the maximum amount of these radionuclides that could have been discharged was very small, additional sampling was carried out by both the Environment Agency and Food Standards Agency for confirmation. There was no increase in levels of these radionuclides in the environment or seafood.

In Scotland, samples of water from the reactor basement at Chapelcross were taken to check the level of tritium in the waste determined by the operator, which underpinned SEPA's agreement for disposals to sea outwith the tidal window specified in the authorisation. As relatively low levels of activity in the water were confirmed, the discharge was allowed to continue.

In 2008, the diets and living habits of people near nuclear sites at Capenhurst, Dounreay, Hartlepool and Sellafield were surveyed. The findings were used to strengthen and update radiological assessments of the results of the monitoring programmes.

Radiation doses and levels at other locations in the UK

Food and drinking water in people's general diet and sources of public drinking water were analysed across the United Kingdom. Results showed that the general population was mostly exposed to radioactivity from natural sources. Man-made radionuclides only contributed a small proportion of the total public radiation dose in people's general diet.

Monitoring artificial radioactivity on the Isle of Man and in Northern Ireland showed that consumer doses were all less than 2 per cent of the annual limit of 1 mSv for members of the public. 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 per cent of the limit.

In the past discharges were made as liquid slurry containing thorium and uranium into the Irish Sea from a phosphate plant near Whitehaven. This site stopped operating at the end of 2001 and the plant has subsequently been demolished. Concentrations of naturally-occurring radionuclides in fish and shellfish near Whitehaven have been found to be higher than the maximum of the expected ranges due to natural sources. Levels of natural radionuclides have declined in the last 10 years so that in 2008 the levels are very close to natural background, making any increase due to the past discharges difficult to determine. Estimates of the concentrations of naturally-occurring radionuclides in seafood caused by past discharges from the site have been made by subtracting the expected natural concentration of these radionuclides in UK seafood from the measured levels. Polonium-210, which is naturally-occurring, is present in some seafood samples at slightly above background levels. People in the Sellafield area that consume large amounts of seafood were estimated to receive a dose of 0.39 mSv, mostly from polonium-210.

SEPA carried out monitoring at Dalgety Bay in Fife to assess the impact of radium contamination in the intertidal area. The objective of this monitoring was to characterise the

contamination and obtain data to enable a determination, in accordance with the Scottish Government's Statutory Guidance on the Radioactive Contaminated Land (Scotland) Regulations 2007. SEPA concluded at this stage that while some of the dose estimates were above the criteria set out in the Guidance, there remained sufficient uncertainty, especially in the assessment of skin dose, such that a determination could not be made. In addition it was also noted at that time that the wording of the Regulations (which have since been amended) excluded radon and its decay daughters from the scope of the assessment and so contributions from polonium-210 and lead-210 could not be included. A copy of the assessment is available from SEPA's website:

(http://www.sepa.org.uk/radioactive_substances/publications/dalgety_bay_reports.aspx)

At the end of May 2009, regulations were laid before the Scottish Parliament to amend the Radioactive Contaminated Land (Scotland) Regulations 2007. The changes removed the exclusion of radon and its daughters. Revised Statutory Guidance has also been prepared. However, it will not come into effect until the Parliament returns after the summer recess. During this time Defence Estates (an executive agency of the Ministry of Defence) have been undertaking a series of investigations into particle repopulation rates on the intertidal areas of Dalgety Bay. SEPA will review the results of the Defence Estates work in the light of the amended regulations and guidance.

Food imported into the UK may contain radioactive contamination. A monitoring system is in place to detect radioactivity in consignments. In 2008, the Food Standards Agency analysed samples of fruit products that had been imported into Dover and Felixstowe. The maximum concentration found was 550 Bq kg^{-1} (fresh weight) caesium-137. By law the concentration in the final food product has to be compared with the maximum level permissible under EC Regulations, which is 600 Bq kg^{-1}. In this case, the fruit products were below the maximum. As a result, UK authorities did not need to take any further action.

Concentrations of tritium were found in leachate from some landfill sites, but only at levels that were of very low radiological significance. There are several disposal routes for radioactive waste to landfill that could contain tritium. These are from hospitals, industrial sites and due to past disposals of gaseous tritium light devices, such as fire exit signs and other similar items.

The environmental effects of the Chernobyl accident continued to be monitored in 2008. There are still restrictions on moving, selling and slaughtering sheep in some upland areas of the UK. The effects were limited to 373 farms in 2008, compared with 9,700 farms in 1986, when the accident happened.

The distribution of radionuclides in coastal seas away from nuclear sites continues to be monitored. 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 of the UK's coastal seas. These surveys, together with the results of monitoring at nuclear sites, form essential evidence 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 to measure progress towards the UK Government's targets for improving the state of the marine environment.

Disposal of dredge spoil from harbours and other areas is licensed under the Food and Environment Protection Act, 1985. In 2008, the Department for Environment, Food and Rural Affairs (Defra) considered a proposal for the disposal of sediment from Lancaster in Lancashire. Samples of the dredge spoil were analysed for radioactivity and an assessment of potential radiation doses was made. Doses to members of the public were all less than the International Atomic Energy Agency (IAEA) *de minimis* criterion of 0.010 mSv per year, and a licence was issued.

The monitoring programmes and further research

The monitoring programmes in this report involved six specialist laboratories working together, 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 Food Standards Agency, the Northern Ireland Environment Agency, and SEPA (the agencies) and they are independent of the industries discharging radioactive effluents. The programmes include monitoring on behalf of the Scottish Government (formerly known as the Scottish Executive), Channel Island States, the Department for Environment, Food and Rural Affairs, the Manx Government and the Welsh Assembly Government. Overall, around 16,000 analyses and dose rate measurements were completed in 2008.

The results of the analysis of food samples collected near nuclear sites in England and Wales are published quarterly on the Food Standards Agency's website (www.food.gov.uk). More information about all programmes described in this report is available from the sponsoring agencies. Their contact details can be found on the back cover of this report.

The routine monitoring programmes were supported by a number of research studies, investigating specific issues such as the potential for transfer of radionuclides from sea to land. Results of the completed studies are used to improve the radiological assessment of monitoring data. The agencies are also funding work to improve the methods for estimating public exposure.

1. Introduction

1.1 Background

1.1.1 Purpose and scope of the monitoring programmes

This report gives the results of programmes that monitored food and environmental materials for radioactivity in the UK during 2008. In England and Wales, the Food Standards Agency conducts food monitoring, whilst the Environment Agency carries out environmental and dose rate monitoring. In Scotland, the Scottish Environment Protection Agency (SEPA) carries out food and environmental monitoring, working closely with the Food Standards Agency on its programme, and in Northern Ireland this is carried out by the Northern Ireland Environment Agency. The Food Standards Agency continues to monitor some upland areas in England, Wales and Scotland for caesium-137, arising from the 1986 Chernobyl accident. Drinking water, air and rain are monitored on behalf of the Department for Environment, Food and Rural Affairs (Defra) and the Scottish Government. The Food Standards Agency and SEPA also carry out nationwide monitoring of whole diet, milk and crops that are not near nuclear sites. The marine environment of the whole of the British Isles away from nuclear sites is monitored for Defra.

The Food Standards Agency is responsible for food safety throughout the UK (under the Food Standards Act 1999). The Environment Agency, the Northern Ireland Environment Agency and SEPA, referred to together as the environment agencies in this report, are responsible for environmental protection in England and Wales, Northern Ireland and Scotland, respectively. The environment agencies are regulators of radioactive waste disposal under the Radioactive Substances Act 1993 (United Kingdom – Parliament, 1993). The Environment Agency and SEPA also have broader responsibilities (under the Environment Act 1995 (United Kingdom – Parliament, 1995a)) for protecting (and determining general concentrations of pollution in) the environment.

The monitoring programmes have several purposes. Ongoing monitoring helps to establish the long-term trends in concentrations of radioactivity over time and at distance from nuclear licensed sites. The results are also used to confirm the safety of the food chain. Monitoring the environment provides indicators of radionuclide dispersion around each site. Environmental and food results are used to assess dose to the public compared with the UK statutory dose limits. Most of the monitoring carried out and presented in this report concerns the local effects of discharges from nuclear licensed sites in the UK. Other work includes the Chernobyl monitoring, which provides the authorities with information on caesium-137 concentrations in affected areas and helps them decide whether restrictions are still needed. Monitoring of food and the environment remote from nuclear licensed sites is also carried out. This gives information on background concentrations of radionuclides.

Key points

- Report represents collaboration by regulatory bodies across the UK
- It is an independent assessment of radioactivity in food and the environment
- Provides a check on food safety and the public's exposure to radiation
- Monitoring programme results contribute to the UK meeting its international treaty obligations

The European Commission is reviewing how Article 35 of the Euratom Treaty is implemented by signature states, which includes the UK. Article 35 requires member states to facilitate monitoring for radioactivity. The Commission is required to verify the operation and efficiency of these facilities. The first stage of the review has begun (Hunt *et al.*, 2007). Member states have been asked to provide information on the scope of the facilities they use to monitor radioactivity. The Environment Agency and the Food Standards Agency have responded to this with a summary report covering monitoring in England and Wales (Rowe *et al.*, 2005).

An explanatory section giving details of methods of sampling and analysis and explaining how results are interpreted in terms of public radiation exposures is provided in Appendix 1 on the CD accompanying the main report.

The analytical science for the monitoring programmes was carried out by a number of UK laboratories, including those listed below. These laboratories also carried out most of the sample collection for the programmes.

- Centre for Environment, Fisheries and Aquaculture Science (Cefas)
- Health Protection Agency (HPA)
- LGC Ltd (formerly Laboratory of the Government Chemist)
- Scientifics Ltd (SL)
- Veterinary Laboratories Agency (VLA)
- Winfrith Environmental Level Laboratory (Amec NNC Ltd)

1.1.2 Dose assessments

The majority of the monitoring was carried out to check the effect of discharges from nuclear and non-nuclear operators on the environment. The results are also used to assess doses

to the public that can then be compared with the relevant dose limits. The dose assessments are retrospective in that they apply to 2008, using monitoring results for that year. The radioactivity concentrations and dose rates reported include the consequences of all past discharges made up to the time of sampling.

In this report, two main types of retrospective dose assessment are made. A retrospective dose assessment is one that considers effects from exposures that have already happened. One type is an assessment for groups of people (or a single representative person) near nuclear sites who may be affected by radioactivity in food and the environment from discharges of radioactive waste. The group that receives the highest dose near each site is considered to be the 'critical group' from past discharges.

The other type of assessment also includes exposure to direct radiation from nuclear sites. This gives an estimate of *total dose* to the critical group around the nuclear sites. Direct radiation can be significant close to operating power stations or close to where radioactive materials are stored. The regulation of direct radiation is the responsibility of the Health and Safety Executive (HSE). Nuclear site operators provide estimates of direct radiation doses to HSE which are made available for use in these assessments. The assessments also use recent habit survey data which has been profiled using an agreed method (Camplin *et al*., 2005).

The calculated doses can be compared with the dose limit for members of the public of 1 mSv per year. Dose assessments for exposure to skin are also made at some sites and compared with the relevant skin dose limit. The approaches used are for relatively widespread contamination in food and the environment where the probability of encounter/consumption is certain. These methods are not appropriate for exposure to small radioactive particles where the chance of encounter is a relevant factor to be considered (Dale *et al,*. 2008). All dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP) (International Commission on Radiological Protection, 1991).

An additional comparison can be made with doses from natural radioactivity. The UK average is 2.2 mSv per year, with a range across counties from 1.5 mSv per year to 7 mSv per year (Watson *et al*., 2005).

Collective doses are beyond the scope of this report. They are derived using modelling techniques. The European Commission has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for the gaseous and liquid waste disposals in the years 1997 to 2004 (Harvey *et al.*, 2008).

Radiation exposures to some specific groups of workers are included in the assessment of doses from nuclear sites. These are workers who may be exposed incidentally, but do not work specifically with ionising radiation. These include fishermen, farmers, sewage workers, nature wardens, etc. It is appropriate to compare their doses to the dose limit for members of the public (Allott, 2005). Doses to workers who are involved with ionising radiation and receive a dose from their work should be assessed as part of their employment.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

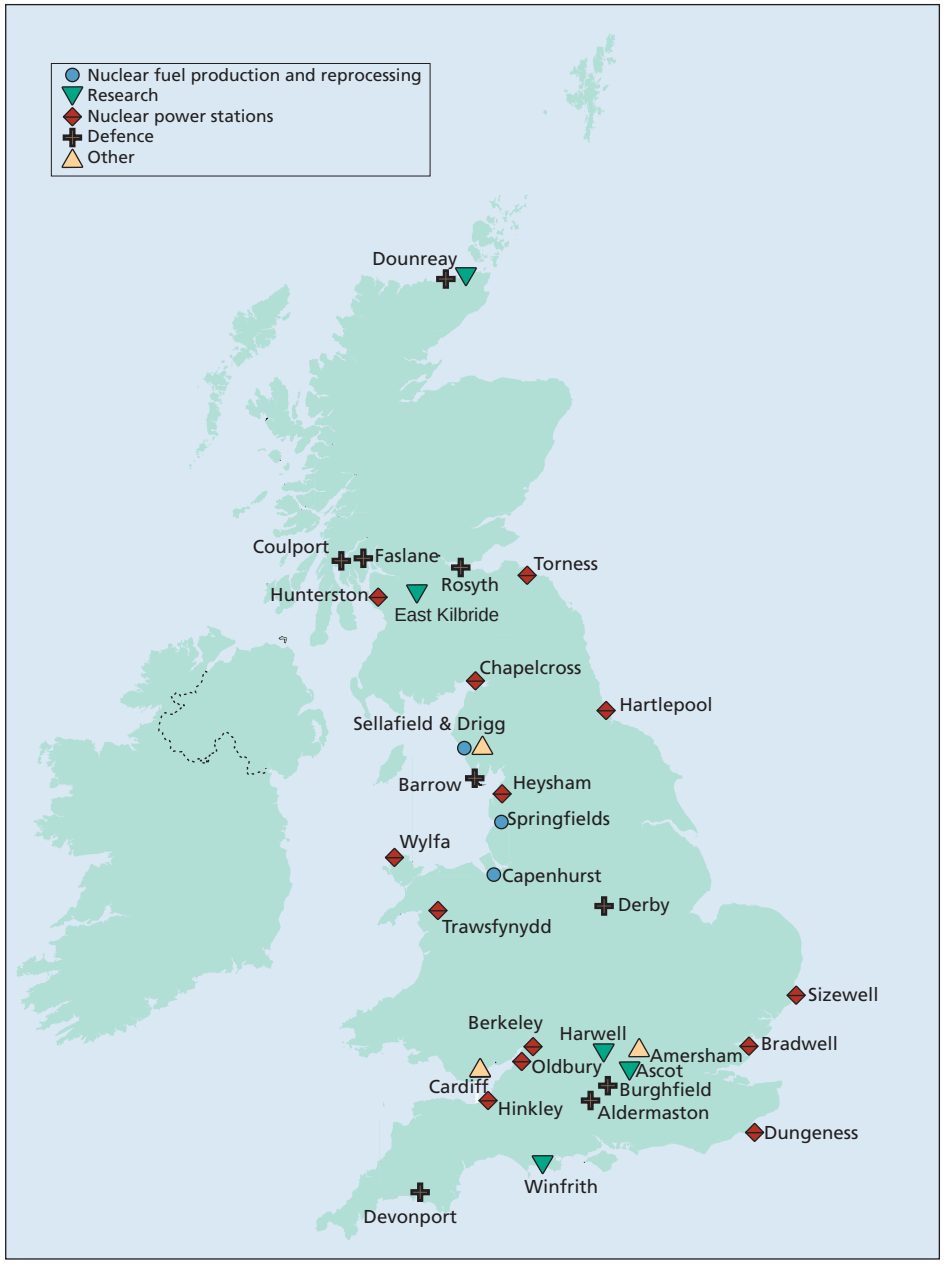
Nuclear sites in the UK discharge radioactive waste as liquid and/or gas as part of their operations. In addition, solid low level waste (LLW) from nuclear sites can be transferred to the low level waste repository (LLWR) near Drigg for disposal. There is also a solid LLW facility at Dounreay. These discharges and disposals are authorised by the environment agencies in the UK under the Radioactive Substances Act 1993 (RSA 93) (United Kingdom – Parliament, 1993).

Figure 1.1 shows the nuclear licensed sites that produce waste containing man-made radionuclides. Nuclear licensed sites are authorised to dispose of radioactive waste (United Kingdom – Parliament, 1993). They are also subject to the Nuclear Installations Act (United Kingdom – Parliament, 1965). The programmes reported here include monitoring at each of these sites. Discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also regulated 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, these programmes detect radioactivity in the environment as a result of these discharges. For example, iodine-131 from hospitals is occasionally detected in some marine samples. Small amounts of very low level solid radioactive waste are disposed of from some non-nuclear sites. There is also a significant radiological impact due to the legacy of past discharges of radionuclides from non-nuclear industrial activity that also occur naturally in the environment. This includes radionuclides discharged from the former phosphate processing plant at Whitehaven, and so monitoring is carried out near this site. Discharges from other non-nuclear sites are generally considered insignificant and so monitoring to protect public health is not usually carried out. However, this situation is reviewed from time to time and, where appropriate, surveys are included in the programme.

Appendix 2 gives a summary of the discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2008. The tables also list the discharge and disposal limits that are authorised or, in the case of the Ministry of Defence (MoD), administratively agreed. In 2008, all discharges and disposals were below the authorised limits. The tables show the percentage of the limit actually discharged in 2008. Section 7 gives information on discharges from non-nuclear sites.

The discharge limits are set through an authorisation assessment process, which either the operator or the relevant environment agency can initiate. In support of the assessment process, prospective assessments of doses to the public are made assuming discharges at the authorised limits. Authorisations are set so that doses to the public from the site will be below

Figure 1.1. Principal sources of radioactive waste disposal in the UK, 2008 (Showing main initial operation. Some operations are undergoing decommissioning)



the dose constraint of 0.3 or 0.5 mSv per year if discharges occurred at the authorised limits. The implications of the authorisation for the food chain are also considered. In 2008, and in other years, discharges were below the specified limits. Therefore, provided the limits are not exceeded, the public and the food chain should be adequately protected. During the determination of the authorisation, the effect of the planned discharges on the environment is also considered. In addition, the authorisations require Best Practicable Means to be used to minimise discharges still further.

The discharges and disposals made by sites are generally regular throughout the 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. These events must be 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. Where monitoring took place because of these events, the results are presented and discussed in the relevant site text later in this report. Appendix table A2.4 summarises the types of events that took place in 2008.

The UK Government and devolved administrations began a consultation process on standardised approaches to reporting radioactive discharges in 2007. Their findings have now been published (Department for Environment, Food and Rural Affairs, 2008a). The aim of the proposed changes was to standardise reporting across EU member states, so that accurate and meaningful comparisons of discharges across the Community can be made. The UK's proposed approach is intended to establish reporting requirements on a secure statistical basis, to minimise over- and under-reporting of radioactive discharges and to ensure a consistent regulatory

approach across the UK and industry. There was general agreement that there is benefit in standardising reporting. The main concern expressed was the need for further cost-benefit analysis to confirm that the costs of implementing new systems do not outweigh the benefits. The UK Government and devolved administrations will now arrange for trials of the new reporting systems and, in light of the results, will publish their finalised policy and provide guidance to the environment agencies.

1.2.2 International agreements and the UK discharge strategy

This section gives information on the context of UK radioactive discharges as they relate to international agreements. The UK has ratified the Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention'). This provides a framework for preventing and eliminating pollution in the north-east Atlantic, including the seas around the UK (OSPAR, 2000a). The OSPAR Convention replaced the separate Oslo and Paris Conventions.

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, 2002). This described how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the strategy related to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes.

Results of a public consultation to update this strategy were published in 2009 (Department of Energy and Climate Change, 2009). DECC* and the devolved administrations have now issued a revised Strategy (Department of Energy and Climate Change, Department of the Environment, Northern Ireland, the Scottish Government and Welsh Assembly Government, 2009).

The new strategy builds on the initial UK strategy, published in 2002, and expands its scope to include aerial, as well as liquid discharges, from decommissioning as well as operational activities, and from the non-nuclear as well as the nuclear industry sectors. It also includes considerations of uncertainties associated with discharges from new nuclear power stations, the possible extension of the lives of some of the existing nuclear power reactors, and discharges arising from decommissioning activities. The objectives of this revised strategy are:

- To implement the UK's obligations, rigorously and transparently, in respect of the OSPAR Radioactive Substances Strategy (RSS) intermediate objective for 2020
- To provide a clear statement of Government policy and a strategic framework for discharge reductions, sector by sector, to inform decision making by industry and regulators

The expected outcomes of the UK strategy are:

- Progressive and substantial reductions in radioactive discharges, to the extent needed to achieve the sectoral outcomes, while taking into account the uncertainties
- Progressive reductions in concentrations of radionuclides in the marine environment resulting from radioactive discharges, such that by 2020 they add close to zero to historic levels
- Progressive reductions in human exposures to ionising radiation resulting from radioactive discharges, as a result of planned reductions in discharges

To support implementation of Government policy, the Scottish Government has consulted on its Statutory Guidance to be issued to SEPA (Scottish Executive, 2005) and the guidance was issued to SEPA in early 2008. DECC is preparing equivalent guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment (Department for Environment, Food and Rural Affairs, 2008b). The Environment Agency has developed Radioactive Substances Regulation (RSR) Environmental Principles (RSR Environmental Principles, or REPs) to form a consistent and standardised framework for the technical assessments that will be made when regulating radioactive substances (Environment Agency, 2008a). It has also issued guidances for assessment of Best Available Techniques (BAT) (Environment Agency, 2008b).

Information on work in progress within the OSPAR Convention can be found on the OSPAR website (www.ospar.org). The basis for OSPAR's approach is the Radioactive Substances Strategy whose primary objective is to prevent marine pollution (OSPAR, 2003). 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, 2009). It also considers the relationship between OSPAR and its work on radioactivity and the separate initiative to develop a European Marine Strategy. Progress towards reducing man-made inputs of radioactivity into the north-east Atlantic by Contracting Parties has been published (OSPAR, 2007). 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. Inputs in the north-east Atlantic have been summarised, including exceptional discharges from

* *The Department of Energy and Climate Change (DECC) took over responsibility for policy relating to radioactive discharges from Defra in October 2008.*

decommissioning and management of legacy radioactive wastes (OSPAR, 2008a). An assessment of the impact of anthropogenic sources of radioactive substances on marine biota has been made (OSPAR, 2008b). A summary of implementation of the principle of using Best Available Technology (BAT) has also been published (OSPAR, 2008c).

The European Commission (EC) has considered various options for a new policy instrument concerning the protection and conservation of the marine environment and has now issued a Marine Strategy Directive (Commission of the European Communities, 2008). The Directive has a target date to become law by 15 July 2010. It requires member states to achieve Good Environmental Status in waters under their jurisdiction by 2021, and this includes consideration of radionuclides.

The importance of an integrated approach to stewardship of the marine environment has been recognised in the UK, and a strategy to achieve this has been published (Department for Environment, Food and Rural Affairs, 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, b; Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005) and is planning to issue a new assessment in 2010 (Department for Environment, Food and Rural Affairs, 2007a). Draft UK legislation, which is complementary to the EC Marine Strategy Directive, has been published (United Kingdom – Parliament, 2008).

1.2.3 Managing radioactive liabilities in the UK

The UK Government and devolved administrations have 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 the harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. The 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). A third Joint Convention report was published by the UK in May 2008.

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up. The Energy Act 2004, which became law in 2004, led to the establishment of the Nuclear Decommissioning Authority (NDA) in April 2005. The NDA is responsible for nuclear sites formerly owned by British Nuclear Fuels Ltd (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 current strategy was published in 2006 (Nuclear Decommissioning Authority, 2006) and the plan for 2009/12 is available (Nuclear Decommissioning Authority, 2009). 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. Further improvements and modernisation of the Radioactive Substances Act in its application in England and Wales are planned through the phase 2 Environmental Permitting programme (Department for Environment, Food and Rural Affairs, 2008c).

In 2007, the Government issued a new UK policy for managing low level waste (Department for Environment, Food and Rural Affairs, 2007b), which includes:

- Maintaining a focus on safety whilst allowing greater flexibility in managing LLW
- An emphasis on community involvement
- The NDA creating a UK-wide strategy for managing LLW from the nuclear industry, including considering whether a replacement(s) of the national disposal facility near Drigg in Cumbria might be needed
- Initiating a UK-wide strategy for managing LLW from non-nuclear industries
- Minimising waste

Complementing the low-level waste policy, the UK Government published its policy for managing higher activity radioactive waste in the White Paper *'Managing Radioactive Waste Safely (MRWS): A Framework for Implementing Geological Disposal'* in June 2008 (Department for Environment, Food and Rural Affairs, Department for Business, Enterprise and Regulatory Reform, National Assembly for Wales and Northern Ireland Assembly, 2008). This followed from the independent Committee on Radioactive Waste Management's (CoRWM) recommendations that geological disposal, preceded by safe and secure interim storage, was the best available approach for the long-term management of higher activity radioactive waste (Department for Environment, Food and Rural Affairs, 2007c). The UK Government takes a partnership approach to siting a facility, and so communities were invited to discuss with Government the possibility of hosting a geological disposal facility at some point in the future.

The Scottish Government has decided not to progress geological disposal as it does not accept that this is the right way forward for Scotland. The policy for waste in Scotland is to support long-term "near surface near site" storage facilities so that the waste is monitorable and retrievable and the need for transporting it over long distances is minimal (Scottish Government, 2007).

The Welsh Assembly Government continues to play a full part in the Managing Radioactive Waste Safely programme in order to secure the long term safety of radioactive wastes, to ensure the implementation of a framework appropriate to the needs of Wales and to ensure that the interests of Wales are taken into account in the development of policies in this area.

Some low level radioactive waste, mostly from non-nuclear sites, and some very low level waste is currently disposed of in landfill by controlled burial (Chapter 7). There is still a large amount of solid low level radioactive wastes that will need to be disposed of. Some will be sent to the LLWR near Drigg, the LLW from Dounreay will be disposed of at a new facility close to the site, and further alternative disposal options are also being considered. With the increasing momentum for decommissioning and clean-up of nuclear sites, the environment agencies have been working on new guidance documents to help manage solid radioactive waste disposal sites (Environment Agency, 2007a). Guidance on requirements for authorisation for geological and near-surface disposal facilities has now been issued (Environment Agency and Northern Ireland Environment Agency (2009) and Environment Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency (2009)).

1.2.4 Protecting the environment

In 2000, the Water Framework Directive (WFD) took effect (Commission of the European Communities, 2000b). Subsequently, legislation was passed to transpose the Directive in the UK (see for example United Kingdom – Parliament, 2003). Defra, the Scottish Government, Welsh Assembly Government and the Department of the Environment Northern Ireland have policy responsibility for implementing the WFD in the UK. As competent authorities, the environment agencies are largely responsible for implementing the WFD.

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 carried out 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 European Commission (Environment Agency, 2005). Subsequent stages within this framework involve designing and implementing monitoring programmes to reflect the results of the initial characterisation, reviewing environmental quality using the results from the monitoring programmes, developing standards and producing management plans to improve the environmental status of the UK aquatic environment.

Under the Habitats Regulations, the Environment Agency and SEPA must review new and existing permits to ensure that they do not have an adverse effect on the integrity of Natura 2000 sites. Assessing the impact on habitats is carried out in stages:

- Stage 1 – identify the relevant permits
- Stage 2 – determine which permits have a potential significant effect
- Stage 3 – appropriate assessment for permits with significant effects
- Stage 4 – revision of permits to ensure no adverse effects

Stage 3 assessments were carried out by calculating dose rates to reference organisms and feature species for authorised discharges under the Radioactive Substances Act 1993. These assessments considered the combined impact of discharges from multiple authorised releases at the permit limits. The calculated total dose rates were compared to a threshold of 40 μGy h^{-1}. The highest dose rate to the worst affected organism (whales and seals) in a Natura 2000 site was 520 μGy h^{-1} in the Ribble and Alt Estuaries Special Protection Areas. This was affected by the Springfields discharges. This was a very conservative assessment based on the assumption that Springfields discharges were made at the site permit levels. This triggered a further more detailed assessment of the impact of the authorised discharges to the Ribble and Alt Special Protection Area. This assessment showed the revised dose rates to be lower than 40 μGy h^{-1} (Allott *et al.*, 2009). The second highest was the Drigg Coast Special Areas of Conservation, at 41 μGy h^{-1} and affected by Sellafield's discharges. Both of these were above the threshold. The next highest dose rate was Teesmouth and Cleveland Coast Special Protection Areas (31 μGy h^{-1}). The rest of the Natura 2000 sites had dose rates less than 20 μGy h^{-1}.

The Ribble and Alt Estuaries Special Protection Areas dose rate was significantly above the agreed stage 3 assessment threshold and so this Natura 2000 site was included in the Stage 4 process (determination of permissions) of the Habitats Regulations implementation. A separate report is available for this determination process. This concluded that new authorisation limits for the Springfields Fuels Ltd site (which come into effect from January 2008) would ensure that the dose rates to reference organisms and feature species will be less than 40 μGy h^{-1} (Allott and Copplestone, 2008a,b).

The total dose rate for the Drigg Coast Special Areas of Conservation (41 μGy h^{-1}) is just greater than the 40 μGy h^{-1} threshold. Since this assessment was made, a new assessment methodology based on the ERICA assessment tool has become available. Using this more recent methodology, the dose rate to the worst affected organism for the Drigg Coast Special Areas of Conservation was reduced to 20 μGy h^{-1} (Allott *et al.*, 2009). The Drigg Coast Special Areas of Conservation was also considered in an ERICA project case study, which concluded that there was no indication of significant impact from ionising radiation on the

sand dune biota. This Natura 2000 site will be kept under review.

The Environment Agency will revise its assessment methodology to include more realistic data from the ERICA assessment tool.

SEPA carried out a Pressures and Impacts Assessment from radioactive substances on Scotland's water environment. 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 to support this conclusion. The report is available from:

http://www.sepa.org.uk/pdf/publications/technical/wfd_Assessment_pressures_impacts.pdf

1.2.5 Solid radioactive waste disposal at sea

In the past, packaged solid waste of low specific activity was disposed of deep in the North Atlantic Ocean. The last disposal of this type was in 1982. The UK Government announced at the OSPAR Ministerial meeting in 1998 that it was stopping disposal of this material at sea. At that meeting, Contracting Parties agreed that there would no longer be any exception to prohibiting the dumping of radioactive substances, including waste (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 2008 are presented in Section 8. They confirm that the radiological impact of these disposals was insignificant.

In the UK, Defra, the Department of the Environment, Northern Ireland, Scottish Government and Welsh Assembly Goverment issue licences under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom – Parliament, 1985) to operators disposing of dredge material. The protection of the marine environment is considered before a licence is issued. Since dredge materials will contain varying concentrations of radioactivity from natural and man-made sources, assessments are carried out, when appropriate, to provide reassurance that there is no significant risk to the food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the IAEA (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003) and which has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2008, a specific assessment was carried out for the disposal of dredged material near the Port of Lancaster, Lancashire. Consistent with results for previous operations at other locations, the impact of the radioactivity associated with the disposal operation was very low. Individual doses to members of the crew and the public were both less than 0.005 mSv per year and within *de minimis* criteria of 0.010 mSv per year. Further details are provided in Appendix 6.

1.2.6 Other sources of radioactivity

There are several other man-made sources of radioactivity that may affect the food chain and the environment. These could include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas nuclear installations and the operation of nuclear powered submarines. The Health Protection Agency (HPA) has assessed incidents involving the transport of radioactive materials in the UK (Hughes *et al*., 2006). Submarine berths in the UK are monitored by the MoD (DSTL, 2009). General monitoring of the British Isles is carried out as part of the programmes described in this report, to detect any gross effects from the sources above. No such effects were found in 2008. Low concentrations of radionuclides were detected in the marine environment around the Channel Islands (Section 8) and these may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague in France.

The Environmental Protection Act 1990 provides the basis, through the Environment Act 1995, for a regulatory regime for identifying and remediating contaminated land. Implementation of the regime initially focused on non-radioactive contamination. In 2006 the regime was extended to provide a system for identifying and remediating land, where contamination is causing people to be exposed to radiation and where intervention is liable to be justified. A second phase of regulations was introduced in December 2007 to further extend the regime to cover radioactive contamination from nuclear licensed sites. A profile of industries which may have caused land contamination has been published (Department for Environment, Food and Rural Affairs, 2006b). Dose criteria for the designation of radioactively contaminated land have been determined for England and Wales (Smith *et al*., 2006).

In October 2007, the Radioactive Contaminated Land (Scotland) Regulations came into force by amending Part ll A of the Environmental Protection Act 1990. SEPA has new statutory duties and powers, including the power to inspect land that may be contaminated with radioactivity, to decide if land should be identified as radioactive contaminated land. It can require remediation if it is considered necessary. Accompanying statutory guidance was issued to SEPA in March 2008. This guidance is broadly similar to that issued to the Environment Agency, apart from the fact that clear criteria are set for discrete point sources for the designation of radioactive contaminated land. Similar to the situation in England and Wales, the regime does not currently apply to radioactive contamination from nuclear licensed sites (except for water and land affected by contamination originating from a site), but a second phase of regulation will be implemented in due course. During May 2009, regulations were laid before the Scottish Parliament to amend the Radioactive Contaminated Land (Scotland) Regulations. The changes removed the

exclusion of radon and its daughter products previously applied to dose assessments. Revised Statutory Guidance will come into effect following the Scottish Parliament summer recess.

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 actual 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 on land. Where this is found, appropriate comments are made in this report.

All sources of ionising radiation exposure to the UK population are 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 use 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 medical procedures, such as x-rays. 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 per cent of the total. These figures represent the exposure of the average person. Much of the information in this RIFE report is directed at establishing the exposure of critical groups who might receive the highest doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is the exposure of these people which form the basis for comparisons with dose limits in EU and UK law.

1.2.7 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 delaying food from rotting or developing mould, and prevent certain food products from ripening, germinating or sprouting. Irradiation may also be used as a phytosanitary measure to rid plants or plant products of harmful organisms.

Food irradiation has been permitted in the UK since 1990, and UK legislation was amended in 2000 to implement two European Directives on food irradiation (Commission of the European Communities, 1999a, 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

2. Nuclear fuel production and reprocessing

Key points

Capenhurst, Cheshire

- Operators changed at each of the sites, and there were minor revisions of radioactive waste authorisations
- Discharges, environmental concentrations, dose rates and doses in 2008 were broadly similar to those in 2007

- Consumer diet and occupancy rates were revised and updated
- Uranium and technetium-99 in Rivacre Brook sediments were significantly lower in 2008, but gamma dose rate measurements increased (but were still very low)
- Radiation doses from all sources were 17 per cent (or less) of the dose limit

Springfields, Lancashire

- Concentrations of thorium-234 and gamma dose rates were higher in 2008
- Doses to wildfowlers and anglers, fishermen and houseboat dwellers increased
- Radiation doses from all sources were 16 per cent (or less) of the dose limit

Sellafield, Cumbria

- Discharges to atmosphere were similar to 2007, except antimony-125 which increased
- Liquid discharges of carbon-14 and iodine-129 were slightly higher, and gross beta, strontium-90 and technetium-99 were lower in 2008
- A new full survey of local diet and occupancy rates was conducted in 2008 to improve dose assessments
- Concentrations and dose rates were generally similar to those in 2007. Antimony-125 in milk samples remained below limit of detection (LoD)s; technetium-99 continued to decline in shellfish
- Radiation dose to seafood consumers from natural radionuclides (0.39 mSv) was higher than in 2007, mostly due to an increase in polonium-210 in shellfish. This was not due to operations at Sellafield. The dose from Sellafield radionuclides (0.23 mSv) was virtually unchanged
- Radiation doses, including the *total dose* and the legacy of phosphate processing, were less than 62 per cent of the public dose limit (Table 2.18)

There are four sites in the UK associated with civil nuclear fuel production and reprocessing. The sites are at: Capenhurst, where there are two licensed nuclear sites (one carrying out uranium enrichment and owned by URENCO UK Limited (UUK), the other undergoing decommissioning and owned by the NDA); Springfields, where fuel for nuclear power stations is fabricated; and Sellafield, where irradiated fuel from nuclear power stations is reprocessed. Both the Springfields and Sellafield sites are owned by the NDA. On 24 November 2008, the NDA confirmed that the programme to secure a new Parent Body Organisation (PBO) for the Sellafield Site Licence Company (SLC), Sellafield Limited, had been completed, by the site management contract being transferred to the consortium, Nuclear Management Partners Ltd (NMP). The NDA's Capenhurst site was also included in the contract. The Windscale nuclear site, also owned by the NDA, is located on the Sellafield site and (until 1 April 2008) both were licensed separately to Sellafield Limited; thereafter the two authorisations were combined into one. Windscale is discussed in Section 3.4. The Low Level Waste Repository LLWR near Drigg is discussed in Section 7.1.

Gaseous and liquid discharges from each of the sites are authorised by the Environment Agency. In 2008, gaseous and liquid discharges were below authorised limits for each of the sites (see Appendix 2). Independent monitoring of food and the environment around each of the sites is conducted by the Food Standards Agency and the Environment Agency.

2.1 Capenhurst, Cheshire

There are two nuclear licensed sites at Capenhurst, located near Ellesmere Port, one owned by the NDA and one by Urenco UK (Capenhurst) Limited. Sellafield Limited operated the NDA site, involving the dismantling and decommissioning of redundant facilities. From 2 June 2008, Urenco (Capenhurst) Limited changed its registered name to URENCO UK Limited. The site operates three plants producing enriched uranium for nuclear power stations.

After reviewing the radioactive waste authorisation held by both Sellafield Limited and Urenco, the Environment Agency announced a public consultation on new authorisations it proposed to issue. To assist the public consultation explanatory documents were issued for each site, in December 2006 for Sellafield Limited (then BNGSL) (Environment Agency, 2006a) and in February 2007 for Urenco (Environment Agency, 2007b). A new authorisation for Sellafield Limited was issued in September 2007, with a minor variation to the authorisation effective from September 2008. A new multi-media authorisation became effective from 1 January 2009 for Urenco.

A habits survey was conducted in September 2008. The potentially critical pathway for public exposure in the aquatic environment was identified as children playing around the Rivacre Brook. The occupancy and inadvertent ingestion rates are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges from Capenhurst, with small amounts of other radionuclides present in discharges by Sellafield Limited. In 2008, discharges from the site incinerator were nil. The main focus for terrestrial sampling was on the content of technetium-99 and uranium in milk, fruit, silage, grass and soil. Results for 2008 are presented in Table 2.2(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 2.1 shows the trend of technetium-99 concentrations in grass from 1999, and reflects the reductions in discharges of technetium-99 from recycled uranium. In future UUK is expecting to increase the enrichment of reprocessed uranium, which may lead to increases in discharges of technetium-99 and neptunium-237. However, no increase in authorised discharge limits is expected.

Liquid waste discharges and aquatic monitoring

The authorisation held by Sellafield Limited allows liquid waste discharges (including liquid discharges from UUK) to the Rivacre Brook for tritium, uranium and daughters, technetium-99 and non uranium alpha (mainly neptunium-237).

Monitoring included the collection of samples of freshwater and sediments for analysis of tritium, technetium-99, gamma emitting radionuclides, uranium, neptunium-237, and gross alpha and beta. Fish and shellfish from the local marine environment were sampled and measured for a range of radionuclides. Dose rate measurements were taken on the banks of the Rivacre Brook. Results for 2008 are presented in Table 2.2(a) and (b). Concentrations of radionuclides and dose rates were very low and similar to those in 2007. Sediment samples from the Rivacre Brook contained very low but measurable concentrations of uranium (enhanced above natural levels) and technetium-99. Some enhancement of these radionuclides was measured close to the discharge point, but in 2008 these levels were significantly lower than corresponding levels in 2007. 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. In 2008, measured dose rates were slightly enhanced relative to natural background near to the discharge point, and slightly higher than corresponding downstream values in 2007. Fish

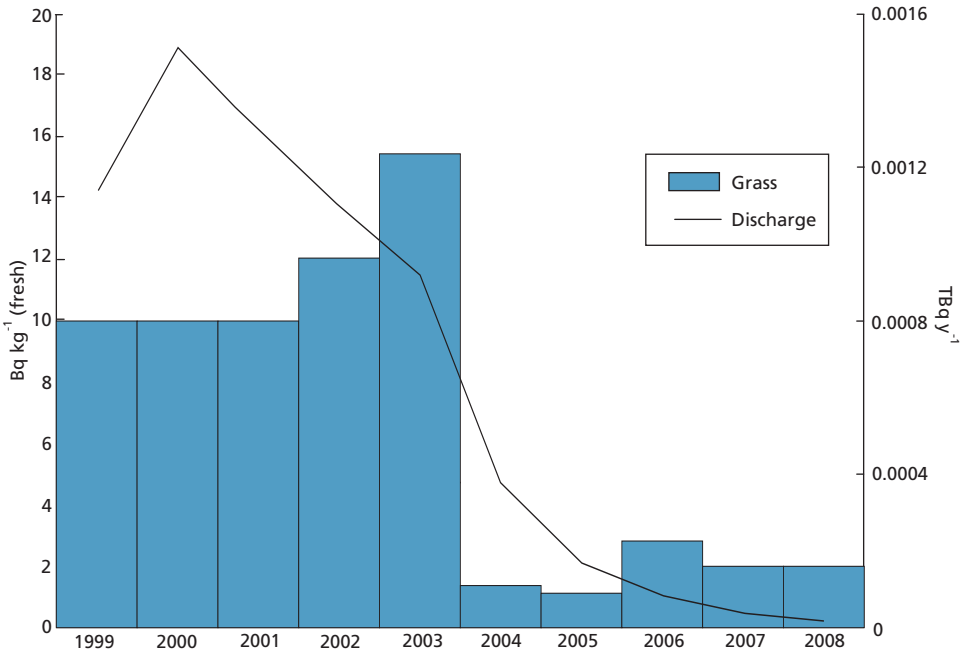


Figure 2.1. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 1999-2008

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 from the operations at the Capenhurst sites. Doses were estimated for children playing in and around Rivacre Brook and consumers of local milk and vegetables. The highest dose was 0.010 mSv for children who play near the Brook and inadvertently ingest water and sediment (Table 2.1). The dose was less in 2007 (0.007 mSv) and the increase in 2008 was attributed to slightly increased dose rates downstream (Rivacre Brook). The dose was estimated assuming a high occupancy of the bank of the Brook, relatively high inadvertent ingestion rates of water and sediment and gamma dose rates. The estimated dose from consumption of terrestrial foodstuffs was much less than 0.005 mSv. In 2008, the dose from non-food pathways arising from discharges to air was also assessed as less than 0.005 mSv. Taking both the pathways into account, the critical group dose in 2008 was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit.

In 2008, the *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.17 mSv or approximately 17 per cent of the dose limit. Most of this was due to direct radiation from the site.

2.2 Springfields, Lancashire

This Springfields site at Salwick, near Preston, is owned by the NDA and operated by Springfields Fuels Limited (SFL), under the management of Westinghouse Electric UK Limited. The main function conducted is the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Fuel manufacture is scheduled to continue until 2023. In addition to fuel manufacture, Springfields is also undertaking decommissioning activities. The most recent habits survey was undertaken in 2006 (Tipple *et al.*, 2007a). In 2008, habits information, based on a five-year rolling average (2004 – 2008) was revised, resulting in an increase in the occupancy rate for high-rate houseboat dwellers (see Appendix 1). The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.2.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges, with small amounts of other radionuclides present in discharges from research and development facilities (National Nuclear Laboratory Limited*).

The main focus of the terrestrial sampling was for the content of tritium, carbon-14, strontium-90, iodine-129, and isotopes of uranium, thorium, plutonium and americium in milk, fruit and vegetables. Gamma-ray spectrometry results are reported for cobalt-60 and caesium-137. Grass and soil samples were collected and analysed for isotopes of uranium. The concentrations of radionuclides found in 2008 are shown in Table 2.3(a). As in previous years, slightly elevated concentrations of uranium isotopes, compared with those at a greater distance, were found in soils around the site but the isotopic ratio showed they are of natural abundance. Low concentrations 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 (including gross alpha and beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides) are made from the Springfields site to the Ribble Estuary by two pipelines. Discharges in 2008 were generally similar to those in 2007, including the short half-life beta-emitting radionuclides (mostly thorium-234) that have recently decreased following the end of the Uranium Ore Concentrate purification process in 2006. The Ribble Estuary monitoring programme consisted of dose rates measurements, and the analysis of sediments for uranium and thorium isotopes, and gamma emitting radionuclides. Locally obtained fish, shellfish and samphire were analysed by gamma-ray spectrometry and for uranium, thorium and plutonium isotopes.

Results for 2008 are shown in Tables 2.3(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 found in the Ribble Estuary originating from Sellafield were technetium-99, caesium-137 and americium-241. Isotopes of uranium and the short half-life radionuclides thorium-234 and protactinium-234, from Springfields, were also found. Concentrations of the latter are closely linked to recent discharges from the Springfields site. In 2008, thorium-234 concentrations were generally increased compared to 2007, but relatively lower than in other recent years as a result of the reduction in discharges (Figure 2.3).

* *National Nuclear Laboratory Limited formally changed its name from Nexia Solutions Limited on 10 November 2008.*

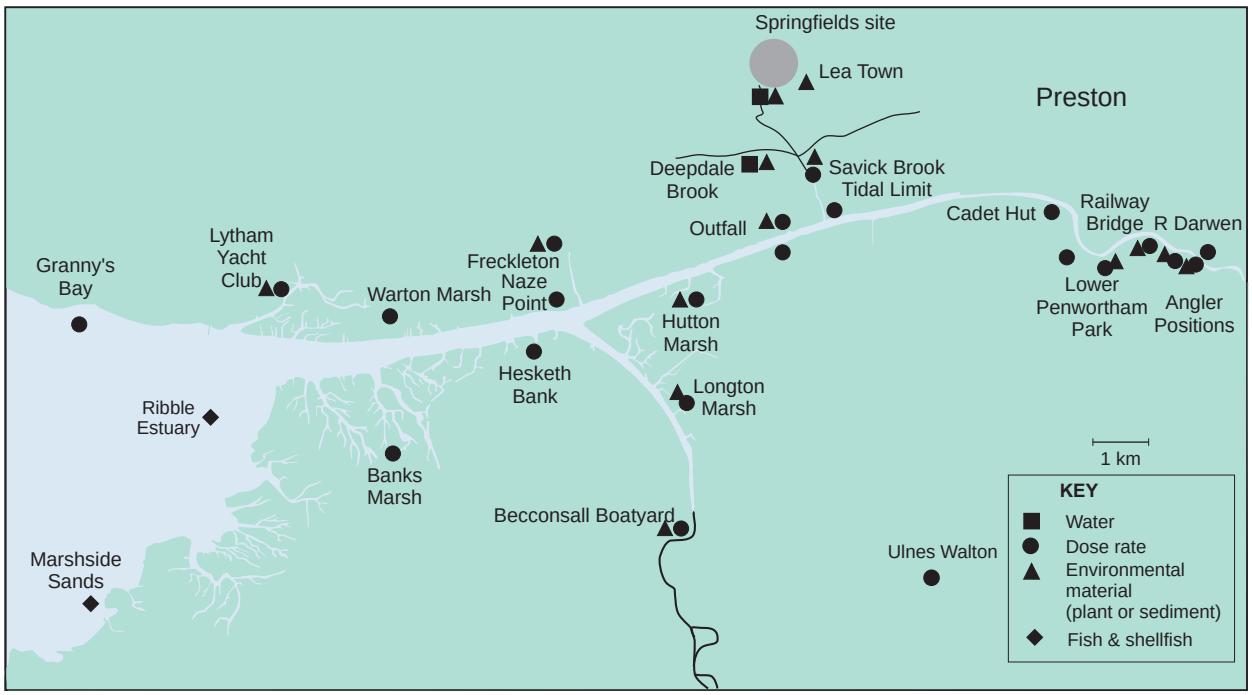


Figure 2.2. Monitoring locations at Springfields, 2008 (not including farms)

Caesium-137, americium-241 and isotopes of plutonium were found in biota and sediments from the Ribble Estuary. 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 higher than expected natural background levels (see Appendix 1, Section 3.7), and this is due to Sellafield-derived gamma-emitting radionuclides (caesium-137 and americium-241). Gamma dose rates in the estuary, including rates taken for houseboat assessments, were generally slightly higher in 2008 than those in 2007. Beta dose rates on fishing nets were also 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 from sediments in 2008 were generally similar to those in 2007.

Solid waste disposals and related monitoring

The Springfields and Capenhurst authorisations permit disposal of solid LLW by controlled burial at Clifton Marsh landfill site, Lancashire. Until 1983, BNFL had also disposed of LLW to the Ulnes Walton landfill site. The results of Environment Agency monitoring of waters, with respect to these landfill sites are presented in Section 7, Table 7.4 (Landfill Sites).

Figure 2.3. Total beta in liquid discharges from Springfields and concentrations in sediment at Lower Penwortham, 1998-2008

Doses to the public

Radiation exposures from terrestrial and aquatic pathways were calculated to the following groups (Table 2.1): those consuming foods such as fruit and vegetables grown around the site; fish and shellfish consumers; people living on houseboats in the Ribble estuary (the critical group of high occupancy); farmers and wildfowlers spending time on the banks of the estuary; children playing on the banks of the estuary; and fishermen handling their gear.

In 2008, the dose to high-occupancy houseboat dwellers in the Ribble Estuary was 0.13 mSv, which was 13 per cent of the 1 mSv dose limit for members of the public. The assessed dose to houseboat dwellers in 2008 was lower in 2007 (0.073 mSv). Gamma dose rate measurements were not taken aboard a houseboat in 2008. Dose rates were derived by using measurements outside the houseboat, and then adjusting the 2008 measurements by the ratio of onboard and outside dose rates from results reported in earlier years. This information was directly applicable to the locations where high-rate occupancy was taking place. The increase in dose in 2008 was attributable to both the increased gamma dose rates (by ~0.040 mSv) and the increase from the revision of the occupancy rate (by ~0.017 mSv). The trend in doses over the period 2001 – 2008 is shown in Figure 2.4. A study conducted by Rollo *et al.* (1994) showed that assessed doses to the public from inhaling Ribble Estuarine sediment resuspended in the air were much less than 0.001 mSv, negligible in comparison with other exposure routes.

In 2008, the dose received by the critical group who consume terrestrial food and are exposed to external and inhalation pathways from gaseous discharges was 0.005 mSv which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.1).

The dose to high-rate seafood consumers in 2008, including a contribution from external exposure, was 0.017 mSv, which was less than 2 per cent of the dose limit for members of the public of 1 mSv. Of this dose 0.014 mSv was from external exposure and the remainder was from seafood consumption. The dose in 2008 was similar in 2007 (0.016 mSv). The majority of the change in dose in 2008 was because external dose rates in the Ribble were slightly increased in 2007, whilst the dose from eating fish was reduced. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site. The dose to children who may play on the riverbanks was less than 0.005 mSv. The skin dose for fishermen handling nets was estimated to be 0.066 mSv, much less than the skin dose limit of 50 mSv. The dose to wildfowlers and farmers from exposure over salt marsh was 0.033 mSv, which was approximately 3 per cent of the dose limit for members of the public of 1 mSv. The increase in dose from 0.017 mSv (in 2007) was due to higher gamma dose rates over marsh, but was the same as the dose in 2006 (0.033 mSv).

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.16 mSv or 16 per cent of the dose limit. This was to houseboat dwellers in the Ribble Estuary, and was entirely attributable to external radiation.

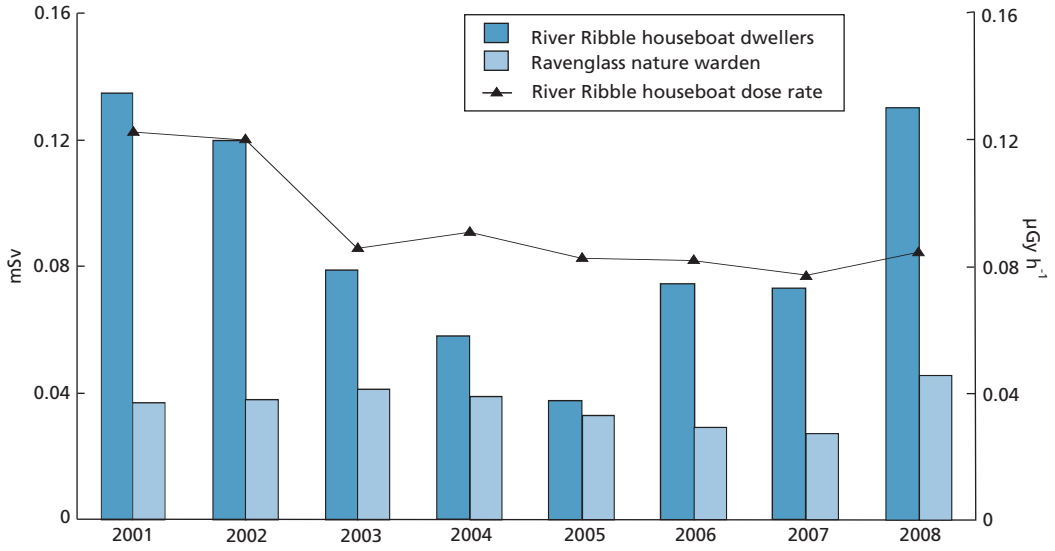


Figure 2.4. Individual radiation exposures to groups affected by external gamma dose, 2001-2008

2.3 Sellafield, Cumbria

This site is operated by Sellafield Limited (formally called British Nuclear Group Sellafield Limited), but is owned by the NDA. The main operations on the 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; the manufacture of mixed oxide fuel and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in March 2003. The Windscale site is located on the Sellafield site, and is discussed in Section 3.

Sellafield Limited has begun to decommission the Calder Hall site. The first stage involves preparations for care and maintenance. These preparations have included, but have not been limited to, the cooling towers demolition and the progressive asbestos strip of 16 reactor heat exchangers. The latter is ongoing. Up to 1,000 tonnes of the asbestos from the heat exchangers may have sufficiently low levels of radioactivity to be considered exempt; allowing disposal of the hazardous wastes to landfill offsite. In 2006, Sellafield Limited initiated a process to characterise the asbestos to support a decision about the quantity of asbestos that can be considered exempt. The process involves establishing provenance; sampling (including use of bag monitors where appropriate) and radiochemical analysis. In September 2008, the Environment Agency began independent check monitoring of the asbestos by random sampling of asbestos (*in situ and ex situ*). Asbestos was analysed for tritium and by gamma-ray spectrometry. This approach has supported a decision that the majority of the asbestos can be considered to be exempt from radioactive controls and disposed offsite. The remaining asbestos requires some further characterisation, as this has a wider range of activity concentrations – to demonstrate that it meets the agreed levels set for exemption.

In December 2008, the Environment Agency began independent check monitoring of the remains of the cooling towers, which have been processed and the majority disposed of on site. The outcome of this monitoring will be reported in next year's report.

The operation of THORP remained suspended, for the most part, throughout 2008. In January 2007, the HSE announced that it had granted consent for the re-start of the THORP facility (Health and Safety Executive, 2007a), and published a report on its investigation into the leak in 2005 (Health and Safety Executive, 2007b). THORP resumed reprocessing for a limited period during June 2008, however the reprocessing plant remained shutdown for the remainder of the year as work continued on the replacement of the medium active salt free evaporator. Therefore, a limited campaign (103.6 tonnes) of spent oxide fuel was reprocessed from THORP, which represented the total amount for the year. The reprocessing of spent Magnox fuel continued during 2008 with a total of 429.6 tonnes of fuel reprocessed, compared to 374 tonnes reprocessed in 2007.

A full habits survey was conducted in the vicinity of the Sellafield site during June 2008. These surveys are conducted approximately every five years and investigate exposure pathways relating to liquid and gaseous discharges, and direct radiation. Between these, annual habits surveys review the shellfish consumption and intertidal occupancy of a targeted group of individuals known as the Sellafield Fishing Community.

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.

2.3.1 Gaseous discharges

Discharges to atmosphere are made under authorisation from a wide range of facilities at the site including the fuel 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 in 2003. The authorisation limits discharges to atmosphere for gross alpha and beta, and 12 specified radionuclides. In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site. A new authorisation limit was effective from 1 April 2008 for antimony-125 to reflect improvements to the aerial effluent sampling arrangements. It is estimated that the previous sampling arrangements led to under-reporting of actual discharges by a factor of 3. However, the contribution to the dose from antimony-125 is sufficiently small that recalculating for the correct discharge values does not alter the previously reported doses. At the same time a new discharge limit was introduced for radon-222 as part of the process to combine the Sellafield and Windscale authorisations. Discharges of gaseous wastes from Sellafield in 2008 (summarised in Appendix 2, with combined Windscale discharges) were much less than the authorised limits. Gaseous discharges in 2008 were generally similar to 2007, with the exception of an increase in antimony-125 discharges (in comparison to 2007 and 2006).

In February 2008, the site operators at Sellafield reported that a temporary elevation in aerial discharges of uranium isotopes and ruthenium-106. The Food Standards Agency collected additional milk samples and analysed by gamma-ray spectrometry, but results were not dissimilar from routine monitoring measurements (Table 2.4). In June 2008, the site operators at Sellafield reported elevated discharges

of iodine-129 (and possibly iodine-131 and carbon-14) from Magnox reprocessing. The Food Standards Agency requested additional milk sampling for analyses of iodine-129, iodine-131 and carbon-14, but found no elevated concentrations of these radionuclides (Table 2.4).

Monitoring around the site related to gaseous discharges

There is a substantial programme of monitoring of terrestrial foods in the vicinity of Sellafield conducted by the FSA, which includes samples collected in Scotland by SEPA. This programme is the most extensive of those for the nuclear sites in the UK, reflecting the scale of the discharges from the site. A wide range of foodstuffs was sampled in 2008 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 conducted 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 2008 are presented in Table 2.4. The concentrations of all radionuclides around the site were low. Concentrations in terrestrial foodstuffs were generally similar to those in 2007. 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 carbon-14 and strontium-90 (tritium and iodine-129 values were below the limit of detection). Plutonium concentrations when detectable, were low and much lower than those found in seafood. A wide range of fruit and vegetables was sampled in 2008 and the levels were similar to those found in previous years. In common with meat and offal samples, only limited evidence of the atmospheric discharges from Sellafield was found in some of these foods. Concentrations of transuranic radionuclides, when detectable in these foods, were very low. Concentrations of antimony-125 were below limits of detection (or very close to, as in grass) in terrestrial samples in 2008, despite the reported increased discharges in 2008, in comparison to recent years.

2.3.2 Liquid discharges

Liquid discharges are made under authorisation from a variety of sources at the site including the fuel storage ponds, the reprocessing plants, from the retrieval and treatment of legacy wastes, the laundry and from general site drainage. Wastes from these sources are treated and then discharged to the Irish Sea via the sea pipelines that terminate 2.1 km beyond low water mark. Liquid wastes are also discharged from the factory sewer to the Ehen Estuary. Discharges from the Sellafield pipelines during 2008 are summarised in Appendix 2. The current authorisation sets limits on gross alpha and beta, and 16 individual nuclides. 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 Ion Exchange Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP). All of the discharges in 2007 were well below the limits in the authorisation. Discharges of carbon-14 and iodine-129 were slightly higher in 2008 compared with those in 2007; conversely discharges of gross beta, strontium-90 and technetium-99 were slightly lower.

Discharges of technetium-99 continued their long-term downward trend, from their peak of 192 TBq in 1995 and later years shown in Figure 2.19. Technetium-99 discharges from Sellafield are now substantially reduced and met the target set for 2006 in the UK National Discharges Strategy (Department for Environment, Food and Rural Affairs, 2002). The reduction of technetium-99 discharges was due to the diversion, since 2003, of the Medium Active Concentrate (MAC) waste stream from Magnox reprocessing to vitrification and, since 2004, use of a new chemical precipitant (Tetraphenylphosphonium Bromide) in the Enhanced Actinde Removal Plant to remove technetium-99 from the historic stock of MAC.

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2008. The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 2.5 and 2.6. Smith *et al*. (2004) have carried out a review of 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 2.5. 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 of specific naturally-occurring radionuclides in fish and shellfish in the Sellafield area are presented in Section 7. 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 are taken from this area. Specific surveys are conducted in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The concentrations of most radionuclides have decreased over the previous decades in response to decreases in discharges. Concentrations generally continue to reflect changes in discharges, over time periods, characteristic of radionuclide mobility and organism uptake. Trends in concentrations of radionuclides, and corresponding discharge levels, in seafood near Sellafield (over the last decade) are shown in Figures 2.7 – 2.12. There is variability from year to year, particularly for the more mobile radionuclides. For the transuranic elements (Figures 2.11 – 2.12), the long-term trends in reductions of concentrations from earlier decades

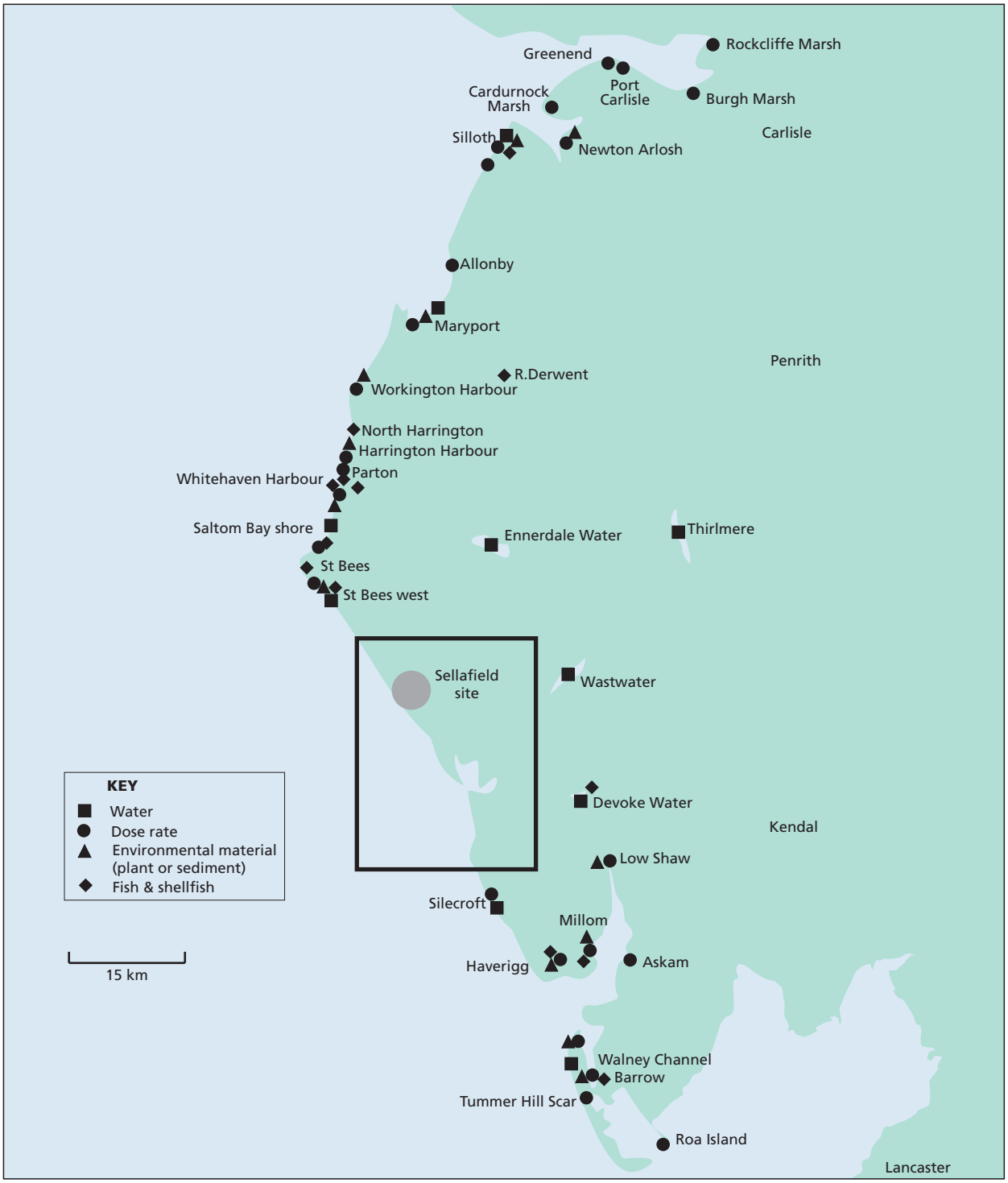


Figure 2.5. Monitoring locations in Cumbria, 2008 (not including farms)

appear to be slowing. In recent years, elevated concentrations of americium-241 in winkles in 2008, and plutonium-239/240 in lobsters in 2007, were observed.

Beta/gamma-emitting radionuclides detected in fish included: tritium, carbon-14, cobalt-60, strontium-90 and caesium-137 (Table 2.5). Concentrations of caesium-137 in fish were generally similar in 2008 to those in recent years. Activity concentrations in fish (and shellfish) 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 originates 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 ~ 0.1 – 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea are similar.

Figure 2.6. Monitoring locations at Sellafield, 2008 (not including farms)

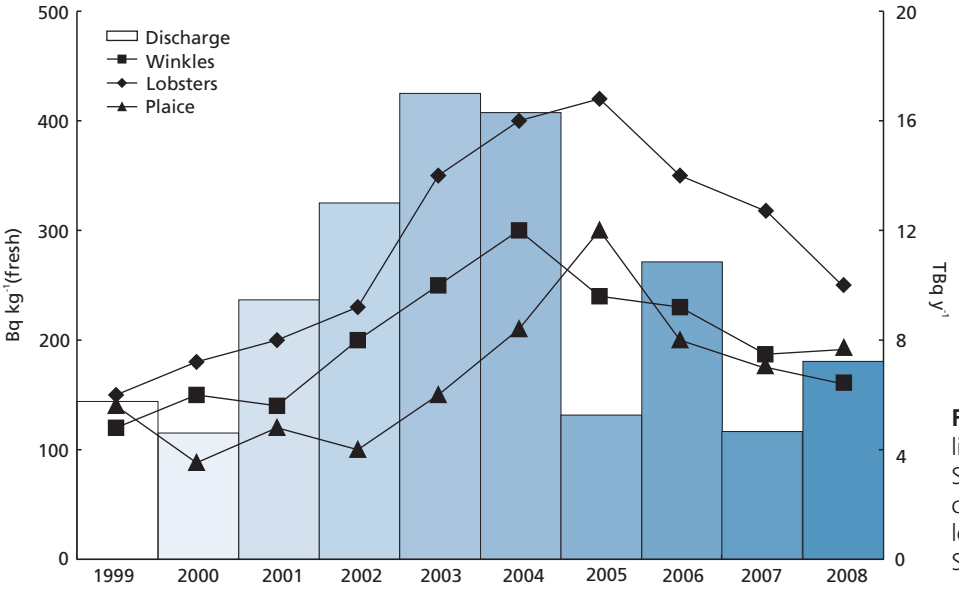


Figure 2.7. Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

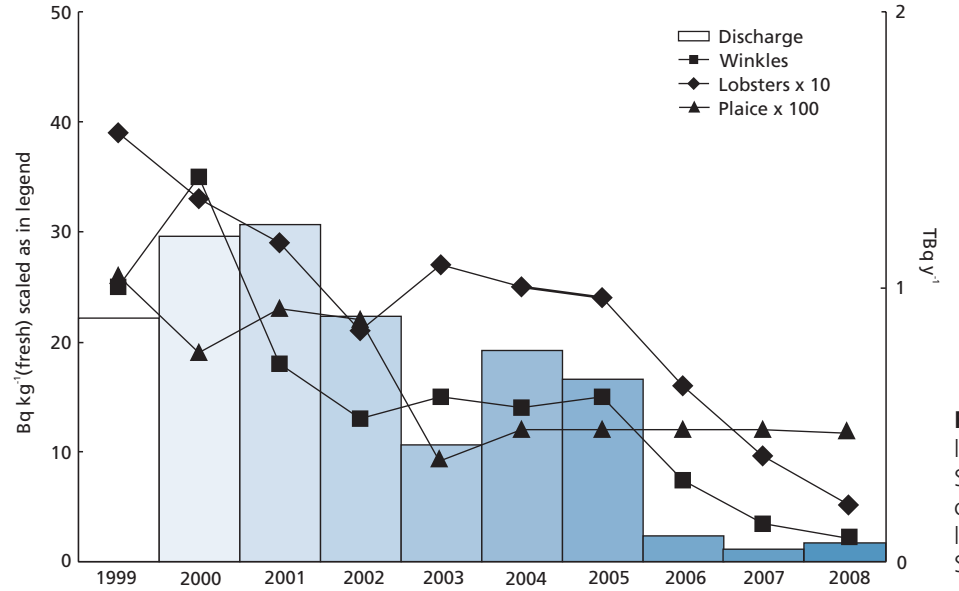


Figure 2.8. Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

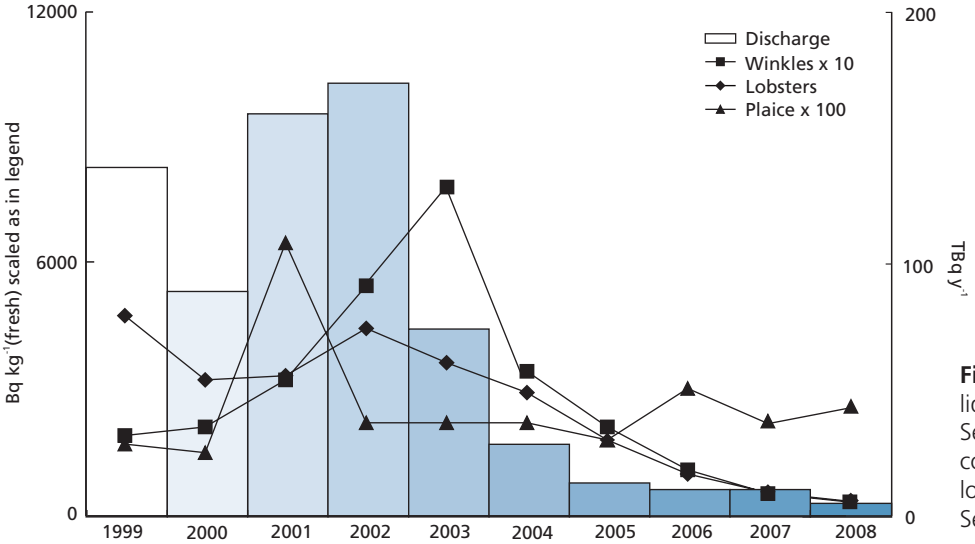


Figure 2.9. Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

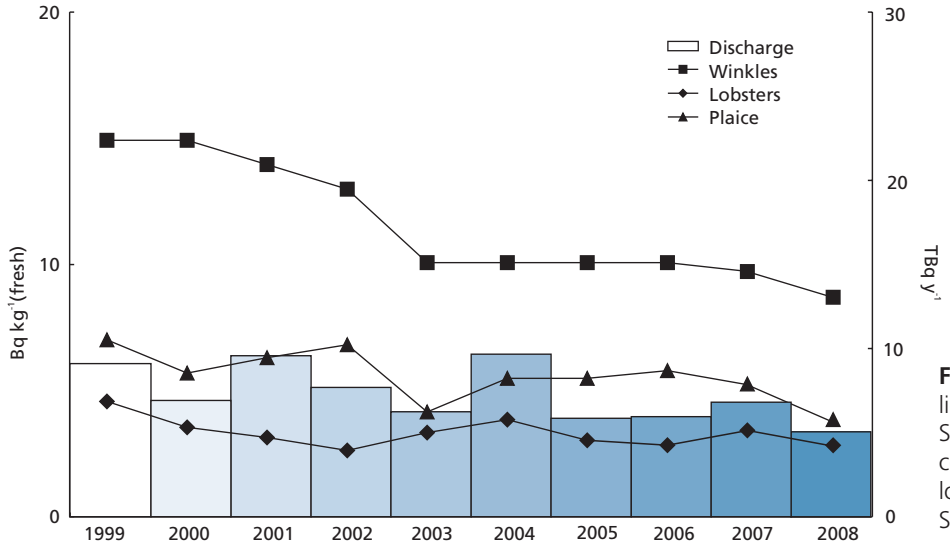


Figure 2.10. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

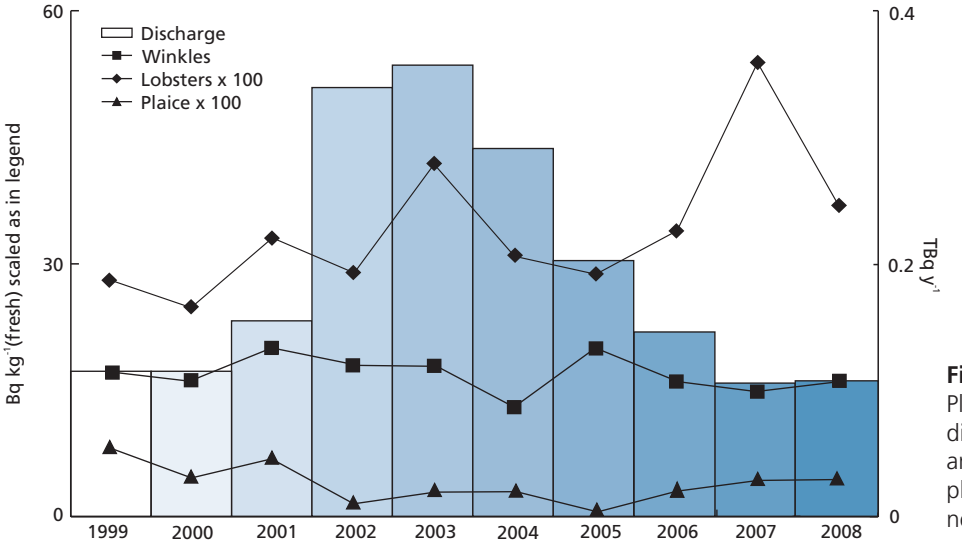


Figure 2.11. Plutonium-239/240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

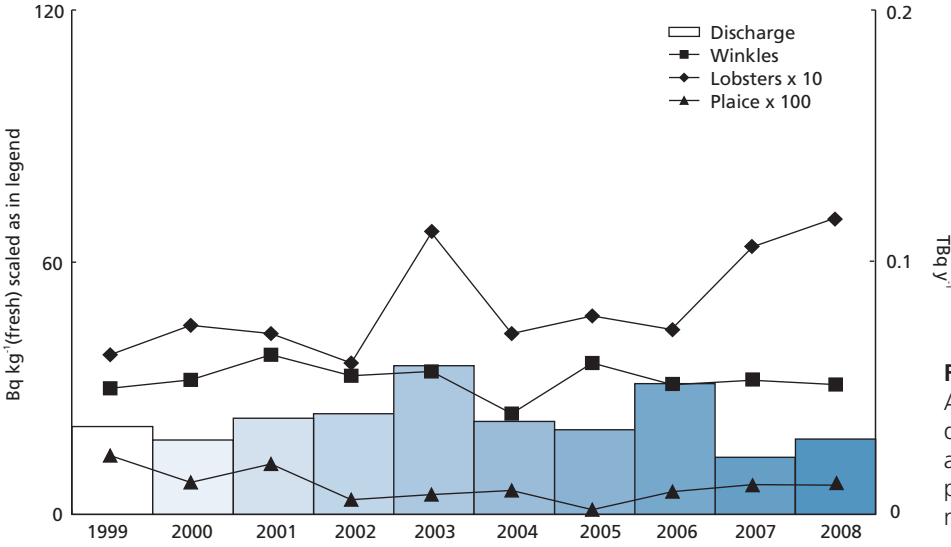


Figure 2.12. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 1999-2008

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 ~ 25 Bq kg^{-1}, the data suggest a local enhancement of carbon-14 due to discharges from Sellafield. Tritium (total) gives the highest concentrations of radioactivity in marine fish of less than 100 Bq kg^{-1}, with similar concentrations of organically associated tritium. These limited results suggest that virtually all of the total tritium in marine samples was associated with organic matter, although due to the low toxicity of this element and the low concentrations observed, the dose implication was very small. Tritium levels in local seawater were less than 10 Bq l^{-1} at St Bees (Table 8.20). 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 6).

For shellfish, a wide range of radionuclides are detectable, owing to generally greater uptake of radioactivity by these organisms from sediments. Generally, molluscs tend to contain higher concentrations than crustaceans and both contain higher concentrations than fish. Concentrations of beta/gamma-emitting radionuclides are shown in Table 2.6 (Table 2.7 for plutonium-241). Consumers who collect seafood in the Sellafield coastal area provided some of the winkles, mussels and limpets sampled. 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). The highest concentrations from Sellafield discharges are of tritium, carbon-14, and technetium-99. Comparing 2008 and 2007 data across a wide range of sampling locations and shellfish species, concentrations of radionuclides were slightly reduced for technetium-99 due to progressive reductions in discharges of this radionuclide. Concentrations of other radionuclides were broadly similar.

The data for the analysis of fish and shellfish samples (chosen on the basis of potential radiological significance) for transuranic radionuclides in 2008 are presented in Table 2.7. Transuranics are less mobile than other radioelements 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 2008 were generally similar to those in 2007; those from the north-eastern Irish Sea were the highest concentrations of transuranics found in foodstuffs in the UK. In comparison to 2007 data, some higher concentrations were measured for plutonium radionuclides and americium-241 at specific locations. However the elevated concentrations observed in 2007 in lobsters and a range of molluscs in the Sellafield coastal area were reduced in 2008, and similar to previous levels in 2006 (albeit americium-241 in lobster was slightly higher in 2008). Overall, a similar reduction in 2008 was also generally observed with relatively lower concentrations measured for plutonium radionuclides and americium-241 in winkles from Tarn Bay, in mussels from Whitehaven, and in a range of molluscs and crustaceans from the North Solway coast, in comparison to 2007 and 2006 data. These observations are likely to have resulted from a combination of mechanisms including natural environmental variability, in-growth of americium-241 from its parent radionuclide and redistribution of sediments due to natural processes.

Monitoring of sediments

Radionuclides in Sellafield liquid discharges are taken up into sediments along the Cumbrian Coast in particular in more muddy (fine grained) areas such as estuaries. Some of these areas are used by the public. Levels of radionuclides are regularly monitored, both because of their relevance to exposure and in order to keep distributions of radioactivity under review. The results for 2008 are shown in Table 2.8. 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, rather than the coarser-grained sands on open beaches. 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 2008 were generally similar to those in 2007.

The trends over the last decade of discharges from Sellafield and concentrations in mud from Ravenglass are shown in Figures 2.13 – 2.16. The concentrations of most radionuclides have decreased over the past 25 years in response to decreases in discharges, with sustained reductions in discharges of caesium-137 and transuranic elements. Discharges of cobalt-60 have been variable over the last decade but reducing in recent years, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 2.15). Over the last decade, caesium-137 and transuranic levels in sediments have generally remained constant with the lowest levels reported in 2008 (Figures 2.13 – 2.14, 2.16). Since the mid 1990s, discharges of caesium-137, plutonium isotopes and americium-241 have remained at low levels, but there has been some variability and even a suggestion of progressive increases in the concentrations in sediments (peaking over the period, ~2003 – 2006). The likely explanation is that this is 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 in-growth from the parent plutonium-241 already present in the environment. The effect is less apparent in fish and shellfish (Figures 2.10 – 2.12) and will continue to be monitored. Caesium-137 and americium-241 in sediments from coastal locations in the vicinity of Sellafield are also shown in Figure 2.17. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations at a given location are generally similar in most recent years, and any fluctuations are most likely due to normal variability in the environment. There is no suggestion of progressive increases in the concentrations in sediments in recent years for locations at distance from Sellafield.

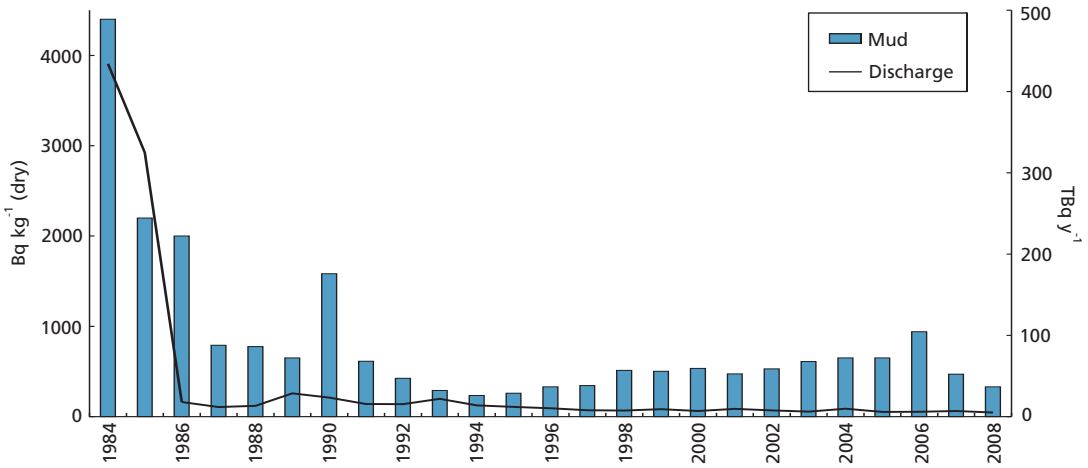


Figure 2.13. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1984-2008 (data prior to 1988 are from BNFL surveys)

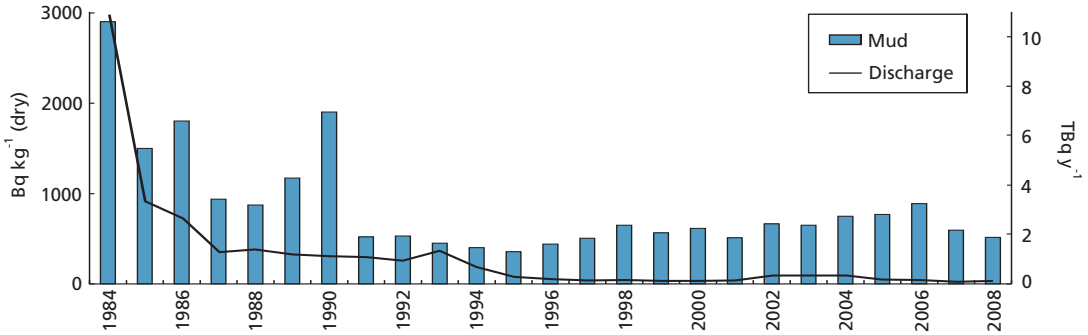


Figure 2.14. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass, 1984-2008 (data prior to 1988 are from BNFL surveys)

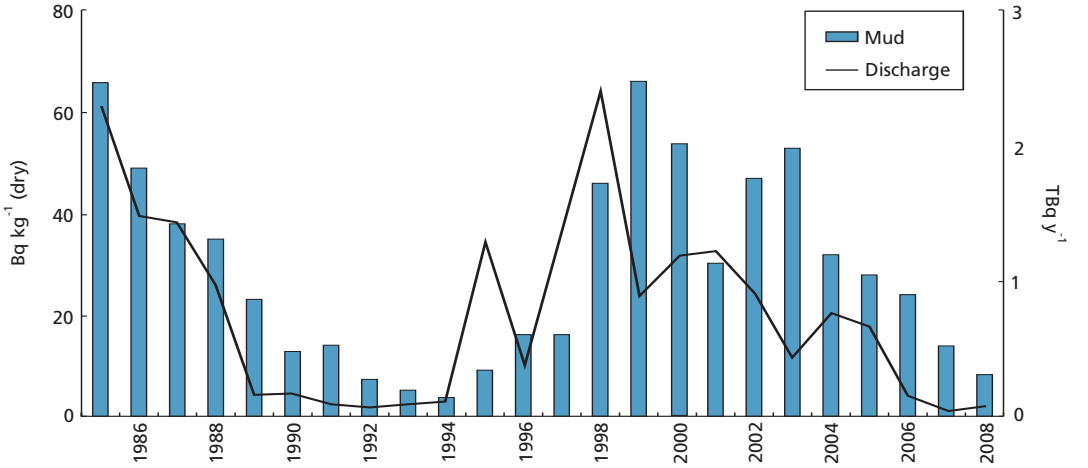


Figure 2.15. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1985-2008 (data prior to 1988 are from BNFL surveys)

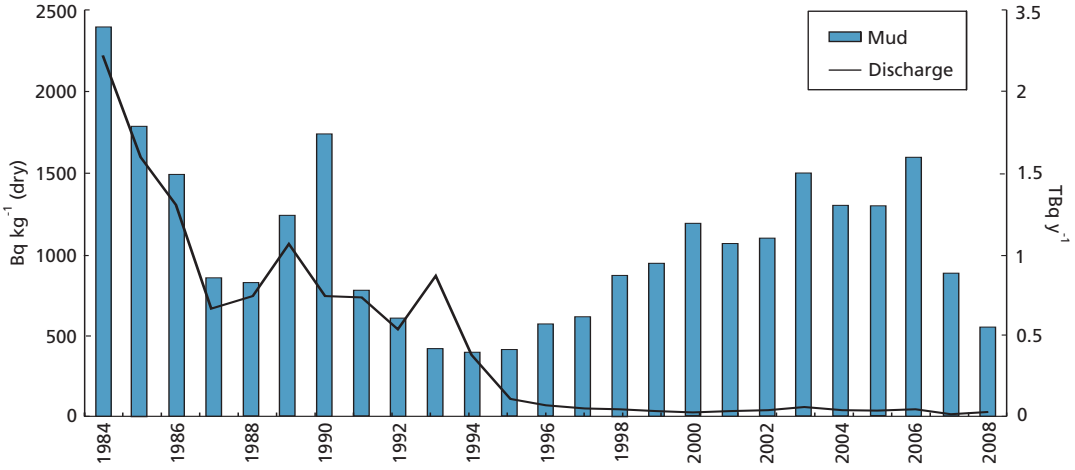


Figure 2.16. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1984-2008 (data prior to 1988 are from BNFL surveys)

Monitoring of dose rates

Dose rates are regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation dosimeters. Table 2.9 lists the locations monitored by the environment agencies and the gamma dose rates in air at 1 m above ground. Dose rates over intertidal areas throughout the Irish Sea in 2008 were similar to those data for the same locations in 2007. Slightly higher gamma dose rates from Greenend and Workington Harbour were measured in 2008, than in 2007. This is likely to have been due to normal variability in the environment. Gamma dose rates measured on the banks of the River Calder, which flows through the Sellafield site, continued to show significant excess above natural background downstream of the site (of approximately 0.04 μGy h^{-1}). Although the dose rates are locally enhanced, occupancy by the public, mainly anglers, is low in this area (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.

Gamma dose rates above mud and salt marshes, from a range of coastal locations in the vicinity of Sellafield, are shown in Figure 2.18. 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 prominent in recent years. Spatial variability of dose rates is expected, depending on ground type; generally higher dose rates being recorded over areas with finely divided sediments. For each location, there has been variation over time. Locations that are further afield from Sellafield show dose rate values that only marginally exceed average UK natural background rates. In 2008, gamma doses around the North Wales coast were overall slightly higher, in comparison to 2007.

Over the last 30 years, levels of radioactivity in the environment around Sellafield have declined as a result of reduced discharges. In more recent years the levels in the Esk have shown a less clear trend, with concentrations of some radionuclides fluctuating from year to year (for example, see Figure 2.14). This effect could be due to the dynamic nature of the sediment in the estuary, which is eroded and transported by tide and freshwater, periodically exposing older deeper sediment containing radioactivity from historic discharges. Due to the variations seen in recent years and local concerns, the Environment Agency initiated a more detailed study of dose rates in the Esk Estuary in 2007. The objectives of the study were to assess the current level of external gamma radiation exposure in the estuary, and changes in the measured dose rates, relative to a more detailed survey of the estuary undertaken in 1989 (Kelly and Emptage, 1991). In July and August 2007, a six week intensive survey of gamma dose rates was undertaken at 576 locations in the Esk Estuary. The University of Liverpool (Institute for Sustainable Water Integrated Management and Ecosystem Research (SWIMMER)) undertook the study.

The mean dose rate across all 576 locations was 0.14 µGy h^{-1}, with a range of 0.07 – 0.28 µGy h^{-1}. This indicates a significant decrease compared to the mean dose rate reported in 1989 (at similar locations) of 0.23 µGy h^{-1} (range 0.07 – 0.61 µGy h^{-1}). The highest gamma dose rates measured in both surveys are from comparable locations within the estuary. The reduced dose rates in the 2007 survey are due to the effects of reductions in radionuclide discharges from the Sellafield site and also radioactive decay of the inventory within the Esk Estuary sediments and soils since 1989. The full report on this study (Wood *et al*., in prep) will be published by the Environment Agency later this year.

Monitoring of fishing gear

During immersion in seawater, particles of sediment on which radioactivity is adsorbed may become trapped on fishing gear. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination meters. Results for 2008 are presented in Table 2.10. Overall, measured dose rates were generally similar to those in 2007 and lower than in recent years.

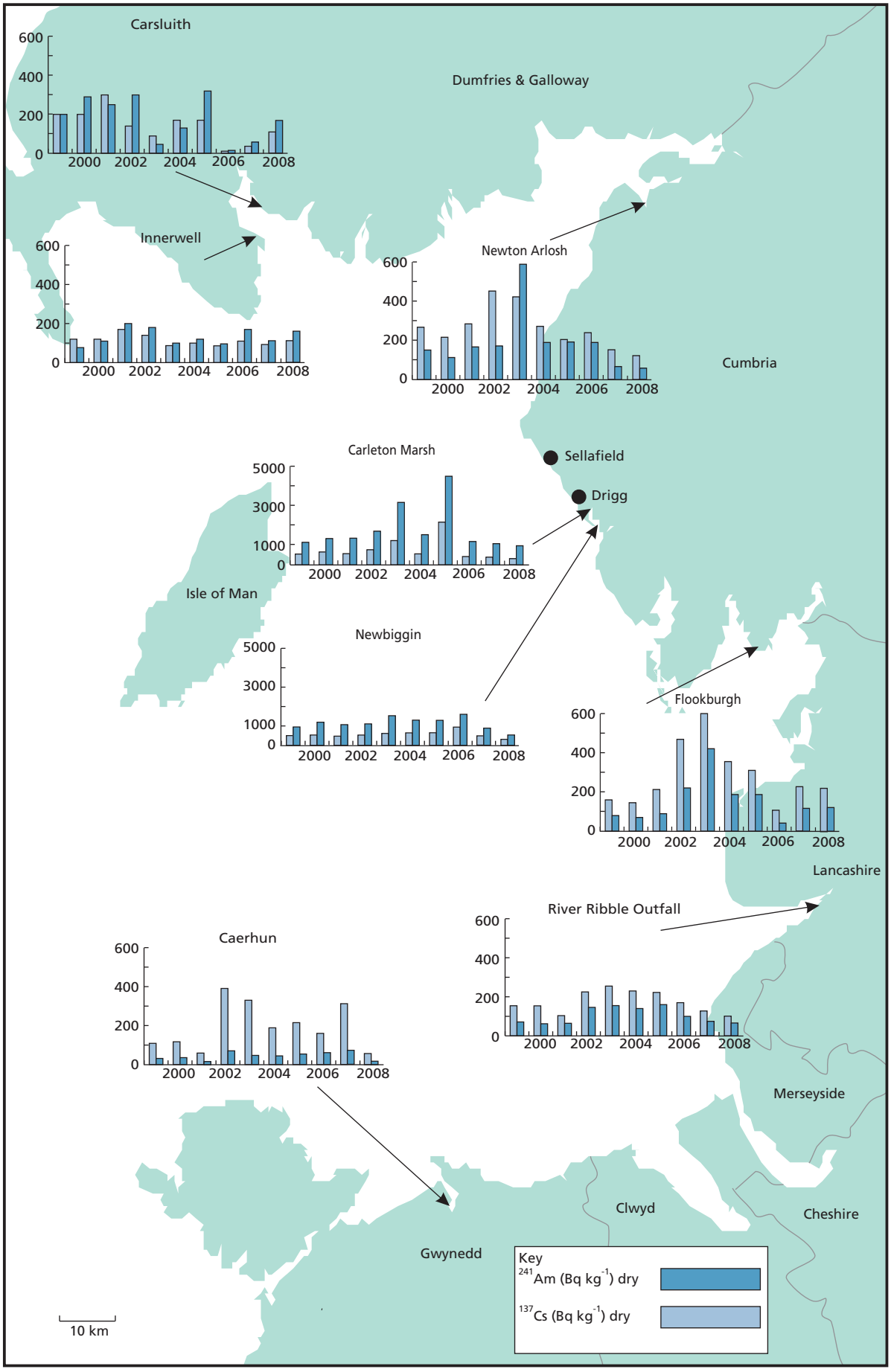


Figure 2.17. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 1999-2008 (Note different scales used for Newbiggin and Carleton Marsh)

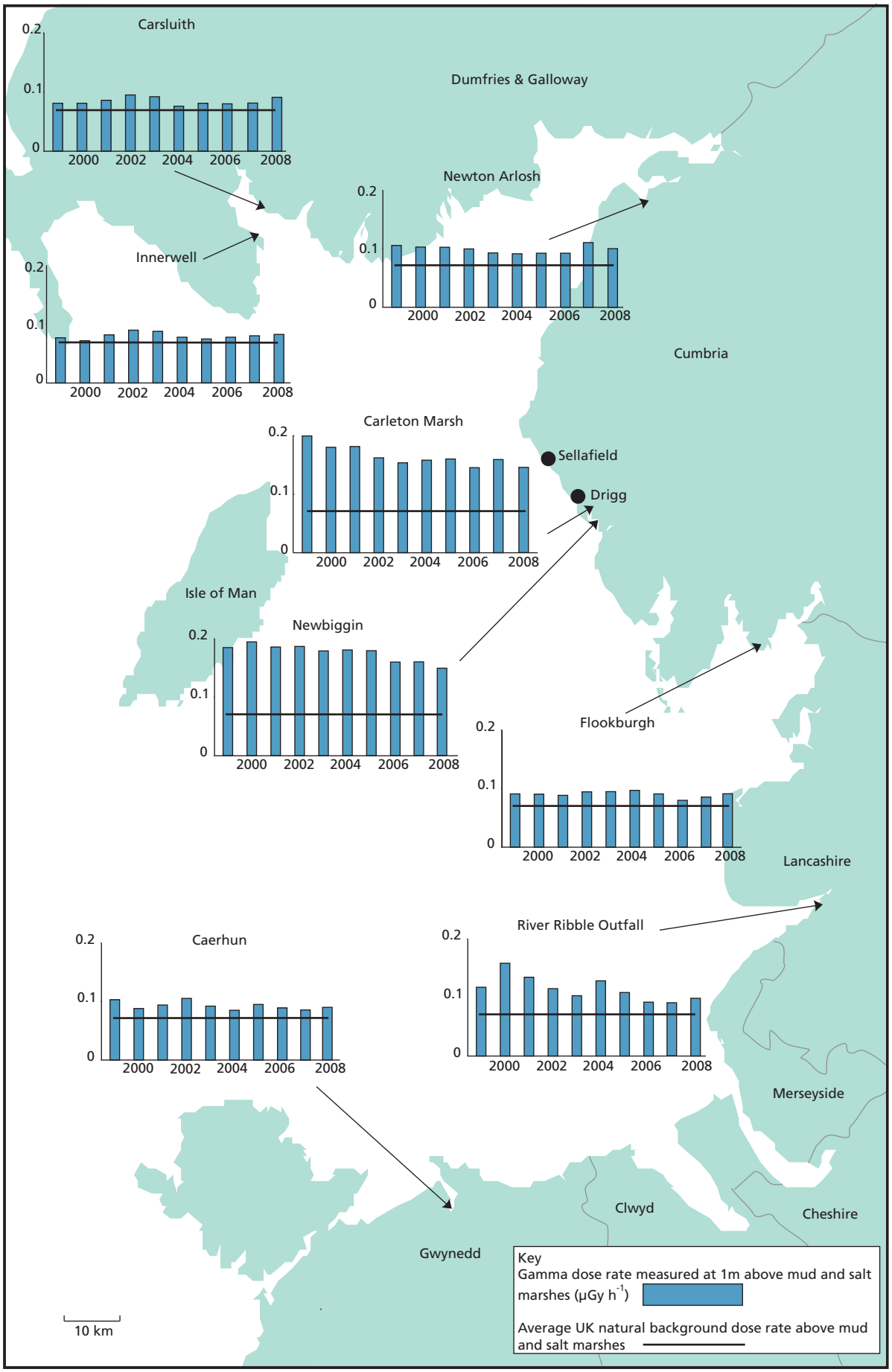


Figure 2.18. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 1999-2008

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments, using contamination monitors, to allow estimation of exposure for people who handle sediments regularly are presented in Table 2.11. In 2008, dose rates were reduced at the majority of sites, in comparison to 2007, with some measurements not detecting beta activity.

More general beta/gamma monitoring for the Environment Agency of contamination on beaches using portable probes continued to establish whether there are any localised 'hot spots' of activity, particularly in strand lines and beach debris. In 2008, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

In February 2008, the Environment Agency published a formal programme of work for the assessment of contamination by radioactive particles on and around the west Cumbrian coastline. The assessment is focussed on public protection from high activity discrete radioactive particles that have been released to the environment from activities at Sellafield site (Environment Agency, 2008c). In June 2009, the Environment Agency reported on the current status of the work, in the context of delivery against the original objectives, and the focus and direction that are needed to take the work forward, ultimately to a point of completion (Environment Agency, 2009). The work reported here included investigating the distribution and behaviour of Sellafield-related particles, particle analysis and identification, risks from particles, and a review of particle dispersion and transport models focused on the Eastern Irish Sea and Solway Firth.

Since vehicle-mounted beach survey work began in November 2006, and to the end of 2008, a total of around 540 Ha of beach area has been surveyed by the Sellafield site operator's contractors, stretching from the north Solway coastline (at the request of SEPA), down to Drigg point. The survey equipment used to date is the Groundhog evolution system, which was developed for Dounreay, and has specific capability in relation to the detection of medium/high energy gamma emitting radionuclides. The finds that have been identified in this period comprise 570 stones, pebbles and particles, with around 40% being less than 2 mm in diameter. All have been removed from the beaches. The vast majority of the finds are concentrated on the 3 km stretch of beach running NW from Sellafield site.

The work carried out in 2006 and 2007 has been previously summarised (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2008). Initial dose measurements and gamma spectrometry results indicate that these finds fit within the broad scope of particle characteristics identified during the previous year's beach surveys.

Overall find rates (numbers per hectare surveyed) are in the main lower in 2008 compared to the figures for 2007. Monitoring along the Cumbrian coast will continue in 2009/10 as part of the operator's routine environmental monitoring programme, and will include enhanced strandline and large area beach monitoring capability in relation to the detection of americium-241, strontium-90 and plutonium isotopes.

The Health Protection Agency (HPA) has restated the advice that it originally offered to the Environment Agency in 2007, that no special precautionary measures are necessary regarding access to or use of beaches in the area. However, the HPA and the Environment Agency will continue to work with relevant authorities to keep the situation under review.

Periodic updates on the beach monitoring and Sellafield radioactive particles are available from the Environment Agency (Environment Agency, 2009). Further detail on the monitoring data compiled so far can be obtained from Sellafield Limited (www.sellafieldsites.com).

In December 2007, SEPA published a strategy document for the assessment of the potential impact of Sellafield radioactive particles on members of the public in south-west Scotland (Scottish Environment Protection Agency, 2007). Also in December 2007, the beach monitoring programme was temporarily extended to include two locations on the north Solway coastline (Kirkcudbright Bay and Southerness) based on some limited modelling work on the movement of particles undertaken for the Environment Agency following a request by SEPA. No particles were detected at these locations. SEPA is maintaining a watching brief on the situation in as much as it may effect Scotland.

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials (concentrating particular radionuclides), facilitating assessments and assisting the tracing of these radionuclides in the environment. Table 2.12 presents the results of measurements in 2008 of seaweeds from shorelines of the Cumbrian coast and further afield.

Fucus seaweeds are particularly useful indicators of most fission product radionuclides; 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. The effects of technetium-99 discharges from Sellafield on concentrations in seaweed, between 1990 and 2008, are shown in Figure 2.19. In the north-east Irish Sea there has been a continued decrease in technetium-99 levels, over the last few years, concurrent with a reduction in discharges; the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s. In general, 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. In comparison to 2007, technetium-99 levels in *Fucus* were lower in 2008, including at locations (Cemaes Bay, Carlingford Lough and Auchencairn) previously known to have had fluctuating levels over recent years. Variations in levels in the past were most likely the result of complex hydrographic

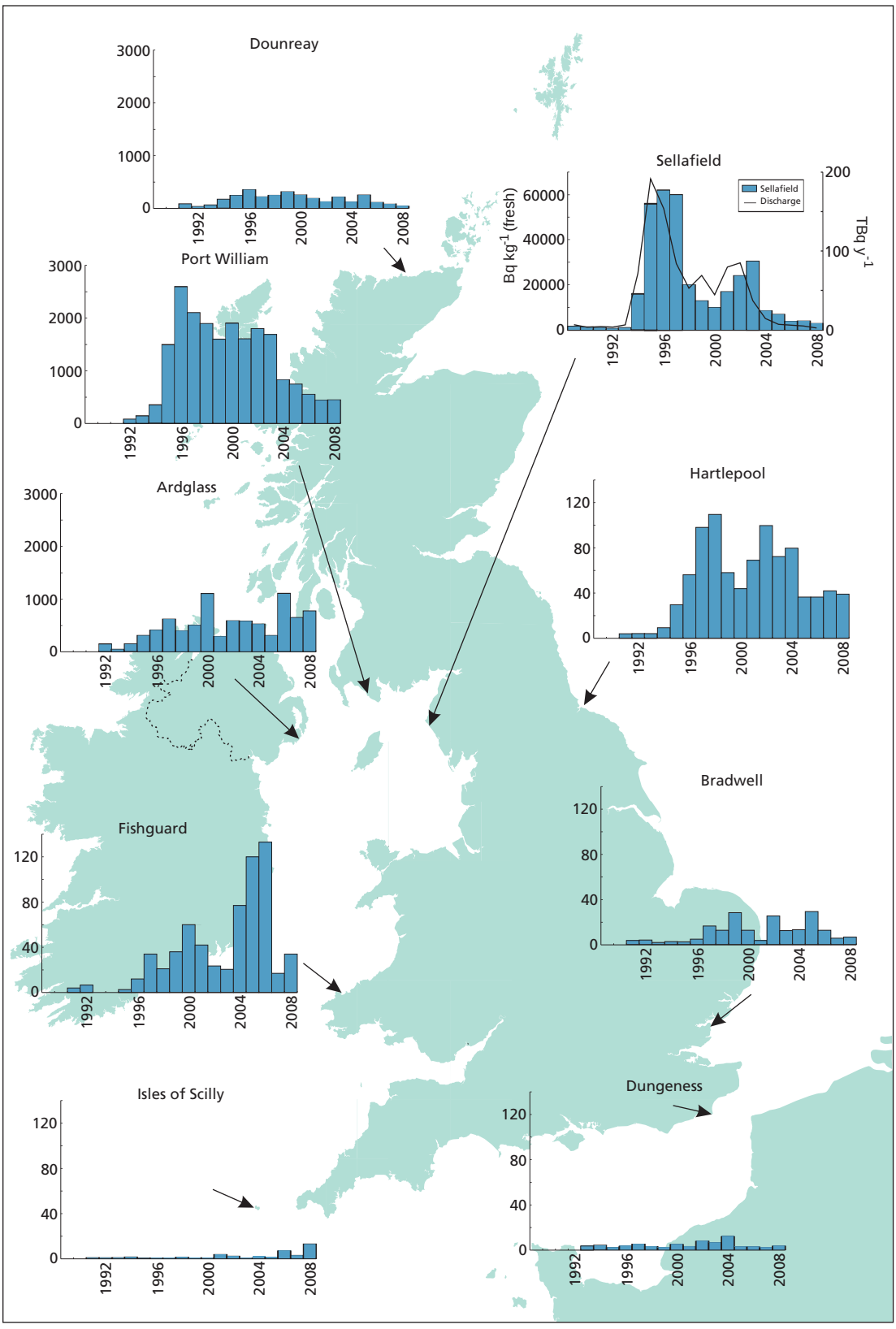


Figure 2.19. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1990-2008

transport patterns in the Irish Sea, with technetium-99 being dispersed to a variable degree before arriving at distant locations (Leonard *et al.,* 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, such as Auchencairn, and as was observed in seawater in Liverpool Bay for 1998 (McCubbin *et al.*, 2002).

Seaweeds are sometimes used as fertilisers and soil conditioners and this potential pathway for the transfer of radionuclides into the food chain continues to be investigated. The results in 2008 are shown in Table 2.13 (together with data for Hinkley Point). 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). Although seaweed harvesting in the Sellafield area continues to be rare, several plots of land were identified and investigated further. Samples of soil were analysed by gamma-ray spectrometry and for technetium-99. The Sellafield soil (compost) data show enhanced concentrations of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Where comparisons can be made, technetium-99 concentrations in edible parts of the vegetables grown in these soils were similar to those found in 2007. Concentrations of gamma-emitting radionuclides were close to or below the LoD in vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2008; this pathway has, therefore, remained 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 2008 are presented in Table 2.12. In 2008, ruthenium-106 concentrations in *Porphyra* from the Cumbrian coast were similar to those in 2007 and reduced in comparison with recent years (due to the decreased discharges of this radionuclide in 2005 and 2006). Samples of laverbread from the major manufacturers are regularly collected from markets in South Wales and analysed. Results for 2008 are also presented in Table 2.12; concentrations of radionuclides were below the LoD.

In the Scottish islands, seaweed is also eaten directly by sheep and cattle grazing on the foreshore. The research study being undertaken by FSA, EA and HPA, mentioned above, is also investigating the potential transfer of radionucldies from seaweed to meat products. Further information is given in Appendix 5. Investigations have shown that this transfer pathway 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 2006 suggested that this dose estimate remains valid (Environment Agency, Environment and Heritage Service, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2007).

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 2008 are presented in Table 2.14. In general, the data are similar to those for 2007 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. The evidence for sea to land transfer is very limited in 2008. In comparison to the positively detected data in 2007, technetium-99 levels in cabbage and grass were very low or below the LoD. 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 if the source was only (or entirely) due to 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. 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 three 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 2008 in Tables 2.5 and 2.7 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 8.

Sampling of fresh water from rivers and lakes in west Cumbria is conducted 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 2008 are included in Table 2.15. The gross alpha and beta activities for drinking waters were below the World Health Organisation (WHO) recommended values of 0.5 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 to the Ehen Estuary, at the confluence with the River Calder. There was some evidence of tritium at the outfall (Table 2.15). However, the waters are not potable and the low concentrations are of no radiological significance. Table 2.15 also includes the results of monitoring from the Ehen Spit (Figure 2.6) 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 2008 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).

2.3.3 Monitoring of unusual pathways

In 1998, high concentrations 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 only 20 birds contaminated at the highest concentration would have given a 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, the site operator has 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 2008 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon increased in 2008 (22 Bq kg^{-1}), in comparison to the value reported in 2007 (0.35 Bq kg^{-1}), but lower than in 2006 (35 Bq kg^{-1}). Concentrations of artificial radionuclides were low and would add little to the exposure of local consumers. The Food Standards Agency will continue to monitor this pathway. 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.

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 2008, samples were taken from the same drains as in previous years. The results of analyses in 2008 are shown in Table 2.16. In recent years, concentrations have generally fallen significantly since remedial measures to reduce contamination were taken.

2.3.4 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 Appendix 1. The results are presented in Table 2.18. Calculations were performed for four ages (adult, 10y, 1y and prenatal); doses received by infants (1y) were found to be the highest, at 0.027 mSv (adult: 0.019; 10y: 0.018; prenatal: 0.012). The most significant contributions to infants' dose were from strontium-90 and ruthenium-106, the latter concentrations in foods measured below the LoD, and therefore the dose was likely to be a maximum value. The increase in infants' dose in 2008 (0.023 mSv in 2007) was largely attributed to the inclusion of the LoD for cobalt-60 in milk. Cobalt-60 was included this year because detectable activity was observed in other samples from the terrestrial environment. The most important foodstuff in 2008 was milk, which accounted for 61 per cent of the dose. Doses as a result of environmental non-food pathways (mostly inhalation of radionuclides and external dose from noble gases) were very low and less than 0.005 mSv.

The pathway (food and external/inhalation) and radionuclide contributions to dose from gaseous discharges from Sellafield for the period 2002 – 2008 are shown in Figure 2.20. Prior to 2008, the trend has been a generally declining one with reductions in doses of about 10 per cent over the last 5 years. The increase in 2008 is attributed to the inclusion of the LoD for cobalt-60 in milk. 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.

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 revised, further to the habits survey in 2008; small changes were found in the amounts and mixes of species consumed, with a decrease in mollusc consumption (for 2008 only) and a decrease in occupancy rates over sediments (for both 2008 and 2004 – 2008). The revised habits data are given in detail in Appendix 1. Two sets of habit data were used in the assessments. One was based on the habits seen in the area each year (2008 habits survey). The second was based on a five-year rolling average using habit data gathered from 2004 to 2008. 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 data and also rolling five-year averages. 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. These are used for the main assessment of doses from liquid discharges, and follow the recommendations of the report of the Consultative Exercise on Dose Assessments (Food Standards Agency, 2001a).

Table 2.18 summarises doses to seafood consumers in 2008. The doses to the local critical group of high-rate consumers from artificial radionuclides, using annual and rolling average habits data, were both 0.23 mSv. These doses each include a contribution due to external radiation exposure over sediments. The rolling average derived dose is slightly lower than the corresponding dose reported in 2007 (0.24 mSv), and the same as in 2006. Most of this dose was due to historic discharges from Sellafield. The breakdown, by nuclide, of the contributions to dose is shown in Figure 2.21. Recent and current discharges of technetium-99 contributed just over 1 per cent (~2 per cent in 2007) of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose (75 per cent) were plutonium-239/240 and americium-241.

Data for naturally-occurring radionuclides in fish and shellfish are discussed in Section 7. However, the effects on the Sellafield critical group of the historic discharges of naturally-occurring radionuclides from non-nuclear industrial activity from the former phosphate works at Whitehaven (Cumbria) 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 1). However, using maximising assumptions for the dose coefficients, and the rolling average habits data, the dose to the local group of seafood consumers due to the enhancement of concentrations of naturally-occurring radionuclides from former non-nuclear industrial activity in the Sellafield area in 2008 was estimated to be 0.39 mSv. Most of this was due to polonium-210. Slightly higher concentrations of polonium-210 in mollusc and fish samples, and to a lesser extent higher concentrations of lead-210 in mollusc and crustacean samples, contributed to the increase in dose from 2007 (0.28 mSv). The origin of the polonium-210 in shellfish and its variation in recent years is considered in more detail in Section 7. Taken with the 0.23 mSv dose from artificial radionuclides from Sellafield this gives, when rounded again to two significant figures, a combined dose to the critical group of 0.62 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.

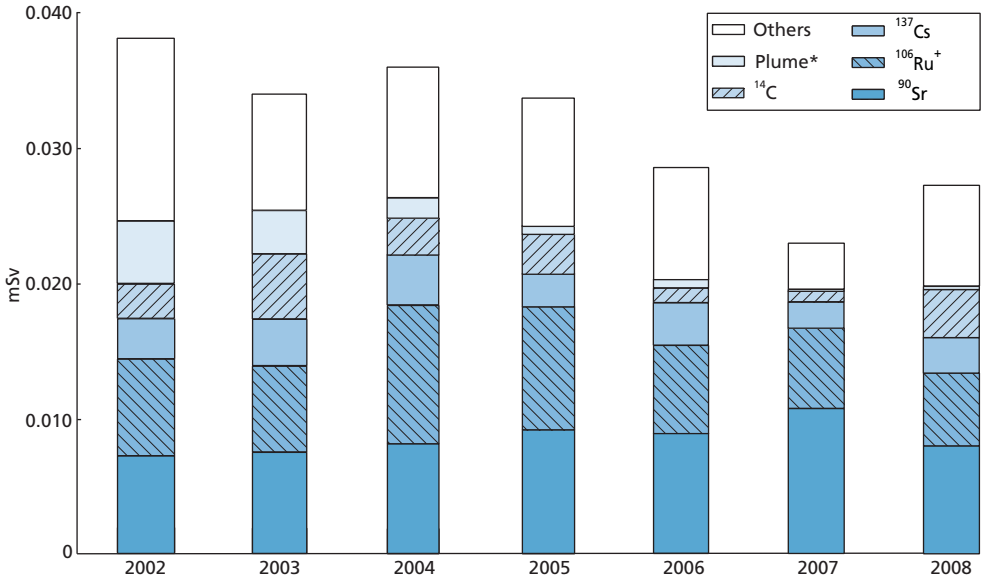


Figure 2.20. Contibutions to dose from gaseous discharges from Sellafield, 2002-2008
(* External and inhalation pathways, + based on limits of detection for concentrations in foods)

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 2.18). Where appropriate, the dose from consumption of seafood in wider communities 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 generally small changes in the doses in each area when compared with those in 2007 (given in Figure 2.22 and Table 2.17). For the Dumfries and Galloway coast, the dose decreased from 0.060 mSv in 2007 to 0.047 mSv in 2008, due to a combination of lower gamma dose rates and a reduction in americium-241 in mollusc samples from North Solway. At the North Wales coast, in 2008, the dose was 0.018 mSv (0.014 mSv in 2007). The increase was largely attributed to a slight overall increase in gamma dose rates in 2008. 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 per year of fish from landings at Whitehaven and Fleetwood, is also given in Table 2.17. This consumption rate represents an average for typical fish-eating members of the public in Cumbria. The dose to such a person was very low, less than 0.005 mSv in 2008.

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 2008 are presented in Table 2.9. The results of the assessment of external exposure pathways are included in Table 2.18. 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 2008, their dose was 0.13 mSv or 13 per cent of the dose limit for members of the public (see Section 2.2). Other groups received lower external doses in 2008. The most important of these was found in the Ravenglass estuary, where exposure is represented by a nature warden (0.046 mSv). In 2007, the radiation exposure to a nature warden was 0.027 mSv, the increase was largely attributed to the inclusion of the new habits data in 2008, resulting in an increase in occupancy rates (see Appendix 1). Prior to 2008, doses in areas relevant to the Ravenglass nature warden have remained broadly similar over recent years (Figure 2.4).

A further group was identified, during the habits survey along the Dumfries and Galloway coast in 2007, consisting of wildfowlers that were exposed to external radiation whilst on salt marshes. The total exposure to wildfowlers including external dose was 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.18). The decrease in dose from 0.008 mSv in 2007 was attributed

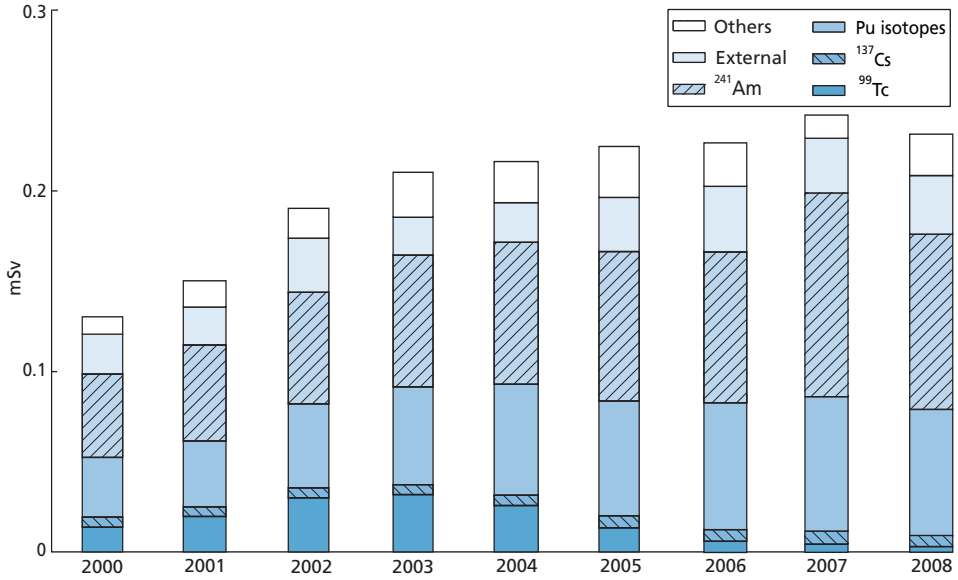


Figure 2.21. Contributions to dose to seafood consumers at Sellafield, 2000-2008

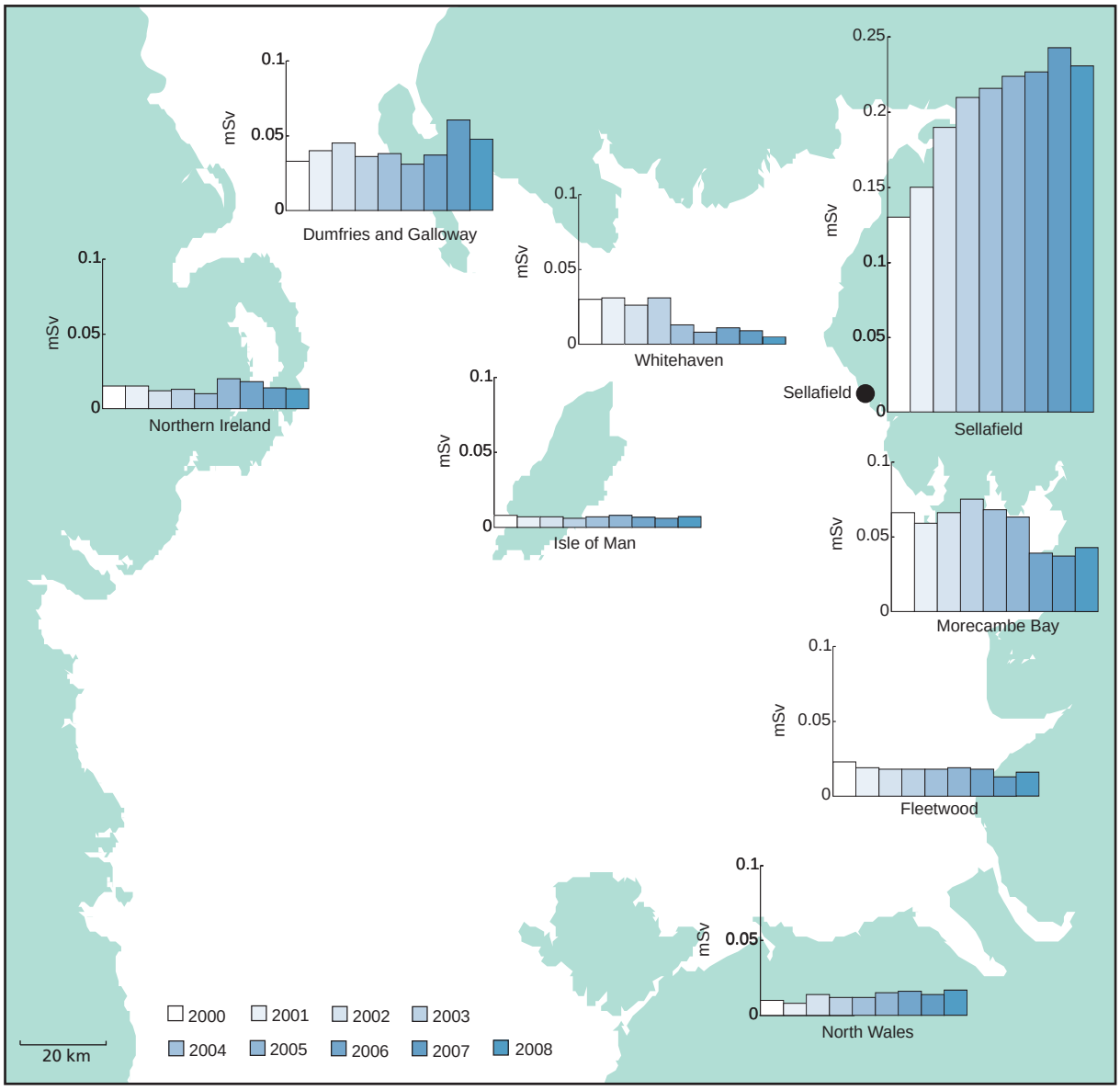


Figure 2.22. Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2008

to a reduction in measured dose rates at Skyreburn Bay, and this observation is consistent with gamma dose rates being generally lower than in 2007.

As in 2007, the doses received from a number of other activities were estimated in 2008. Assessments were undertaken of typical residents using local intertidal areas for recreational purposes. The use by residents of two different environments, at a number of locations at a distance from the Sellafield influence, have been assessed; residents that visit and use beaches and residents that visit local muddy areas or salt marsh. Typical occupancy rates have been assumed and appropriate gamma dose rates used from Table 2.9. Occupancy rates are provided in Appendix 1. The doses are represented spatially in Figure 2.23.

Dose from recreational use of beaches varied from 0.007 to 0.012 mSv with the higher doses being closer to the Sellafield source. The equivalent doses for use of saltmarsh and muddy areas had a greater variation from <0.005 to 0.020 mSv but were of a similar order of magnitude. The values were similar to those for 2007. As in 2007, an assessment was undertaken of the radiation exposure of the typical tourist visiting the coast of Cumbria. The activities included consumption of local seafood and occupancy on beaches. Typical occupancy rates have been assumed, concentrations of radioactivity in fish and shellfish used from Table 2.5, and appropriate gamma dose rates used from Table 2.9. Consumption and occupancy rates are provided in Appendix 1. Including a contribution from external exposure the dose to a typical tourist was estimated to be 0.005 mSv. The dose in 2007 was less than 0.005 mSv and the increase was attributed to slightly higher gamma doses in 2008.

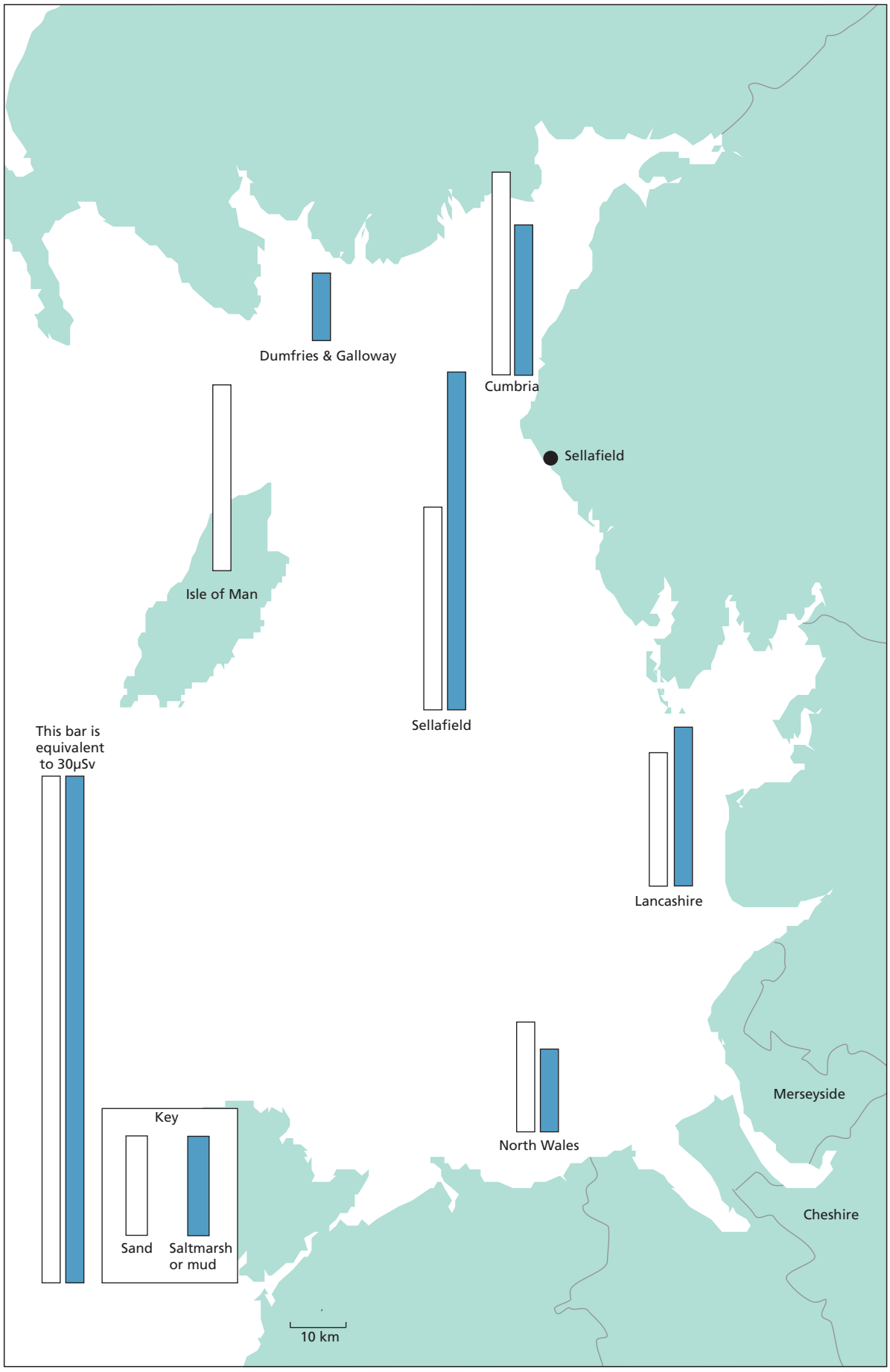


Figure 2.23. Individual radiation exposures to typical residents visiting beaches and other intertidal areas, 2008

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 fishing gear, and by bait diggers and shellfish collectors handling sediment. Revised handling figures are provided in Appendix 1. For those most exposed, a time handling nets and pots of 980 h per year was appropriate in 2008. The skin dose from handling of fishing gear in 2008, including a component due to naturally-occurring radiation, was 0.049 mSv, which was less than 0.5 per cent of the appropriate annual dose limit of 50 mSv specifically for skin. The dose was less, at 0.036 mSv in 2007. The increase in dose was attributed to the inclusion of the new habits data resulting in an increase in handling rates. Nevertheless, handling of fishing gear continued to be a minor pathway of radiation exposure. The skin dose to bait diggers and shellfish collectors, based on a time handling sediment of 960 h per year, was 0.026 mSv in 2008 which was also less than 0.5 per cent of the skin dose limit. The decrease in dose from 2007 (0.083 mSv) was attributed to the reduction in measured dose rates at the majority of sites in 2008.

Doses from atmospheric sea to land transfer

The exposure due to consumption of terrestrial foods potentially affected by sea to land transport by sea spray of radionuclides at Ravenglass in 2008 is given in Table 2.18. The infant age group received the highest exposure, the largest contribution of dose was from strontium-90 and ruthenium-106 in milk. The ruthenium-106 concentration was at the LoD. The dose, including contributions from Chernobyl and weapon test fallout, was calculated to be 0.014 mSv, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv, and similar to that in 2007. Sea-to-land transfer therefore is not of radiological importance in the Ravenglass area.

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 2008 was estimated to be 0.009 mSv. Although lower than the value in 2006 (0.012 mSv), the decrease in dose was attributed to the unavailability of a legume sample in 2008, which accounted for the disparity. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales are expected to be much lower than near Sellafield. Exposure of vegetable consumers at Hinkley Point is given in Section 4.6. 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 on beaches in 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 1 mSv per year for members of the public in 1998 when concentrations of technetium-99 would have been at substantially higher levels than in 2008 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999). A study of seaweed related pathways with a focus on Scotland began in 2006 and is due to complete in 2009 (see Appendix 5 for further information).

Doses from all sources

The *total dose* from all sources (discharges and direct radiation) has been assessed using the methods in Appendix 4. The highest *total dose* in 2008 was 0.47 mSv to the mollusc consumer group. This is an increase from 0.37 mSv in 2007 and is largely attributed to increased concentrations of natural radionuclides in mollusc samples. The *total dose* was made up of 0.18 mSv from radionuclides from Sellafield (as in 2007), and 0.29 mSv from the residue of past discharges of natural radionuclides (in particular polonium-210) from the now closed industrial phosphate plant near Whitehaven.

Table 2.1. Individual radiation exposures - Capenhurst and Springfields, 2008

Site	Exposed population group[a]	Exposure, mSv per year					
		Total	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Capenhurst	Consumers of locally grown food[b,e]	<0.005	-	<0.005	-	-	<0.005
	Children playing at Rivacre Brook[d,e]	0.010	-	-	0.010	<0.005	-
	All sources[d,f]	0.17	-	-	-	-	-
Springfields	Seafood consumers	0.017	<0.005	-	0.014	-	-
	Houseboat occupants	0.13	-	-	0.13	-	-
	Fishermen handling nets or pots[c]	0.066	-	-	0.066	-	-
	Children playing at Lower Penwortham[d,e]	<0.005	-	-	<0.005	<0.005	-
	Farmers and wildfowlers	0.033	-	-	0.033	-	-
	Consumers of locally grown food[e]	<0.005	-	<0.005	-	-	<0.005
	All sources[f]	0.16	-	-	-	-	-

[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*
[f] *The* total dose *due to discharges and direct radiation. See Appendix 4*

Table 2.2(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{234}Th	^{234}U	^{235}U
Marine samples											
Flounder	Liverpool Bay	1	<25								
Flounder	Mersey Estuary	1	<25								
Dab	Liverpool Bay	1	<25								
Dab	Mersey Estuary	1	<25								
Shrimps	Wirral	2	<25	<0.04	0.79	<0.39	<0.10	1.5	*		
Mussels	Liverpool Bay	2	<25								
Mussels	Mersey Estuary	2	<25								
Cockles	River Dee	4		<0.10	2.0	<0.95	<0.23	2.3	<3.9		
Sediment	Rivacre Brook	1[E]			110			3.0	56	96	4.4
Sediment	Rivacre Brook (1.5 km downstream)	2[E]			100			2.5	<24	38	1.8
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			43			<1.7	<18	28	1.5
Sediment	Rossmore (4.3 km downstream)	2[E]			29			<0.90	<15	16	<2.0
Freshwater	Rivacre Brook	2[E]	<4.5		<0.55					0.26	<0.014
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<4.5		<0.25					0.036	<0.0050
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.0		<0.30					0.054	<0.0060
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.5		<0.30					0.040	<0.0050

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{238}U	^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples											
Shrimps	Wirral	2					<0.07				
Cockles	River Dee	4			0.19	1.1	2.6	*	0.0040		
Sediment	Rivacre Brook	1[E]	51	<1.0						390	1000
Sediment	Rivacre Brook (1.5 km downstream)	2[E]	23	<1.0						270	820
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	16	<1.0						<210	760
Sediment	Rossmore (4.3 km downstream)	2[E]	8.9	<1.0						<130	920
Freshwater	Rivacre Brook	2[E]	0.14	<0.10						0.26	0.65
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	0.020	<0.10						<0.075	0.31
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	0.028	<0.10						<0.060	0.31
Freshwater	Rossmore (4.3 km downstream)	2[E]	0.020	<0.10						<0.13	0.34

Table 2.2(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H[c]	^{99}Tc	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		5	<2.6	<0.0045		<0.0017	<0.00052	<0.0015
Milk	max		<2.8			0.0032	<0.00070	0.0028
Cabbage		1				0.0020	<0.00070	0.0015
Gooseberries		1		<0.018		0.0021	<0.00070	0.0030
Potatoes		1		<0.018		0.0071	<0.00090	0.0058
Grass		4		0.018		0.0055	<0.0018	0.053
Grass	max					0.12	0.0022	0.11
Grass/herbage	North of Ledsham	1[E]		<3.0	<3.3	<0.40	<0.40	<0.80
Grass/herbage	South of Capenhurst	1[E]		2.0	<2.0	0.34	<0.11	0.31
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<1.1		<0.50	<0.40	<0.40
Grass/herbage	East of station	1[E]		1.9		0.66	<011	0.42
Silage		2		0.018		0.68	<0.027	0.69
Silage	max					1.3	0.053	1.4
Soil		1[#]				8.3	0.36	7.8
Soil	North of Ledsham	1[E]		<9.0	22	17	<2.0	18
Soil	South of Capenhurst	1[E]		9.9	14	20	<2.0	13
Soil	Off lane from Capenhurst to Dunkirk	1[E]		<4.0		10	<2.0	10
Soil	East of station	1[E]		9.9		18	<2.0	20

* *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 (except for those soil samples marked with a # which are fresh concentrations)*

[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*

[#] *Fresh concentrations*

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Mud and grass	1	0.097
Rivacre Brook Plant outlet	Concrete and grass	1	0.10
Rivacre Brook 1.5 km downstream	Grass and mud	1	0.082
Rivacre Brook 1.5 km downstream	Grass	1	0.084
Rossmore Road West 3.1 km downstream	Grass and mud	2	0.082
Rivacre Brook 4.3 km downstream	Mud	1	0.079
Rivacre Brook 4.3 km downstream	Mud and grass	1	0.083

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{129}I	^{137}Cs
Marine samples										
Dover sole	Ribble Estuary	1			<0.18			<0.37		2.2
Salmon	Ribble Estuary	1			<0.07			<0.17		0.18
Bass	Ribble Estuary	1			<0.10			<0.27		11
Grey mullet	Ribble Estuary	2			<0.12			<0.30		3.5
Shrimps	Ribble Estuary	2		34	<0.06		<0.96	<0.17		1.8
Mussels	Ribble Estuary	2			<0.06			<0.13		0.80
Wild fowl	Ribble Estuary	1	<25	45	<0.07	0.70		<0.18	<1.5	0.86
Samphire	Marshside Sands	1			<0.03			<0.07		0.49
Sediment	River Ribble outfall	4[E]			<1.4					100
Sediment	Savick Brook	2[E]			<1.6					140
Sediment	Lea Gate	2[E]			<2.1					270
Sediment	Lower Penwortham Park	4[E]			<2.1					310
Sediment	Penwortham rail bridge	4[E]			<1.1					58
Sediment	Penwortham rail bridge - West bank	2[E]			<2.6					320
Sediment	Penwortham position 1	4[E]			<1.8					95
Sediment	Penwortham position 2	1[E]			<1.7					31
Sediment	Lytham Yacht Club	1[E]			<0.49					140
Sediment	Becconsall	4[E]			<1.5					140
Sediment	Freckleton	1[E]			<0.58					260
Sediment	Hutton Marsh	1[E]			<1.4					580
Sediment	Longton Marsh	1[E]			<2.2					370
Grass	Hutton Marsh	1[E]					2.0			
Soil	Hutton Marsh	1[E]					43			

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{228}Th	^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np
Marine samples										
Dover sole	Ribble Estuary	1				*				
Salmon	Ribble Estuary	1				*				
Bass	Ribble Estuary	1				*				
Grey mullet	Ribble Estuary	2				*				
Shrimps	Ribble Estuary	2	0.0092	0.0030	0.0016	*				<0.0010
Mussels	Ribble Estuary	2	0.19	0.16	0.066	<4.6				
Wild fowl	Ribble Estuary	1	0.0032	0.0074	0.0026	*				
Samphire	Marshside Sands	1								
Sediment	River Ribble outfall	4[E]	23	39	18	<440	15	<1.2	15	
Sediment	Savick Brook	2[E]	34	66	21	3600	25	<1.6	22	
Sediment	Lea Gate	2[E]	47	110	33	15000	40	1.6	37	
Sediment	Lower Penwortham Park	4[E]	61	480	58	<1800	39	<1.9	33	
Sediment	Penwortham rail bridge	4[E]	22	32	17	<830	17	<2.0	16	
Sediment	Penwortham rail bridge - West bank	2[E]	46	150	35	<2400	34	<1.8	32	
Sediment	Penwortham position 1	4[E]	26	95	22	<22	21	<1.0	20	
Sediment	Penwortham position 2	1[E]	15	26	12	<20	17	<2.0	14	
Sediment	Lytham Yacht Club	1[E]	26	40	20	71	220	8.8	220	
Sediment	Becconsall	4[E]	28	55	22	<160	21	<2.0	19	
Sediment	Freckleton	1[E]	45	87	33	870	24	<3.0	25	
Sediment	Hutton Marsh	1[E]	46	260	43	120	29	1.6	25	
Sediment	Longton Marsh	1[E]	27	170	31	<27	25	<2.0	26	

Table 2.3(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Dover sole	Ribble Estuary	1			<0.13				
Salmon	Ribble Estuary	1			<0.07				
Bass	Ribble Estuary	1			<0.10				
Grey mullet	Ribble Estuary	2			<0.25				
Shrimps	Ribble Estuary	2	0.0016	0.011	0.017	*	*		
Mussels	Ribble Estuary	2			1.0				
Wild fowl	Ribble Estuary	1	0.0014	0.0074	0.011	*	*		
Samphire	Marshside Sands	1			0.22				
Sediment	River Ribble outfall	4[E]			67			<320	1100
Sediment	Savick Brook	2[E]			84			560	6700
Sediment	Lea Gate	2[E]			160			1000	20000
Sediment	Lower Penwortham Park	4[E]			160			1600	5200
Sediment	Penwortham rail bridge	4[E]			36			430	1900
Sediment	Penwortham rail bridge - West bank	2[E]			190			820	1700
Sediment	Penwortham position 1	4[E]			44			650	940
Sediment	Penwortham position 2	1[E]			9.8			310	570
Sediment	Lytham Yacht Club	1[E]			100			3400	1600
Sediment	Becconsall	4[E]			88			550	1200
Sediment	Freckleton	1[E]			170			530	2500
Sediment	Hutton Marsh	1[E]			200			1100	2000
Sediment	Longton Marsh	1[E]			110			780	1400

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{90}Sr	^{129}I	^{137}Cs	Total Cs
Terrestrial samples								
Apples		1	<5.0	14	0.029	<0.029		0.031
Blackberries		1	<5.0	16	0.088	<0.028		0.094
Broad beans		1	<5.0	35	0.059	<0.043		0.11
Cabbage		1	<5.0	12	0.38	<0.026		0.055
Onions		1	<5.0	13	0.013	<0.028		0.092
Potatoes		1	<5.0	17	0.042	<0.029		0.17
Rabbit		1	<6.0	15	0.023	<0.025		0.19
Sediment	Deepdale Brook	2[E]					<1.4	
Grass		1					1.8	

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		5				<0.0015	<0.00042	<0.0010
Milk	Max					0.0034	0.00060	<0.0012
Apples		1	0.0019	<0.00070		<0.0011	<0.00040	0.0019
Blackberries		1	0.0024	<0.00090		0.0027	0.00060	0.0038
Broad beans		1	0.0030	<0.0012		0.0044	0.00070	0.0061
Cabbage		1	0.0018	<0.0013		0.0070	0.0016	0.0074
Onions		1	0.0012	0.0014		0.0012	<0.00040	0.00080
Potatoes		1	0.0061	<0.0010		0.0036	<0.00060	0.0040
Rabbit		1	0.0025	<0.0022		0.0025	<0.00080	0.0014
Sediment	Deepdale Brook	2[E]			<46	53	1.8	51
Grass		1				0.77	0.036	0.73
Grass	Site fence	1[E]				3.0	<0.26	2.3
Grass	Opposite site entrance	1[E]				1.3	<0.071	0.93
Grass	Opposite windmill	1[E]				2.0	<0.14	1.9
Grass	Deepdale Brook	1[E]				0.71	<0.14	0.49
Grass	Lea Town	1[E]				0.61	<0.081	0.53
Grass	N of Lea Town	1[E]				0.73	<0.016	0.55
Silage		1				0.17	0.0072	0.16
Soil		1[#]				16	0.80	16
Soil	Site fence	1[E]				88	5.0	80
Soil	Opposite site entrance	1[E]				100	4.0	85
Soil	Opposite windmill	1[E]				110	4.1	110
Soil	Deepdale Brook	1[E]				97	4.6	92
Soil	Lea Town	1[E]				30	1.0	27
Soil	N of Lea Town	1[E]				68	<3.6	59
Freshwater	Deepdale Brook	4[E]				0.37	<0.020	0.36

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples								
Apples		1	<0.00010	<0.00020	<0.038	<0.00020		
Blackberries		1	0.00010	<0.00020	<0.034	0.00040		
Broad beans		1	<0.00010	0.00020	<0.064	0.00070		
Cabbage		1	<0.00010	<0.00020	<0.033	<0.00020		
Onions		1	<0.00020	<0.00010	<0.064	<0.00030		
Potatoes		1	<0.00010	<0.00020	<0.037	<0.00020		
Rabbit		1	<0.00050	0.00050	<0.15	0.00060		
Sediment	Deepdale Brook	2[E]					460	1600
Grass		1				1.0		
Freshwater	Deepdale Brook	4[E]					0.40	0.46

* *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 (except for those soil samples marked with a # which are fresh concentrations)*

[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*

[#] *Fresh concentrations*

Table 2.3(b). Monitoring of radiation dose rates near Springfields, 2008

Location	Material or ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Lytham Yacht Club	Grass and salt marsh	1	0.10
Warton Mud Marsh	Grass and mud	1	0.10
Warton Mud Marsh	Grass and mud[a]	1	0.10
Warton Mud Marsh	Salt marsh[a]	1	0.13
Warton Mud Marsh	Salt marsh	1	0.12
Warton Salt Marsh	Grass and mud	1	0.11
Warton Salt Marsh	Salt marsh	1	0.11
Freckleton	Grass	1	0.090
Naze Point	Grass and mud	1	0.11
Naze Point	Grass	1	0.11
Banks Marsh	Grass and mud[a]	1	0.14
Banks Marsh	Grass and mud	1	0.13
Banks Marsh	Grass[a]	1	0.11
Banks Marsh	Grass	1	0.11
Hesketh Bank	Grass	2	0.10
Becconsall Boatyard	Grass and mud	2	0.091
Becconsall Boatyard	Grass	2	0.084
Becconsall (vicinity of houseboats)	Grass	1	0.081
Becconsall (vicinity of houseboats)	Tarmac	2	0.080
Longton Marsh	Grass	1	0.12
Hutton Marsh	Grass	1	0.12
River Ribble outfall	Mud	2	0.10
River Ribble outfall	Grass and mud	2	0.098
Savick Brook, confluence with Ribble	Grass and mud	2	0.083
Savick Brook, tidal limit	Grass and mud	1	0.091
Savick Brook, tidal limit	Grass	1	0.097
Savick Brook, Lea Gate	Grass and mud	1	0.095
Savick Brook, Lea Gate	Grass	1	0.097
South bank opposite outfall	Grass	1	0.097
Penworthham Bridge cadet hut	Grass and mud	1	0.087
Penworthham Bridge cadet hut	Grass	1	0.079
Lower Penwortham Park	Grass	4	0.085
Lower Penwortham Railway Bridge	Mud and stones	2	0.084
Lower Penwortham Railway Bridge	Sand and stones	1	0.073
Lower Penwortham Railway Bridge	Grass	1	0.079
River Darwen	Grass	4	0.082
Riverbank Angler location 1	Grass and mud	3	0.084
Riverbank Angler location 1	Grass	1	0.085
Riverbank Angler location 2	Mud and sand	1	0.083
Ulnes Walton, BNFL area survey	Grass	3	0.085
Mean beta dose rates			µSv h^{-1}
Lytham - Granny's Bay	Salt marsh	1	0.020
Ribble Estuary	Gill net	2	0.049
Ribble Estuary	Shrimp net	2	0.14
Banks Marsh	Grass and mud	1	0.10
Banks Marsh	Grass	1	*
Warton Mud Marsh	Grass and mud	1	*
Warton Mud Marsh	Salt marsh	1	0.020
Warton Salt Marsh	Grass and mud	1	*
Warton Salt Marsh	Salt marsh	1	0.040

[a] *15cm above substrate*

* *Not detected by the method used*

Table 2.4. Concentrations of radionuclides in terrestial food and the environment near Sellafield, 2008

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{131}I
Milk		18	<4.7	<4.9	18	<0.19	0.069	<0.0055	<1.3	<0.38	<0.0094	<0.0053
Milk	max		<5.7	<6.8	24	<0.24	0.20		<1.4	<0.47	<0.014	<0.0062
Milk[d]		1				<0.20			<1.0	<0.60		
Milk[d]		1				<0.30			<1.7	<0.70		
Milk[e]		1				<0.30			<2.4	<0.60		
Milk[f]		1			16						<0.010	<0.0040
Milk[f]		1			8.0						<0.010	<0.0050
Milk[g]		1			22						<0.0090	<0.0040
Milk[g]		1			16						<0.012	<0.0040
Apples		2	<3.0	<8.0	6.0	<0.20	0.17	<0.027	<0.90	<0.40	<0.036	
Apples	max		<5.0	11			0.27		<1.2		<0.039	
Barley		1		<7.0	76	<0.20	0.52		<1.3	<0.40	<0.043	
Beef kidney		1	<9.0	<9.0	17	<0.30	0.36	<0.018	<1.5	<0.60	<0.039	
Beef liver		1	<7.0	<7.0	14	<0.10	0.31	0.029	<1.0	<0.30	<0.050	
Beef muscle		1	<6.0	6.0	15	<0.20	<0.0060	0.028	<1.4	<0.40	<0.037	
Beetroot		1	<4.0	<4.0	9.0	<0.20	0.12		<0.90	<0.60	<0.043	
Blackberries		1	<8.0	5.0	15	<0.20	0.49		<1.4	<0.40	<0.047	
Blackcurrants		1	<5.0	<5.0	18	<0.20	0.11		<1.7	<0.50	<0.029	
Broad beans		1	<5.0	<5.0	11	<0.30	0.15		<1.5	<0.50	<0.034	
Broccoli		1	<5.0	<5.0	3.0	<0.20	0.072		<2.1	<0.70	<0.032	
Cabbage		1	<4.0	<4.0	<3.0	<0.20	0.23		<1.0	<0.40	<0.048	
Carrots		1	<5.0	<5.0	8.0	<0.10	0.14	<0.023	<1.5	<0.40	<0.036	
Cauliflower		1	<5.0	<5.0	4.0	<0.30	0.071		<1.3	<0.40	<0.030	
Deer muscle		2	<6.0	<6.0	23	<0.20	<0.0060	<0.027	<1.1	<0.35	<0.027	
Deer muscle	max									<0.40		
Dwarf beans		1	<4.0	<4.0	<2.0	<0.40	0.29		<2.1	<0.80	<0.028	
Eggs		1	<14	14	16	<0.20	0.027		<1.2	<0.50	<0.031	
Elderberries		1	<4.0	<4.0	22	<0.10	0.61		<1.4	<0.50	<0.026	
Honey		1		<7.0	78	<0.20	0.039		<1.4	<0.70	<0.015	
Mushrooms		1	<6.0	<6.0	<5.0	<0.30	0.35		<2.3	<0.40	<0.025	
Onions		1	<5.0	<5.0	6.0	<0.20	0.070		<1.0	<0.50	<0.030	
Pheasants		1	<6.0	<6.0	39	<0.20	0.0090	<0.021	<0.90	<0.30	<0.030	
Potatoes		1	<5.0	<5.0	15	<0.30	0.048		<0.70	<0.40	<0.035	
Rabbit		1	<6.0	<6.0	18	<0.10	0.021	<0.025	<0.90	<0.40	<0.025	
Raspberries		1	<7.0	<5.0	11	<0.20	0.088		<1.3	<0.40	<0.033	
Sheep muscle		2	<6.5	<6.5	20	<0.15	0.11	<0.023	<0.90	<0.30	<0.032	
Sheep muscle	max		<7.0	<7.0	22	<0.20	0.19		<1.0		<0.040	
Sheep offal		2	<9.0	<9.0	18	<0.25	0.68	<0.021	<1.7	<0.55	<0.045	
Sheep offal	max					<0.30	0.85			<0.60	<0.046	
Swede		1	<5.0	<5.0	5.0	<0.20	0.13		<2.1	<0.60	<0.031	
Wheat		1		<7.0	110	<0.20	1.4		<1.5	<0.50	<0.040	
Wood pigeon muscle		2	<6.0	<6.0	34	<0.20	0.015		<1.6	<0.40	<0.041	
Wood pigeon muscle	max				42		0.021		<2.2		<0.050	
Grass		5				<0.17		<0.021	<0.57	<0.45		
Grass	max					<0.20		<0.022	<0.80	0.70		
Soil		3				<0.37			<1.0	<0.53	<3.4	
Soil	max					0.70			<1.4	<0.60	4.4	

Table 2.4. continued

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{134}Cs	^{137}Cs	Total Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Milk		18	<0.19	<0.23	0.20				<0.00011	<0.00014	<0.028	<0.00014
Milk	max		<0.21	0.43	0.43				<0.00013	<0.00020	<0.032	<0.00015
Milk[d]		1	<0.20	0.20								
Milk[d]		1	<0.20	0.40								
Milk[e]		1	<0.30	<0.30								
Apples		2			0.37				0.00030	0.00085	<0.099	0.00065
Apples	max				0.56					0.0013	<0.11	0.00070
Barley		1			0.19				0.00040	0.0030	<0.064	0.0037
Beef kidney		1			0.80	0.0035	<0.00060	0.0066	<0.00020	0.00040	<0.066	0.00070
Beef liver		1			0.97				<0.00020	0.0027	<0.065	0.0028
Beef muscle		1			1.3				<0.00010	<0.00020	<0.058	0.00020
Beetroot		1			0.099	0.0043	<0.00070	0.0053				
Blackberries		1			0.32				<0.00010	<0.00030	<0.17	0.00050
Blackcurrants		1			0.12				<0.00020	0.00070	<0.041	0.0012
Broad beans		1			0.28				<0.00020	0.00040	<0.11	<0.00050
Broccoli		1			0.19				0.00010	0.00020	<0.093	<0.00030
Cabbage		1			0.041				0.00010	<0.00020	<0.12	<0.00030
Carrots		1			0.15							
Cauliflower		1			0.13	0.0042	0.00080	0.0024	<0.00010	<0.00020	<0.12	<0.00030
Deer muscle		2	<0.20	2.3	0.44				<0.00050	0.00020	<0.22	0.00060
Deer muscle	max											
Dwarf beans		1			0.12				0.00010	0.0014	<0.095	0.00070
Eggs		1			0.23				<0.00020	<0.00020	<0.041	<0.00020
Elderberries		1			0.18				0.0013	0.0082	<0.063	0.018
Honey		1			3.7				<0.00010	0.00020	<0.016	<0.00040
Mushrooms		1			0.44				0.013	0.085	0.84	0.12
Onions		1			0.074							
Pheasants		1			0.66				0.00010	0.00020	<0.76	0.00030
Potatoes		1			0.16							
Rabbit		1			0.87				<0.00020	0.00050	<0.085	0.00050
Raspberries		1			0.062				<0.00020	0.00030	<0.044	0.00040
Sheep muscle		2			0.61				<0.00025	<0.0011	<0.056	<0.00020
Sheep muscle	max				0.72				0.00030	0.0019	<0.058	0.00020
Sheep offal		2			0.33	<0.0050	<0.0013	<0.0058	<0.00040	0.0033	<0.056	0.0025
Sheep offal	max				0.45	0.0069	<0.0017	0.0088	0.00060	0.0039	<0.059	0.0030
Swede		1			0.28							
Wheat		1			1.2				0.00030	0.0043	<0.15	0.0042
Wood pigeon muscle		2			11				<0.00020	<0.00025	<0.057	<0.00035
Wood pigeon muscle	max				22					<0.00030	<0.063	0.00050
Grass		5	<0.13	1.5								0.08
Grass	max		<0.20	2.6								
Soil		3	<0.17	52		18	1.3	18				6.8
Soil	max		<0.20	65								7.2

[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] *Additional milk sampling week commencing 4 February 2008*
[e] *Additional milk sampling week commencing 11 February 2008*
[f] *Additional milk sampling week commencing 2 June 2008*
[g] *Additional milk sampling week commencing 9 June 2008*

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Cumbria										
Maryport	Plaice	4				<0.13		<0.81	<1.9	
River Derwent	Sea trout	1				<0.29		*	*	
Parton	Cod	4				<0.10		<0.39	<0.54	
Whitehaven	Cod	4			58	<0.10	0.15	<0.49	<0.78	
Whitehaven	Plaice	4				<0.11	0.10	<0.47	<0.80	
Whitehaven	Skates / rays	4				<0.13		<0.78	<0.80	
Whitehaven	Sole	4				<0.12		<0.56	<0.91	
River Ehen	Sea trout	1				<0.29		<2.5	<6.4	
Sellafield coastal area	Cod	8				<0.10		<0.48	<0.87	
Sellafield coastal area	Plaice	4	85	82		<0.11		<0.55	<1.0	
Sellafield coastal area	Bass	1				<0.14		<0.97	<1.9	
Sellafield coastal area	Grey mullet	1				<0.15		<0.52	<0.88	
Sellafield offshore area	Cod	2			130	<0.12	0.039	<0.54	<0.80	<0.31
Sellafield offshore area	Plaice[a]	2			190	<0.12	0.33	<0.58	<0.95	26
Sellafield offshore area	Dab	1				0.11		<2.2	*	
Sellafield offshore area	Lesser spotted dogfish	2				<0.11		<0.57	<0.81	
Sellafield offshore area	Pollack	1				<0.18		<0.71	<1.1	
Sellafield offshore area	Skates / rays	1				<0.15		<0.63	<0.84	
Sellafield offshore area	Gurnards	1				<0.18		<1.0	<1.9	
Ravenglass	Cod	6				<0.10		<0.59	<1.2	
Ravenglass	Plaice	4	71	61		<0.16		<0.73	<1.3	
Morecambe Bay (Flookburgh)	Flounder	4			87	<0.14		<0.98	<1.0	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.06		<0.26	<0.35	
Morecambe Bay (Morecambe)	Bass	2				<0.06		<0.41	<0.83	
Morecambe Bay (Morecambe)	Flounder	4	<25	<25		<0.14	0.068	<1.1	<0.46	0.98
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.06	0.25	<0.21	<0.25	
Fleetwood	Cod	4			81	<0.11	0.096	<0.64	<1.5	<0.45
Fleetwood	Plaice	4				<0.06		<0.40	<0.44	
Ribble Estuary	Grey mullet	2				<0.12		<0.71	<1.4	
Ribble Estuary	Salmon	1				<0.07		<0.45	<0.86	
Ribble Estuary	Sole	1				<0.18		<1.0	<1.8	
Ribble Estuary	Bass	1				<0.10		<0.46	<0.74	
Liverpool Bay	Flounder	1		<25						
Liverpool Bay	Dab	1		<25						
Mersey Estuary	Flounder	1		<25						
Mersey Estuary	Dab	1		<25						
Scotland										
Shetland	Fish meal	2				<0.21	0.11	<0.68	<0.73	
Shetland	Fish oil	2				<0.13		<0.31	<0.24	
Minch	Herring	1				<0.06		<0.16	<0.13	
Minch	Mackerel	1			90	<0.11	<0.095	<0.81	<1.7	
West of Scotland	Mackerel	1				<0.10		<1.0	*	
West of Scotland	Farmed salmon	1				<0.13		<1.0	<2.2	
Dumfries	Plaice	2			81	<0.13		<0.24	<0.30	1.5
Inner Solway	Flounder	4			56	<0.10	<0.10	<0.14	<0.12	1.4

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	Gross beta
Cumbria									
Maryport	Plaice	4	<1.3	<0.30	<0.13	3.0	<0.59	<0.22	
River Derwent	Sea trout	1	<5.3	<0.85	<0.39	2.2	<3.3	<0.66	
Parton	Cod	4	<0.96	<0.25	<0.10	6.5	<0.52	<0.24	
Whitehaven	Cod	4	<1.1	<0.27	<0.11	3.8	<0.59	<0.27	
Whitehaven	Plaice	4	<1.0	<0.28	<0.11	3.9	<0.59	<0.25	
Whitehaven	Skates / rays	4	<1.3	<0.32	<0.13	6.3	<0.60	<0.25	
Whitehaven	Sole	4	<1.3	<0.32	<0.13	3.3	<0.65	<0.26	
River Ehen	Sea trout	1	<3.8	<0.75	<0.35	2.3	<1.5	<0.46	
Sellafield coastal area	Cod	8	<0.99	<0.27	<0.11	10	<0.51	<0.21	230
Sellafield coastal area	Plaice	4	<1.0	<0.25	<0.10	4.5	<0.48	<0.18	210
Sellafield coastal area	Bass	1	<1.4	<0.37	<0.15	11	<0.80	<0.34	
Sellafield coastal area	Grey mullet	1	<1.2	<0.29	<0.13	5.9	<0.50	<0.20	
Sellafield offshore area	Cod	2	<1.2	<0.32	<0.12	6.4	<0.65	<0.27	
Sellafield offshore area	Plaice[a]	2	<1.1	<0.29	<0.11	3.8	<0.60	<0.25	
Sellafield offshore area	Dab	1	<1.3	<0.25	<0.11	5.2	<0.61	<0.17	
Sellafield offshore area	Lesser spotted dogfish	2	<1.2	<0.33	<0.13	7.7	<0.64	<0.27	
Sellafield offshore area	Pollack	1	<1.8	<0.47	<0.16	7.4	<0.90	<0.45	
Sellafield offshore area	Skates / rays	1	<1.5	<0.42	<0.16	5.6	<0.86	<0.41	
Sellafield offshore area	Gurnards	1	<2.0	<0.39	<0.19	4.4	<0.66	<0.26	
Ravenglass	Cod	6	<1.0	<0.26	<0.10	8.5	<0.58	<0.24	
Ravenglass	Plaice	4	<1.5	<0.35	<0.16	3.7	<0.63	<0.24	
Morecambe Bay (Flookburgh)	Flounder	4	<1.6	<0.41	<0.15	11	<0.91	<0.35	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<0.65	<0.18	<0.07	6.3	<0.42	<0.19	
Morecambe Bay (Morecambe)	Bass	2	<0.70	<0.18	<0.07	9.7	<0.45	<0.18	
Morecambe Bay (Morecambe)	Flounder	4	<1.7	<0.38	<0.16	7.3	<0.80	<0.30	
Morecambe Bay (Sunderland Point)	Whitebait	1	<0.62	<0.17	<0.06	4.6	<0.39	<0.18	
Fleetwood	Cod	4	<1.1	<0.23	<0.11	3.9	<0.44	<0.18	
Fleetwood	Plaice	4	<0.62	<0.15	<0.07	2.9	<0.34	<0.14	
Ribble Estuary	Grey mullet	2	<1.2	<0.30	<0.12	3.5	<0.63	<0.25	
Ribble Estuary	Salmon	1	<0.78	<0.17	<0.08	0.18	<0.35	<0.13	
Ribble Estuary	Sole	1	<2.0	<0.37	<0.19	2.2	<0.65	<0.25	
Ribble Estuary	Bass	1	<1.0	<0.27	<0.11	11	<0.43	<0.17	
Scotland									
Shetland	Fish meal	2	<2.0	<0.50	<0.21	0.61	<1.0	<0.45	
Shetland	Fish oil	2	<1.2	<0.35	<0.14	<0.13	<0.67	<0.29	
Minch	Herring	1	<0.57	<0.16	<0.06	0.19	<0.34	<0.16	
Minch	Mackerel	1	<1.3	<0.28	<0.13	<0.11	<0.69	<0.29	
West of Scotland	Mackerel	1	<1.3	<0.28	<0.12	<0.10	<0.80	<0.31	
West of Scotland	Farmed salmon	1	<1.5	<0.30	<0.14	0.19	<0.66	<0.23	
Dumfries	Plaice	2	<1.2	<0.32	<0.12	3.4	<0.66	<0.29	
Inner Solway	Flounder	4	<0.48	<0.17	<0.10	14	<0.32	<0.17	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Isle of Man										
Isle of Man	Cod	4				<0.05		<0.28	<0.52	
Isle of Man	Herring	4				<0.05		<0.18	<0.25	
Wales										
North Anglesey	Skates / rays	2				<0.05		<0.20	<0.28	
North Anglesey	Spurdog	1				<0.17		<2.2	*	
North Anglesey	Lesser spotted dogfish	1				<0.12		<0.78	<1.7	
North Anglesey	Plaice	2	<25	<25	72	<0.10		<0.36	<0.49	
North Anglesey	Bass	1				<0.04		<0.12	<0.14	
Northern Ireland										
North coast	Spurdog	4[N]				<0.10		<0.74	<1.3	
Ardglass	Herring	2[N]				<0.25		<2.7	<3.1	
Kilkeel	Cod	4[N]			57	<0.08		<0.47	<0.46	
Kilkeel	Plaice	4[N]				<0.07		<0.63	<0.75	
Kilkeel	Spurdog	1[N]				<0.15		<1.8	*	
Kilkeel	Haddock	4[N]				<0.12		<0.71	<0.63	
Kilkeel	Hake	3[N]				<0.08		<0.29	<0.36	
Glenarm	Brown trout	1				<0.09		<0.42	<0.86	<0.58
Further afield										
Baltic Sea	Cod	2				<0.12		<0.50	<0.78	
Baltic Sea	Herring	2				<0.10		<0.49	<0.81	
Barents Sea	Cod	2				<0.07		<0.69	<0.88	
Norwegian Sea	Cod	1				<0.07		<0.45	<1.0	
Norwegian Sea	Haddock	1				<0.09		<0.59	<1.2	
Norwegian Sea	Saithe	1				<0.08		<0.50	<1.0	
Norwegian Sea	Whiting	1				<0.09		<0.50	<1.0	
Norwegian processed	Cod	1			25	<0.04		<0.22	<0.41	
Iceland area	Cod	1				<0.05		<0.25	<0.44	
Skagerrak	Cod	2				<0.06		<0.24	<0.37	
Skagerrak	Herring	2				<0.09		<0.88	<0.24	
Northern North Sea	Cod	1				<0.06	0.051	<0.17	<0.20	
Northern North Sea	Plaice	1				<0.09		<1.0	*	
Northern North Sea	Haddock	2			28	<0.06		<0.31	<0.49	
Northern North Sea	Herring	1				<0.10		<1.9	*	
Northern North Sea	Whiting	2				<0.06		<0.36	<0.79	
Mid North Sea	Cod	2			51	<0.04	0.064	<0.19	<0.30	
Mid North Sea	Plaice	2			33	<0.04	0.049	<0.17	<0.28	
Gt Yarmouth (retail shop)	Cod	2				<0.04		<0.15	<0.19	
Gt Yarmouth (retail shop)	Plaice	2				<0.05		<0.33	<0.15	
Southern North Sea	Cod	2				<0.05	0.043	<0.16	<0.16	
Southern North Sea	Sole	1				<0.07		<0.42	<0.90	
Southern North Sea	Herring	1				<0.09		<0.46	<0.78	
Southern North Sea	Skates / rays	1				<0.06	0.069	<0.19	<0.22	
English Channel-East	Cod	1				<0.07		<0.52	<1.1	
English Channel-East	Plaice	1				<0.08		<0.32	<0.51	
English Channel-East	Whiting	1				<0.04		<0.12	<0.15	
English Channel-East	Flounder	1				<0.04		<0.14	<0.17	
English Channel-West	Mackerel	2				<0.08		<0.59	<0.08	
English Channel-West	Plaice	2			29	<0.05		<0.32	<0.61	
English Channel-West	Whiting	2				<0.06		<0.37	<0.06	
Celtic Sea	Cod	1				<0.05		<0.26	<0.45	
Celtic Sea	Haddock	1				<0.04		<0.22	<0.37	
Celtic Sea	Pollack	1			46	<0.07	0.043	<0.29	<0.47	
Celtic Sea	Witch	1				<0.06		<0.40	<0.82	
Northern Irish Sea	Dab	1				<0.09		<0.82	*	
Northern Irish Sea	Lesser spotted dogfish	1				<0.17		<1.8	*	
Northern Irish Sea	Skates / rays	1				<0.18		<1.7	*	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu
Isle of Man								
Isle of Man	Cod	4	<0.52	<0.13	<0.05	1.8	<0.28	<0.12
Isle of Man	Herring	4	<0.42	<0.11	<0.05	1.5	<0.24	<0.11
Wales								
North Anglesey	Skates / rays	2	<0.47	<0.11	<0.05	1.5	<0.24	<0.10
North Anglesey	Spurdog	1	<2.2	<0.45	<0.19	1.7	<1.2	<0.39
North Anglesey	Lesser spotted dogfish	1	<1.2	<0.28	<0.13	1.3	<0.72	<0.28
North Anglesey	Plaice	2	<0.94	<0.21	<0.10	1.5	<0.36	<0.14
North Anglesey	Bass	1	<0.37	<0.10	<0.04	6.8	<0.18	<0.08
Northern Ireland								
North coast	Spurdog	4^{N}	<1.1	<0.22	<0.10	1.7	<0.48	<0.17
Ardglass	Herring	2^{N}	<3.2	<0.63	<0.27	0.60	<1.6	<0.55
Kilkeel	Cod	4^{N}	<0.88	<0.19	<0.09	2.2	<0.40	<0.17
Kilkeel	Plaice	4^{N}	<0.70	<0.16	<0.07	1.9	<0.32	<0.11
Kilkeel	Spurdog	1^{N}	<1.7	<0.37	<0.16	5.6	<0.73	<0.25
Kilkeel	Haddock	4^{N}	<1.3	<0.28	<0.13	0.98	<0.59	<0.25
Kilkeel	Hake	3^{N}	<0.85	<0.19	<0.08	0.78	<0.42	<0.19
Glenarm	Brown trout	1	<0.85	<0.20	<0.09	0.16	<0.41	<0.16
Further afield								
Baltic Sea	Cod	2	<1.3	<0.30	<0.13	7.6	<0.61	<0.27
Baltic Sea	Herring	2	<1.0	<0.24	<0.10	5.0	<0.47	<0.20
Barents Sea	Cod	2	<0.79	<0.16	<0.07	0.22	<0.40	<0.13
Norwegian Sea	Cod	1	<0.62	<0.12	<0.07	0.27	<0.21	<0.08
Norwegian Sea	Haddock	1	<0.93	<0.20	<0.09	0.21	<0.50	<0.21
Norwegian Sea	Saithe	1	<0.63	<0.13	<0.07	0.15	<0.22	<0.08
Norwegian Sea	Whiting	1	<0.73	<0.15	<0.09	0.17	<0.26	<0.10
Norwegian processed	Cod	1	<0.41	<0.09	<0.04	0.12	<0.20	<0.08
Iceland area	Cod	1	<0.40	<0.08	<0.04	0.13	<0.14	<0.05
Skagerrak	Cod	2	<0.50	<0.11	<0.06	0.19	<0.22	<0.09
Skagerrak	Herring	2	<0.97	<0.22	<0.10	0.26	<0.52	<0.18
Northern North Sea	Cod	1	<0.49	<0.11	<0.06	0.23	<0.22	<0.10
Northern North Sea	Plaice	1	<0.98	<0.20	<0.10	<0.09	<0.41	<0.15
Northern North Sea	Haddock	2	<0.59	<0.13	<0.07	<0.10	<0.26	<0.11
Northern North Sea	Herring	1	<1.2	<0.22	<0.11	0.26	<0.57	<0.17
Northern North Sea	Whiting	2	<0.60	<0.14	<0.06	0.26	<0.34	<0.15
Mid North Sea	Cod	2	<0.44	<0.11	<0.05	0.31	<0.28	<0.12
Mid North Sea	Plaice	2	<0.39	<0.09	<0.04	0.17	<0.18	<0.07
Gt Yarmouth (retail shop)	Cod	2	<0.38	<0.10	<0.04	2.1	<0.20	<0.09
Gt Yarmouth (retail shop)	Plaice	2	<0.50	<0.11	<0.05	<0.05	<0.21	<0.08
Southern North Sea	Cod	2	<0.45	<0.10	<0.05	0.25	<0.23	<0.10
Southern North Sea	Sole	1	<0.65	<0.14	<0.07	0.13	<0.28	<0.11
Southern North Sea	Herring	1	<0.81	<0.18	<0.09	0.31	<0.34	<0.13
Southern North Sea	Skates / rays	1	<0.51	<0.11	<0.06	0.29	<0.21	<0.09
English Channel-East	Cod	1	<0.72	<0.16	<0.08	0.19	<0.40	<0.17
English Channel-East	Plaice	1	<0.71	<0.15	<0.08	<0.07	<0.28	<0.12
English Channel-East	Whiting	1	<0.37	<0.09	<0.04	0.26	<0.23	<0.10
English Channel-East	Flounder	1	<0.38	<0.09	<0.04	0.15	<0.19	<0.08
English Channel-West	Mackerel	2	<0.90	<0.20	<0.09	0.19	<0.53	<0.21
English Channel-West	Plaice	2	<0.57	<0.13	<0.06	<0.08	<0.28	<0.12
English Channel-West	Whiting	2	<0.53	<0.11	<0.05	0.25	<0.21	<0.08
Celtic Sea	Cod	1	<0.48	<0.12	<0.05	0.32	<0.33	<0.13
Celtic Sea	Haddock	1	<0.42	<0.10	<0.04	0.06	<0.27	<0.11
Celtic Sea	Pollack	1	<0.63	<0.14	<0.07	1.4	<0.27	<0.11
Celtic Sea	Witch	1	<0.61	<0.14	<0.07	<0.06	<0.29	<0.11
Northern Irish Sea	Dab	1	<0.85	<0.17	<0.09	0.87	<0.30	<0.10
Northern Irish Sea	Lesser spotted dogfish	1	<2.0	<0.42	<0.18	2.4	<1.1	<0.37
Northern Irish Sea	Skates / rays	1	<2.1	<0.40	<0.19	1.0	<0.82	<0.25

* *Not detected by the method used*

[a] *The concentrations of ^{129}I and ^{147}Pm were <1.7 and <0.096 Bq kg^{-1} respectively*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria												
Silloth	Mussels	4		<25		0.44	<0.19		<0.29	<0.36		<0.85
Silloth	Shrimps	4				<0.10	<0.26		<0.37	<0.59		<0.94
Parton	Crabs	4				<0.25	<0.36		<0.63	<1.1		<1.4
Parton	Lobsters	4				<0.16	<0.33		<0.48	<0.78		<1.2
Parton	Winkles	4				1.1	<0.28		<0.44	<0.62		<3.3
Whitehaven	*Nephrops*	4			91	<0.08	<0.21	0.15	<0.31	<0.47	59	<0.69
Whitehaven	Cockles	2				<0.05	<0.12		<0.19	<0.24		<0.51
Whitehaven	Mussels	2				<0.05	<0.14	0.052	<0.23	<0.35		<0.61
Whitehaven outer harbour	Mussels	2				0.62	<0.15		<0.26	<0.45		2.4
Saltom Bay	Winkles	4				1.4	<0.28		<0.44	<0.68		3.0
St Bees	Winkles[a]	4			160	1.6	<0.25	2.2	<0.39	<0.55	36	4.5
St Bees	Mussels	4				1.1	<0.26		<0.50	<0.90		4.7
St Bees	Limpets	4				0.98	<0.30		<0.46	<0.65		3.2
Nethertown	Winkles	12	<25	<25	160	2.3	<0.31	6.0	<0.49	<0.78	32	7.6
Nethertown	Mussels	4	46	65	260	1.7	<0.20		<0.31	<0.40	68	5.6
Sellafield coastal area	Crabs[b]	8			180	0.83	<0.26	0.41	<0.47	<0.89	11	<1.1
Sellafield coastal area	Lobsters	8			250	0.52	<0.28	0.27	<0.49	<0.95	370	<0.97
Sellafield coastal area	*Nephrops*	1				<0.06	<0.15		<0.24	<0.39	98	<0.54
Sellafield coastal area[c]	Winkles	8			130	1.9	<0.26	6.0	<0.44	<0.72	52	<5.7
Sellafield coastal area[c]	Mussels	4				1.1	<0.19	0.94	<0.34	<0.56		<2.9
Sellafield coastal area[c]	Limpets	4			86	1.1	<0.29	1.8	<0.50	<0.86	150	3.4
Whitriggs	Shrimps	1				<0.26	<0.84		<2.1	<5.4		<2.9
Drigg	Winkles	4			210	2.5	<0.33		<0.52	<0.92	98	6.9
Ravenglass	Crabs	4				0.35	<0.20	0.26	<0.45	<1.0	9.3	<0.76
Ravenglass	Lobsters	6				<0.26	<0.25	0.066	<0.56	<0.91	230	<0.83
Ravenglass	Winkles	2				1.3	<0.31		<0.52	<0.87		5.0
Ravenglass	Cockles	4			160	3.8	<0.26	1.6	<0.43	<0.62	8.7	4.2
Ravenglass	Mussels	4		36		1.6	<0.22		<0.34	<0.53	180	4.1
Tarn Bay	Winkles	4				1.4	<0.32		<0.47	<0.72		<4.5
Haverigg	Cockles	4				1.7	<0.20		<0.37	<0.58		<1.4
Millom	Mussels	2				0.27	<0.19		<0.37	<0.71		<0.92
Barrow	Crabs	4				<0.17	<0.22		<0.37	<0.56		<0.80
Barrow	Lobsters	4				<0.10	<0.25		<0.42	<0.76	120	<0.85
Roosebeck	Pacific oysters	2				<0.09	<0.12		<0.17	<0.22		<0.44
Morecambe Bay (Flookburgh)	Shrimps	4			77	<0.08	<0.22		<0.34	<0.54	1.2	<0.81
Morecambe Bay (Flookburgh)	Cockles	4			82	0.36	<0.20	0.29	<0.38	<0.75	2.3	<0.75
Lancashire and Merseyside												
Morecambe Bay (Morecambe)	Shrimps	2				<0.06	<0.18		<0.34	<0.62		<0.67
Morecambe Bay (Morecambe)	Mussels	4	<27	<28	65	<0.13	<0.16		<0.22	<0.27	29	<0.64
Red Nab Point	Winkles	4				0.25	<0.22		<0.31	<0.42		<0.83
Morecambe Bay (Middleton Sands)	Cockles	2				0.41	<0.15		<0.21	<0.26		<0.58
Knott End	Cockles	2				0.45	<0.20		<0.37	<0.66		<0.82
Fleetwood	Squid	1				<0.08	<0.25		<0.56	<1.5		<0.75
Ribble Estuary	Shrimps	2			34	<0.06	<0.18		<0.28	<0.39	<0.96	<0.66
Ribble Estuary	Mussels	2				<0.06	<0.13		<0.20	<0.27		<0.51
Liverpool Bay	Mussels	2		<25								
Mersey Estuary	Mussels	2		<25								
Dee Estuary	Cockles	4				<0.10	<0.21		<0.28	<0.31	2.0	<0.95
Wirral	Shrimps	2		<25		<0.04	<0.10		<0.16	<0.24	0.79	<0.39

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{154}Eu	^{155}Eu	Gross beta
Cumbria											
Silloth	Mussels	4	<0.15	<0.44	<0.08	2.8	<0.42		<0.23	<0.19	
Silloth	Shrimps	4	<0.19	<0.25	<0.10	3.4	<0.48		<0.28	<0.22	
Parton	Crabs	4	<0.27	<0.30	<0.14	1.4	<0.53		<0.37	<0.20	
Parton	Lobsters	4	<0.24	<0.27	<0.12	2.1	<0.51		<0.36	<0.21	
Parton	Winkles	4	<0.24	0.75	<0.11	8.4	<0.63		<0.31	<0.29	
Whitehaven	*Nephrops*	4	<0.15	<0.19	<0.07	3.3	<0.39		<0.22	<0.18	200
Whitehaven	Cockles	2	<0.10	<0.13	<0.05	0.07	<0.31		<0.13	<0.14	
Whitehaven	Mussels	2	<0.11	<0.15	<0.06	<0.06	<0.34		<0.15	<0.14	
Whitehaven outer harbour	Mussels	2	<0.12	0.80	<0.06	1.9	<0.41		<0.16	<0.18	
Saltom Bay	Winkles	4	<0.29	1.1	<0.11	4.7	<0.62		<0.33	<0.29	
St Bees	Winkles[a]	4	<0.54	1.0	<0.10	7.2	<0.60	0.60	<0.29	<0.28	
St Bees	Mussels	4	<0.20	1.2	<0.10	3.2	<0.60		<0.28	<0.26	
St Bees	Limpets	4	<0.27	1.7	<0.12	6.5	<0.60		<0.35	<0.27	
Nethertown	Winkles	12	0.79	<1.1	<0.12	8.7	<0.67	1.6	<0.36	<0.31	280
Nethertown	Mussels	4	<0.16	2.1	<0.08	2.5	<0.43		<0.23	<0.19	250
Sellafield coastal area	Crabs[b]	8	<0.31	<0.40	<0.09	1.9	<0.48	0.11	<0.27	<0.20	160
Sellafield coastal area	Lobsters	8	0.60	<0.27	<0.09	2.9	<0.52	0.24	<0.26	<0.22	650
Sellafield coastal area	*Nephrops*	1	<0.11	<0.17	<0.05	3.6	<0.35		<0.16	<0.15	
Sellafield coastal area[c]	Winkles	8	<0.65	0.90	<0.11	7.8	<0.59	1.1	<0.32	<0.26	
Sellafield coastal area[c]	Mussels	4	<0.14	1.1	<0.08	3.2	<0.44		<0.21	<0.19	
Sellafield coastal area[c]	Limpets	4	<0.30	2.2	<0.11	3.7	<0.55		<0.31	<0.23	
Whitriggs	Shrimps	1	<0.55	<0.58	<0.30	2.7	<1.1		<0.73	<0.37	
Drigg	Winkles	4	0.72	0.96	<0.12	5.2	<0.65	0.62	<0.36	<0.29	340
Ravenglass	Crabs	4	<0.16	<0.18	<0.07	1.1	<0.41		<0.19	<0.15	140
Ravenglass	Lobsters	6	<0.29	<0.20	<0.08	2.3	<0.42		<0.24	<0.16	400
Ravenglass	Winkles	2	0.57	1.1	<0.12	7.8	<0.73		<0.32	<0.34	
Ravenglass	Cockles	4	<0.19	<0.63	<0.10	4.4	<0.49		<0.29	<0.22	210
Ravenglass	Mussels	4	<0.16	1.1	<0.08	1.4	<0.49		<0.23	<0.22	
Tarn Bay	Winkles	4	<0.46	<0.72	<0.12	6.1	<0.58		<0.36	<0.26	
Haverigg	Cockles	4	<0.16	0.60	<0.09	4.2	<0.48		<0.24	<0.22	
Millom	Mussels	2	<0.14	0.42	<0.07	1.3	<0.35		<0.18	<0.15	
Barrow	Crabs	4	<0.17	<0.20	<0.08	1.0	<0.40		<0.23	<0.16	
Barrow	Lobsters	4	<0.18	<0.21	<0.09	1.8	<0.44		<0.26	<0.19	290
Roosebeck	Pacific oysters	2	<0.16	<0.15	<0.05	1.0	<0.21		<0.13	<0.09	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.15	<0.21	<0.08	4.7	<0.46		<0.24	<0.21	
Morecambe Bay (Flookburgh)	Cockles	4	<0.14	<0.21	<0.08	3.7	<0.39		<0.20	<0.17	
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2	<0.14	<0.18	<0.07	4.5	<0.38		<0.19	<0.15	
Morecambe Bay (Morecambe)	Mussels	4	<0.12	<0.20	<0.07	2.1	<0.29		<0.19	<0.13	
Red Nab Point	Winkles	4	<0.16	<0.35	<0.09	3.9	<0.41		<0.24	<0.18	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.11	0.20	<0.06	4.0	<0.34		<0.16	<0.15	
Knott End	Cockles	2	<0.15	<0.28	<0.08	3.7	<0.44		<0.21	<0.22	
Fleetwood	Squid	1	<0.16	<0.15	<0.07	0.17	<0.34		<0.21	<0.12	
Ribble Estuary	Shrimps	2	<0.13	<0.17	<0.07	1.8	<0.39		<0.20	<0.18	
Ribble Estuary	Mussels	2	<0.10	<0.13	<0.05	0.80	<0.25		<0.13	<0.10	
Liverpool Bay	Mussels	2									
Mersey Estuary	Mussels	2									
Dee Estuary	Cockles	4	<0.15	<0.23	<0.09	2.3	<0.46		<0.24	<0.20	
Wirral	Shrimps	2	<0.08	<0.10	<0.04	1.5	<0.22		<0.11	<0.09	

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}									
			^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland												
Lewis	Mussels	1				<0.10	<0.21		<0.18	<0.14		<0.74
Skye	Lobsters	1				<0.10	<0.18		<0.14	<0.10	16	<0.61
Skye	Mussels	1				<0.10	<0.25		<0.22	<0.16		<0.86
Islay	Crabs	1				<0.10	<0.22		<0.23	<0.21		<0.71
Islay	Scallops	1				<0.10	<0.10		<0.10	<0.10		<0.28
Kirkcudbright	Scallops	4				<0.11	<0.26		<0.29	<0.35	1.4	<0.80
Kirkcudbright	Queens	3				<0.10	<0.15		<0.18	<0.23	<0.50	<0.46
Kirkcudbright	Limpets	1				0.34	<0.25		<0.26	<0.23		<0.86
Southerness	Winkles	4		<5.0		0.34	<0.29	0.23	<0.32	<0.30	58	<1.0
North Solway coast	Crabs	4			78	<0.21	<0.34	0.18	<0.37	<0.41	4.7	<1.1
North Solway coast	Lobsters	4			100	<0.13	<0.31	<0.10	<0.31	<0.32	120	<1.1
North Solway coast	Winkles	4				<0.23	<0.30	0.23	<0.34	<0.34	59	<1.0
North Solway coast	Cockles	1				1.2	<0.21		<0.18	<0.10		<0.72
North Solway coast	Mussels	4		<5.0	47	0.26	<0.15	0.35	<0.16	<0.17	100	<0.49
Inner Solway	Shrimps	2		<5.0		<0.10	<0.24	<0.10	<0.24	<0.20	1.1	<0.81
Isle of Man												
Isle of Man	Lobsters	4				<0.06	<0.17		<0.27	<0.44	50	<0.56
Isle of Man	Scallops	4				<0.07	<0.19		<0.32	<0.66		<0.57
Wales												
Conwy	Mussels	2			47	<0.06	<0.14		<0.20	<0.23		<0.56
North Anglesey	Crabs	2				<0.05	<0.13		<0.17	<0.22	1.5	<0.47
North Anglesey	Lobsters	2				<0.07	<0.21		<0.38	<0.72	69	<0.73
Lavernock Point	Limpets	1	<25	<25	41	<0.15	<0.39		<0.44	<0.47		<1.6
Northern Ireland												
Ballycastle	Lobsters	2[N]				<0.05	<0.16		<0.37	<0.83	130	<0.55
County Down	Scallops	2[N]				<0.11	<0.35		<0.61	<1.2		<1.1
Kilkeel	Crabs	4[N]				<0.10	<0.29		<0.60	<0.79		<1.1
Kilkeel	Lobsters	4[N]				<0.09	<0.25		<0.50	<1.0	29	<0.96
Kilkeel	*Nephrops*	4[N]				<0.12	<0.38		<0.84	<1.5	12	<1.4
Minerstown	Winkles	4[N]				<0.11	<0.31		<0.64	<1.3		<1.2
Carlingford Lough	Mussels	2[N]				<0.18	<0.59		<2.6	<0.89	20	<2.2
Further afield												
Northern North Sea	*Nephrops*	2				<0.03	<0.10		<0.15	<0.21	1.8	<0.35
Cromer	Crabs	1				<0.05	<0.15		<0.19	<0.20		<0.52
Southern North Sea	Cockles	1				<0.08	<0.24		<0.41	<0.83		<0.72
Southern North Sea	Mussels	2				<0.10	<0.15		<0.60	<1.2	0.41	<1.1
Southern North Sea	Cockles[d]	1				<0.06	<0.20		<1.9	*	0.16	<0.78
Southern North Sea	Mussels[d]	1				<0.05	<0.29		<0.29	<0.49		<0.60
English Channel-East	Scallops	2			12	<0.06	<0.18		<0.25	<0.33		<0.58
English Channel-West	Crabs	2			46	<0.14	<0.41		<0.81	<1.5		<1.6
English Channel-West	Lobsters	2				<0.07	<0.21		<0.36	<0.65	0.64	<0.72
English Channel-West	Scallops	2			19	<0.06	<0.18		<0.33	<0.63		<0.56
Northern Irish Sea	Crabs	1				0.34	<0.18		<0.44	<0.97		<0.71
Northern Irish Sea	Octopuses	1				<0.20	<0.65		<2.2	*		<2.5

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	Gross beta
Scotland										
Lewis	Mussels	1	<0.10	<0.22	<0.10	<0.19	<0.45	<0.11	<0.21	
Skye	Lobsters	1	<0.10	<0.18	<0.10	0.20	<0.36	<0.10	<0.17	
Skye	Mussels	1	<0.10	<0.25	<0.10	<0.10	<0.52	<0.13	<0.25	
Islay	Crabs	1	<0.10	<0.21	<0.10	0.20	<0.48	<0.11	<0.22	
Islay	Scallops	1	<0.10	<0.10	<0.10	0.21	<0.24	<0.10	<0.11	
Kirkcudbright	Scallops	4	<0.12	<0.22	<0.11	<0.32	<0.50	<0.13	<0.23	
Kirkcudbright	Queens	3	<0.10	<0.13	<0.10	0.31	<0.28	<0.10	<0.13	
Kirkcudbright	Limpets	1	<0.14	<0.19	<0.10	3.9	<0.55	<0.13	<0.24	
Southerness	Winkles	4	<0.15	<0.31	<0.11	1.6	<0.57	<0.13	<0.24	
North Solway coast	Crabs	4	<0.16	<0.28	<0.13	1.1	<0.60	<0.15	<0.22	
North Solway coast	Lobsters	4	<0.16	<0.31	<0.14	1.7	<0.68	<0.16	<0.28	
North Solway coast	Winkles	4	<0.15	<0.28	<0.12	1.3	<0.60	<0.14	<0.25	
North Solway coast	Cockles	1	<0.11	<0.21	<0.10	9.8	<0.40	<0.10	<0.19	
North Solway coast	Mussels	4	<0.11	<0.21	<0.10	2.4	<0.35	<0.11	<0.15	
Inner Solway	Shrimps	2	<0.13	<0.24	<0.10	2.6	<0.52	<0.13	<0.23	
Isle of Man										
Isle of Man	Lobsters	4	<0.12	<0.13	<0.06	0.42	<0.29	<0.19	<0.13	160
Isle of Man	Scallops	4	<0.13	<0.14	<0.06	0.61	<0.32	<0.19	<0.14	
Wales										
Conwy	Mussels	2	<0.11	<0.14	<0.05	0.14	<0.28	<0.16	<0.13	
North Anglesey	Crabs	2	<0.09	<0.12	<0.05	0.59	<0.25	<0.14	<0.11	
North Anglesey	Lobsters	2	<0.15	<0.16	<0.07	0.85	<0.38	<0.20	<0.16	170
Lavernock Point	Limpets	1	<0.25	<0.31	<0.16	0.43	<0.51	<0.45	<0.22	
Northern Ireland										
Ballycastle	Lobsters	2[N]	<0.11	<0.12	<0.05	0.71	<0.28	<0.14	<0.10	
County Down	Scallops	2[N]	<0.23	<0.25	<0.11	0.38	<0.57	<0.34	<0.25	
Kilkeel	Crabs	4[N]	<0.20	<0.23	<0.10	0.29	<0.56	<0.27	<0.22	
Kilkeel	Lobsters	4[N]	<0.18	<0.20	<0.09	0.31	<0.41	<0.26	<0.17	
Kilkeel	*Nephrops*	4[N]	<0.26	<0.28	<0.13	0.80	<0.56	<0.37	<0.20	
Minerstown	Winkles	4[N]	<0.22	<0.25	<0.11	<0.25	<0.52	<0.30	<0.20	
Carlingford Lough	Mussels	2[N]	<0.41	<0.41	<0.20	0.96	<0.83	<0.51	<0.26	
Further afield										
Northern North Sea	*Nephrops*	2	<0.07	<0.09	<0.04	0.11	<0.22	<0.11	<0.10	
Cromer	Crabs	1	<0.10	<0.13	<0.05	<0.05	<0.25	<0.17	<0.11	
Southern North Sea	Cockles	1	<0.13	<0.16	<0.07	<0.06	<0.39	<0.19	<0.17	
Southern North Sea	Mussels	2	<0.20	<0.22	<0.11	0.13	<0.41	<0.27	<0.16	
Southern North Sea	Cockles[d]	1	<0.18	<0.15	<0.07	<0.05	<0.48	<0.14	<0.14	
Southern North Sea	Mussels[d]	1	<0.12	<0.13	<0.06	<0.05	<0.27	<0.16	<0.11	33
English Channel-East	Scallops	2	<0.12	<0.14	<0.06	<0.06	<0.29	<0.20	<0.13	
English Channel-West	Crabs	2	<0.30	<0.34	<0.16	<0.13	<0.67	<0.40	<0.23	
English Channel-West	Lobsters	2	<0.15	<0.16	<0.07	<0.06	<0.36	<0.22	<0.16	
English Channel-West	Scallops	2	<0.12	<0.13	<0.06	<0.05	<0.33	<0.18	<0.14	
Northern Irish Sea	Crabs	1	<0.13	0.32	<0.06	0.99	<0.42	<0.16	<0.15	
Northern Irish Sea	Octopuses	1	<0.46	<0.52	<0.20	0.18	<1.3	<0.58	<0.46	

* *Not detected by the method used*
[a] *The concentration of ^{129}I was <1.9 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <1.7 Bq kg^{-1}*
[c] *Samples collected by Consumer 12*
[d] *Landed in Holland or Denmark*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

Table 2.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cumbria									
Silloth	Shrimps	1		0.0013	0.0066	<1.2	0.017	*	*
Silloth	Mussels	1		0.89	4.5		9.2	*	0.0093
Maryport	Plaice	4					<0.18		
River Derwent	Sea trout	1					<0.57		
Parton	Cod	4					<0.31		
Parton	Crabs	4					0.83		
Parton	Lobsters	4					1.3		
Parton	Winkles	1		1.6	8.6	63	17	*	0.012
Whitehaven	Cod	1		0.0013	0.0046		0.0013	*	*
Whitehaven	Plaice	1		0.0014	0.0071		0.016	*	0.000023
Whitehaven	Skates / rays	1		0.00033	0.0016		0.0027	*	*
Whitehaven	Sole	1		0.00013	0.00087		0.0015	*	*
Whitehaven	*Nephrops*	1		0.036	0.20		0.95	0.0018	0.00089
Whitehaven	Cockles	1		0.00087	0.0066		0.0085	*	0.00037
Whitehaven	Mussels	1		<0.00034	0.0014	<1.5	0.0015	*	*
Whitehaven outer harbour	Mussels	2					8.0		
Saltom Bay	Winkles	4					12		
St Bees	Winkles	1	0.039	1.9	9.7	75	20	*	*
St Bees	Mussels	2		1.4	7.5	64	15	*	0.028
St Bees	Limpets	1		2.0	10		19	0.022	0.024
Nethertown	Winkles	4	0.045	3.2	16	140	31	*	0.061
Nethertown	Mussels	4		1.4	6.7		16	*	0.033
River Ehen	Sea trout	1					<0.22		
Sellafield coastal area	Cod	2		0.00092	0.0042		0.0075	*	<0.000021
Sellafield coastal area	Plaice	1		0.0019	0.012		0.027	*	0.000031
Sellafield coastal area	Bass	1					<0.38		
Sellafield coastal area	Grey mullet	1					<0.12		
Sellafield coastal area	Crabs	2	0.0029	0.097	0.46	4.4	2.0	*	0.0031
Sellafield coastal area	Lobsters	2	0.019	0.086	0.37	3.3	7.0	<0.0056	0.011
Sellafield coastal area	*Nephrops*	1		0.094	0.50		1.9	*	0.0047
Sellafield coastal area[a]	Winkles	2	0.023	2.8	15	120	30	*	0.040
Sellafield coastal area[a]	Mussels	1		1.4	7.4	58	14	*	0.016
Sellafield coastal area[a]	Limpets	1		1.6	8.2	62	18	*	0.022
Sellafield offshore area	Cod	1		0.00043	0.0025		0.0055	0.000060	0.000029
Sellafield offshore area	Plaice	1	0.00021	0.0029	0.020		0.037	*	0.000078
Sellafield offshore area	Dab	1					<0.10		
Sellafield offshore area	Lesser spotted dogfish	2					<0.29		
Sellafield offshore area	Pollack	1					<0.52		
Sellafield offshore area	Skates / rays	1					<0.48		
Sellafield offshore area	Gurnards	1					0.15		
Whitriggs	Shrimps	1					0.33		
Drigg	Winkles	1	0.021	1.8	9.5	72	20	*	*
Ravenglass	Cod	1		0.00043	0.0024		0.0051	*	*
Ravenglass	Plaice	1		0.0019	0.010		0.021	*	0.000035
Ravenglass	Crabs	1		0.041	0.23	3.2	1.2	*	0.0017
Ravenglass	Lobsters	1		0.043	0.21	1.8	4.3	*	0.034
Ravenglass	Winkles	2					24		
Ravenglass	Cockles	1		1.8	9.3	73	29	0.041	0.052
Ravenglass	Mussels	1		1.1	5.3	45	12	0.0099	0.020
Tarn Bay	Winkles	1		1.8	9.4	72	18	0.036	*
Haverigg	Cockles	1		1.6	8.5		28	0.065	*
Millom	Mussels	2					4.3		
Barrow	Crabs	1		0.023	0.012		0.73	*	0.0012
Barrow	Lobsters	4					1.1		
Roosebeck	Pacific oysters	1		0.18	1.0		1.1	*	0.0014
Morecambe Bay (Flookburgh)	Flounder	1		0.00054	0.0031		0.0074	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0051	0.031	0.21	0.055	*	0.000063
Morecambe Bay (Flookburgh)	Cockles	1		0.34	2.0	12	5.9	*	0.0053

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), 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)	Whiting	4					<0.22		
Morecambe Bay (Morecambe)	Bass	2					<0.17		
Morecambe Bay (Morecambe)	Flounder	4					<0.29		
Morecambe Bay (Morecambe)	Shrimps	2					<0.12		
Morecambe Bay (Morecambe)	Mussels	1		0.19	1.1		2.1	*	0.0017
Red Nab Point	Winkles	1		0.33	1.8		3.5	0.014	0.0030
Morecambe Bay (Middleton Sands)	Cockles	1		0.40	2.4		6.2	*	0.0040
Morecambe Bay (Sunderland Point)	Whitebait	1		0.039	0.24	2.2	0.38	*	0.00051
Fleetwood	Cod	1		0.00047	0.0025		0.0056	*	*
Fleetwood	Plaice	1		0.0050	0.027		0.043	0.000022	0.000057
Fleetwood	Squid	1					<0.07		
Knott End	Cockles	1		0.56	3.2		7.7	0.010	0.0087
Ribble Estuary	Grey mullet	2					<0.25		
Ribble Estuary	Salmon	1					<0.07		
Ribble Estuary	Sole	1					<0.13		
Ribble Estuary	Bass	1					<0.10		
Ribble Estuary	Shrimps	1	<0.0010	0.0016	0.011		0.017	*	*
Ribble Estuary	Mussels	2					1.0		
Dee Estuary	Cockles	1		0.19	1.1		2.6	*	0.0040
Wirral	Shrimps	2					<0.07		
Scotland									
Shetland	Fish meal	1		0.000075	0.00072		0.00070	0.000026	*
Shetland	Fish oil	2					<0.16		
Minch	Herring	1					<0.15		
Minch	Mackerel	1		0.000059	0.00018		0.00023	*	*
West of Scotland	Mackerel	1					<0.44		
West of Scotland	Farmed salmon	1					<0.12		
Lewis	Mussels	1					<0.13		
Skye	Lobsters	1					<0.11		
Skye	Mussels	1					<0.17		
Islay	Crabs	1					<0.12		
Islay	Scallops	1					<0.10		
Kirkcudbright	Scallops	1		0.022	0.12		0.056		
Kirkcudbright	Queens	1		0.013	0.065		0.093		
Kirkcudbright	Limpets	1					6.5		
Southerness	Winkles	1		0.27	1.6	<2.5	3.0		
Dumfries	Plaice	1		0.0015	0.0064		0.0043		
North Solway coast	Crabs	1		0.038	0.17	<1.2	0.51		
North Solway coast	Lobsters	1		0.020	0.099	0.99	0.58		
North Solway coast	Winkles	1		0.24	1.5		2.7		
North Solway coast	Cockles	1		1.5	8.7		19		
North Solway coast	Mussels	1		0.50	2.4	7.9	5.2		
Inner Solway	Flounder	1		0.0047	0.035		0.072		
Inner Solway	Shrimps	1		0.0079	0.054		0.027		
Isle of Man									
Isle of Man	Cod	1		0.00016	0.00096		0.0015	*	*
Isle of Man	Herring	1		0.0023	0.014		0.026	*	0.000059
Isle of Man	Lobsters	4					<0.14		
Isle of Man	Scallops	1		0.043	0.24		0.14	*	0.00027

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Wales							
Conwy	Mussels	1	0.021	0.12	0.29	*	0.00024
North Anglesey	Skates / rays	1	0.000042	0.00024	0.00041	*	*
North Anglesey	Spurdog	1			<0.35		
North Anglesey	Lesser spotted dogfish	1			<0.32		
North Anglesey	Plaice	2			<0.07		
North Anglesey	Bass	1			<0.04		
North Anglesey	Crabs	1	0.0042	0.022	0.074	*	0.000097
North Anglesey	Lobsters	2			<0.18		
Lavernock Point	Limpets	1			<0.11		
Northern Ireland							
North coast	Spurdog	4[N]			<0.11		
Ballycastle	Lobsters	2[N]			0.55		
County Down	Scallops	2[N]			<0.29		
Ardglass	Herring	2[N]			<0.48		
Kilkeel	Cod	4[N]			<0.18		
Kilkeel	Plaice	4[N]			<0.06		
Kilkeel	Spurdog	1[N]			<0.13		
Kilkeel	Haddock	4[N]			<0.28		
Kilkeel	Hake	3[N]			<0.22		
Kilkeel	Crabs	4[N]			<0.23		
Kilkeel	Lobsters	4[N]			<0.14		
Kilkeel	*Nephrops*	1[N]	0.0017	0.0095	0.024	*	*
Minerstown	Winkles	1[N]	0.020	0.11	0.11	*	0.00011
Carlingford Lough	Mussels	2[N]			0.31		
Glenarm	Brown trout	1			<0.09		
Further afield							
Baltic Sea	Cod	2			<0.29		
Baltic Sea	Herring	2			<0.19		
Barents Sea	Cod	2			<0.07		
Norwegian Sea	Cod	1			<0.05		
Norwegian Sea	Haddock	1			<0.25		
Norwegian Sea	Saithe	1			<0.05		
Norwegian Sea	Whiting	1			<0.06		
Norwegian processed	Cod	1	<0.00012	0.00020	0.00060	0.00043	*
Iceland area	Cod	1			<0.03		
Skagerrak	Cod	2			<0.05		
Skagerrak	Herring	2			<0.12		
Northern North Sea	Cod	1	0.000023	0.000043	0.00043	*	*
Northern North Sea	Plaice	1			<0.08		
Northern North Sea	Haddock	1	0.000037	0.00027	0.00042	0.000015	*
Northern North Sea	Herring	1			<0.09		
Northern North Sea	Whiting	2			<0.16		
Northern North Sea	*Nephrops*	1	0.00016	0.0018	0.0026	*	*
Mid North Sea	Cod	2			<0.16		
Mid North Sea	Plaice	2			<0.04		
Cromer	Crabs	1			<0.06		
Gt Yarmouth (retail shop)	Cod	2			<0.07		
Gt Yarmouth (retail shop)	Plaice	2			<0.04		
Southern North Sea	Cod	2			<0.08		
Southern North Sea	Sole	1			<0.06		
Southern North Sea	Herring	1			<0.08		
Southern North Sea	Skates / rays	1			<0.06		
Southern North Sea	Cockles	1	0.0011	0.0073	0.0079	*	0.00036
Southern North Sea	Mussels	1	0.0023	0.016	0.0066	*	*
Southern North Sea	Cockles[b]	1	0.0016	0.0079	0.0075	*	0.00023
Southern North Sea	Mussels[b]	1	0.00021	0.0024	0.0015	*	*
English Channel-East	Cod	1			<0.18		
English Channel-East	Plaice	1			<0.07		
English Channel-East	Whiting	1			<0.10		
English Channel-East	Flounder	1			<0.04		
English Channel-East	Scallops	1	0.00050	0.0024	0.0014	*	0.000044
English Channel-West	Mackerel	2			<0.23		

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
English Channel-West	Plaice	2			<0.09		
English Channel-West	Whiting	2			<0.05		
English Channel-West	Crabs	1	0.00014	0.0011	0.0012	*	*
English Channel-West	Lobsters	2			<0.17		
English Channel-West	Scallops	1	0.00018	0.0032	0.00064	*	*
Celtic Sea	Cod	1			<0.13		
Celtic Sea	Haddock	1			<0.11		
Celtic Sea	Pollack	1			<0.07		
Celtic Sea	Witch	1			<0.06		
Northern Irish Sea	Dab	1			0.06		
Northern Irish Sea	Lesser spotted dogfish	1			<0.33		
Northern Irish Sea	Skates / rays	1			<0.12		
Northern Irish Sea	Crabs	1			1.3		
Northern Irish Sea	Octopodes	1			<0.38		

* *Not detected by the method used*
[a] *Samples collected by consumer 12*
[b] *Landed in Holland or Denmark*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

Table 2.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria												
Newton Arlosh	Sediment	4	<1.4		<2.6	<1.2	<11		<4.8	<1.3	120	<4.9
Maryport Outer Harbour	Sediment	2	<0.94	<1.5	<0.76	<0.33	<3.0		<1.4	<0.36	72	<1.7
Workington Harbour	Sediment	2	<1.0		<1.8	<0.85	<6.4		<3.3	<0.87	57	<3.3
Harrington Harbour	Sediment	2	<1.5		<1.9	<0.87	<7.2		<4.0	<0.94	200	<3.7
Whitehaven Outer Harbour	Sediment	4	<1.2	<1.5	<1.2	<0.82	<4.7		<3.4	<0.61	110	<2.6
St Bees beach	Sediment	4	<1.9		<1.1	<0.50	<4.4		<2.2	<0.54	66	<2.1
Sellafield beach, S of former pipeline	Sediment	2	1.8		<0.58	<0.26	<2.4		<1.1	<0.28	60	<1.4
River Calder - downstream	Sediment	2	1.2		<0.69	<0.30	<2.9		<1.3	<0.33	110	<1.8
River Calder - upstream	Sediment	2	<0.89		<1.8	<0.73	<6.0		<2.9	<0.79	60	<3.5
Seascale beach	Sediment	4	<1.3		<0.93	<0.40	<3.4		<1.7	<0.43	39	<2.0
Ravenglass - Carleton Marsh	Sediment	4	8.6		<3.1	<1.3	<24		<6.9	<1.5	330	<6.1
River Mite Estuary	Sediment	4	7.9	110	<3.1	<1.3	<15		<7.8	<1.7	780	<7.2
Ravenglass - Raven Villa	Sediment	4	3.5		<1.8	<0.74	<7.2		<3.6	<0.86	130	<3.7
Newbiggin (Eskmeals)	Sediment	4	<8.1	120	<3.4	<1.4	<15		<6.3	<1.6	330	<6.6
Haverigg	Sediment	2	<2.2		<0.75	<0.39	<3.1		<1.4	<0.37	70	<1.8
Millom	Sediment	2	<2.1		<2.4	<1.0	<9.3		<4.9	<1.1	120	<4.2
Low Shaw	Sediment	1	<0.47		<0.75	<0.32	<3.1		<1.7	<0.38	96	<1.8
Walney Channel - N of discharge point	Sediment	2	<0.80		<0.75	<0.42	<3.0		<1.3	<0.36	65	<1.8
Walney Channel - S of discharge point	Sediment	2	<0.50		<0.68	<0.33	<2.9		<1.3	<0.34	43	<1.6
Sand Gate Marsh	Sediment	4	<0.80		<1.4	<0.66	<5.4		<2.7	<0.69	65	<2.7
Kents Bank	Sediment	4	<1.1		<2.0	<0.92	<8.6		<3.8	<1.0	220	<4.2
Lancashire												
Morecambe	Sediment	2	<0.31								9.4	
Half Moon Bay	Sediment	2	<0.38								57	
Heysham pipelines	Sediment	2	<0.42								21	
Potts Corner	Sediment	2	<0.40								23	
Sunderland Point	Sediment	4	<0.53		<0.85	<0.53	<0.35		<1.6	<0.45	59	<2.1
Conder Green	Sediment	4	<0.52		<0.91	<0.49	<3.6		<1.6	<0.46	81	<2.2
Hambleton	Sediment	4	1.8		<1.1	<0.52	<5.2		<2.5	<0.59	300	<3.0
Skippool Creek	Sediment	4	<1.5		<1.2	<0.55	<5.3		<2.5	<0.61	280	<2.9
Fleetwood	Sediment	4	<0.35		<0.59	<0.26	<2.2		<0.94	<0.27	11	<1.3
Blackpool	Sediment	4	<0.32		<0.54	<0.24	<1.9		<0.81	<0.25	3.8	<1.1
Crossens Marsh	Sediment	4	<2.1		<3.3	<1.5	<14		<6.6	<1.7	240	<6.4
Ainsdale	Sediment	4	<0.30		<0.48	<0.22	<1.9		<0.79	<0.24	5.4	<1.1
Rock Ferry	Sediment	4	<0.84		<1.5	<0.72	<6.2		<2.5	<0.72	130	<3.2
New Brighton	Sediment	4	<0.34		<0.56	<0.25	<2.0		<0.89	<0.27	5.2	<1.2
Scotland												
Campbeltown	Sediment	1[S]	<0.10		<0.32	<0.12	<0.68	<0.11	<0.22	<0.10	8.0	<0.63
Garlieston	Sediment	1[S]	0.37		<0.21	<0.22	<0.63	<0.10	0.67	<0.10	23	<0.62
Innerwell	Sediment	1[S]	1.9		<0.35	<0.36	<0.98	<0.17	1.7	<0.14	110	<1.2
Carsluith	Sediment	1[S]	1.5		<0.32	<0.30	2.5	<0.15	1.7	<0.13	110	<1.0
Skyreburn	Sediment	1[S]	5.7		<0.52	<0.76	4.6	<0.29	4.7	<0.23	350	<2.0
Cutter's Pool	Sediment	1[S]	1.7		<0.40	<0.41	<1.3	<0.18	2.1	<0.15	150	<1.4
Rascarrel Bay	Sediment	1[S]	0.27		<0.63	<0.27	<0.92	<0.14	1.7	<0.12	65	<0.85
Palnackie Harbour	Sediment	1[S]	1.4		<0.26	<0.26	<1.1	<0.14	1.7	<0.12	120	<0.97
Gardenburn	Sediment	1[S]	1.9		<0.33	<0.31	<1.3	<0.16	1.7	<0.13	160	<1.2
Kippford Slipway	Sediment	1[S]	2.1		<0.26	<032	2.4	<0.16	2.0	<0.13	170	<1.1
Kippford Merse	Sediment	1[S]	0.82		<0.31	<0.36	<1.7	<0.18	<0.41	<0.15	420	<1.5
Southerness	Sediment	1[S]	0.35		<0.18	<0.15	<0.67	<0.11	<0.19	<0.10	32	<0.65
Kirkconnel Merse	Sediment	1[S]	1.4		<1.4	<3.9	<3.3	<0.37	<1.5	<0.26	710	<2.8

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Cumbria										
Newton Arlosh	Sediment	4	<8.8	<2.2				59	310	760
Maryport Outer Harbour	Sediment	2	<2.5	<0.83	11	64	410	76	420	590
Workington Harbour	Sediment	2	<7.1	<1.5				27	400	730
Harrington Harbour	Sediment	2	<7.1	<1.6				69	470	880
Whitehaven Outer Harbour	Sediment	4	<4.6	<1.2	12	67	470	91	440	610
St Bees beach	Sediment	4	<4.3	<1.1				170	330	400
Sellafield beach, S of former pipeline	Sediment	2	<1.9	<0.75				140	280	370
River Calder - downstream	Sediment	2	<2.1	<0.87					280	710
River Calder - upstream	Sediment	2	<5.8	<1.8					360	1400
Seascale beach	Sediment	4	<3.1	<0.99				140	450	460
Ravenglass - Carleton Marsh	Sediment	4	<10	<3.2				960	1900	1500
River Mite Estuary	Sediment	4	<12	<3.3	150	850	6100	1400	2900	1900
Ravenglass - Raven Villa	Sediment	4	<4.9	<1.9				360	1000	920
Newbiggin (Eskmeals)	Sediment	4	<9.4	<3.4	110	520	4900	550	1600	1100
Haverigg	Sediment	2	<2.5	<1.1					560	580
Millom	Sediment	2	<9.1	<1.9				260	710	1100
Low Shaw	Sediment	1	<3.4	<1.0				130	350	580
Walney Channel - N of discharge point	Sediment	2	<2.2	<0.95				130	410	550
Walney Channel - S of discharge point	Sediment	2	<2.4	<0.81				79	440	650
Sand Gate Marsh	Sediment	4	<5.6	<1.3				49	170	500
Kents Bank	Sediment	4	<5.6	<2.3				120	400	640
Lancashire										
Half Moon Bay	Sediment	2			6.6	36		60		
Heysham pipelines	Sediment	2						21		
Potts Corner	Sediment	2						12		
Sunderland Point	Sediment	4	<2.8	<1.1				52	330	650
Conder Green	Sediment	4	<2.8	<1.2				70	430	770
Hambleton	Sediment	4	<3.5	<1.5				240	720	1200
Skippool Creek	Sediment	4	<3.5	<1.4				220	630	1000
Fleetwood	Sediment	4	<1.9	<0.63				12	<140	390
Blackpool	Sediment	4	<1.8	<0.55				3.4	<110	220
Crossens Marsh	Sediment	4	<11	<3.1				180	550	1200
Ainsdale	Sediment	4	<1.6	<0.55				3.4	<110	240
Rock Ferry	Sediment	4	<3.8	<1.6				77	430	860
New Brighton	Sediment	4	<1.9	<0.61				4.2	<110	320
Scotland										
Campbeltown	Sediment	1[S]	<0.16	<0.32				1.2		
Garlieston	Sediment	1[S]	<0.12	<0.25	6.8	36		58		
Innerwell	Sediment	1[S]	1.1	0.78				160		
Carsluith	Sediment	1[S]	0.72	0.64	16	94		170	250	1200
Skyreburn	Sediment	1[S]	2.3	<0.86				530		
Cutter's Pool	Sediment	1[S]	1.1	2.2				<1.2		
Rascarrel Bay	Sediment	1[S]	<0.19	0.53				13		
Palnackie Harbour	Sediment	1[S]	0.89	0.95	18	100		170		
Gardenburn	Sediment	1[S]	0.96	1.1	22	120		210		
Kippford Slipway	Sediment	1[S]	0.77	0.93	25	140		270		
Kippford Merse	Sediment	1[S]	1.0	1.2	30	170		340		
Southerness	Sediment	1[S]	<0.16	0.68	5.4	32		54		
Kirkconnel Merse	Sediment	1[S]	1.5	2.7	35	220		350	270	950

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man											
Ramsey	Sediment	1	<0.35	<0.62	<0.32	<2.5		<0.73	<0.27	13	<1.6
Wales											
Rhyl	Sediment	2	<1.3	<2.3	<1.1	<9.0		<3.3	<1.1	84	<4.4
Llandudno	Sediment	2	<0.27	<0.49	<0.22	<1.8		<0.73	<0.23	3.0	<1.2
Caerhun	Sediment	2	<0.46	<0.90	<0.46	<3.5		<1.4	<0.43	57	<2.2
Llanfairfechan	Sediment	2	<0.39	<0.72	<0.33	<2.8		<1.1	<0.34	24	<1.6
Northern Ireland											
Carrichue	Mud and sand	2^{N}	<0.35	<2.0	<3.5	<4.0	<0.71	<0.95	<0.41	1.5	<2.3
Portrush	Sand	2^{N}	<0.29	<1.4	<2.0	<3.3	<0.66	<0.88	<0.38	0.72	<2.5
Oldmill Bay	Mud	2^{N}	<0.82	<4.9	<7.9	<9.6	<1.9	<2.8	<1.3	57	<6.1
Ballymacormick	Mud	2^{N}	<0.40	<1.7	<2.0	<4.5	<0.85	<1.3	<0.55	15	<3.2
Strangford Lough - Nicky's Point	Mud	2^{N}	<0.66	<3.7	<6.1	<7.3	<1.3	<2.1	<0.91	37	<4.7
Dundrum Bay	Mud	1^{N}	<0.57	<1.7	<1.6	<5.5	<1.1	<1.4	<0.76	4.2	<4.3
Dundrum Bay	Mud and sand	1^{N}	<0.44	<1.8	<2.2	<4.5	<0.86	<1.2	<0.57	5.4	<3.8
Carlingford Lough	Mud	2^{N}	<0.64	<3.0	<4.3	<6.7	<1.3	<2.0	<0.88	45	<3.9

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Isle of Man											
Ramsey	Sediment	1	<1.1	<0.80			2.3			290	500
Wales											
Rhyl	Sediment	2	<5.3	<2.3			49			<270	1100
Llandudno	Sediment	2	<1.5	<0.55			2.4			<100	290
Caerhun	Sediment	2	<2.5	<1.3			18			390	950
Llanfairfechan	Sediment	2	<2.1	<0.84			16			190	510
Northern Ireland											
Carrichue	Mud and sand	2^{N}	<1.1	<0.92	0.041	0.25	0.37	*	*		
Portrush	Sand	2^{N}	<0.92	<1.2			<1.4				
Oldmill Bay	Mud	2^{N}	<3.0	<2.6			<16				
Ballymacormick	Mud	2^{N}	<1.4	<1.5			12				
Strangford Lough - Nicky's Point	Mud	2^{N}	<1.9	<2.2			9.0				
Dundrum Bay	Mud	1^{N}	<1.8	<2.3			<4.3				
Dundrum Bay	Mud and sand	1^{N}	<1.4	<1.8			<2.3				
Carlingford Lough	Mud	2^{N}	<1.9	<1.7	1.9	12	13	0.013	0.016		

* *Not detected by the method used*

^{S} *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

^{N} *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

All other measurements are made on behalf of the Environment Agency

Table 2.9. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2008

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Grass	2	0.083
Burgh Marsh	Grass	2	0.086
Port Carlisle 1	Mud and salt marsh	3	0.092
Port Carlisle 1	Mud and sand	1	0.086
Port Carlisle 2	Mud and salt marsh	2	0.095
Port Carlisle 2	Grass and salt marsh	1	0.094
Port Carlisle 2	Grass	1	0.087
Greenend 1	Mud and pebbles	1	0.093
Greenend 1	Mud and stones	2	0.10
Greenend 1	Pebbles	1	0.11
Greenend 2	Mud and pebbles	1	0.11
Greenend 2	Mud and stones	1	0.096
Greenend 2	Grass and salt marsh	1	0.095
Greenend 2	Grass	1	0.091
Cardurnock Marsh	Grass	4	0.085
Newton Arlosh	Grass	4	0.10
Silloth harbour	Mud and pebbles	1	0.10
Silloth harbour	Pebbles and sand	2	0.097
Silloth harbour	Pebbles	1	0.10
Silloth silt pond	Grass and sand	2	0.085
Silloth silt pond	Grass	2	0.082
Allonby	Sand	2	0.086
Allonby	Pebbles and sand	2	0.10
Maryport harbour	Sand	2	0.095
Workington harbour	Pebbles and sand	1	0.11
Workington harbour	Pebbles and stones	1	0.11
Harrington harbour	Pebbles and sand	2	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	1	0.10
Whitehaven - outer harbour	Pebbles and sand	3	0.10
St Bees	Sand	3	0.079
St Bees	Pebbles and sand	1	0.076
Nethertown beach	Pebbles and stones	1	0.13
Nethertown beach	Pebbles and rock	1	0.12
Braystones	Sand	1	0.079
Braystones	Pebbles and sand	1	0.12
Sellafield dunes	Sand and grass	1	0.10
Sellafield dunes	Grass	1	0.10
North of former pipeline on foreshore	Sand	1	0.088
North of former pipeline on foreshore	Pebbles and sand	1	0.11
South of former pipeline on foreshore	Sand	1	0.085
South of former pipeline on foreshore	Pebbles and sand	1	0.086
River Calder downstream of factory sewer	Grass and sand	1	0.11
River Calder downstream of factory sewer	Grass	1	0.11
River Calder upstream of factory sewer	Grass	2	0.098
Seascale beach	Sand	4	0.081
Seascale	Grass	4	0.087

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Grass and mud	3	0.15
Ravenglass - Carleton Marsh	Grass	1	0.14
Ravenglass - River Mite estuary	Salt marsh	2	0.17
Ravenglass - River Mite estuary	Grass	2	0.17
Ravenglass - Raven Villa	Salt marsh and mud	2	0.15
Ravenglass - Raven Villa	Salt marsh	1	0.16
Ravenglass - Raven Villa	Grass and salt marsh	1	0.16
Ravenglass - boat area	Sand and stones	3	0.11
Ravenglass - boat area	Pebbles and stones	1	0.11
Ravenglass - ford	Mud	1	0.12
Ravenglass - ford	Mud and sand	1	0.10
Ravenglass - ford	Sand	2	0.12
Muncaster Bridge	Grass	4	0.12
Ravenglass - salmon garth	Pebbles and sand	1	0.12
Ravenglass - salmon garth	Sand and stones	3	0.11
Ravenglass - Eskmeals Nature Reserve	Salt marsh and mud	3	0.13
Ravenglass - Eskmeals Nature Reserve	Grass and mud	1	0.13
Newbiggin/Eskmeals viaduct	Salt marsh and mud	2	0.15
Newbiggin/Eskmeals viaduct	Salt marsh	2	0.15
Newbiggin/Eskmeals bridge	Mud	1	0.14
Newbiggin/Eskmeals bridge	Salt marsh and mud	1	0.15
Newbiggin/Eskmeals bridge	Salt marsh	2	0.16
Tarn Bay	Sand	2	0.080
Silecroft	Pebbles and sand	1	0.11
Silecroft	Pebbles	1	0.12
Haverigg	Mud	1	0.097
Haverigg	Mud and sand	1	0.081
Millom	Mud and salt marsh	1	0.11
Millom	Grass and mud	1	0.11
Low Shaw	Grass	1	0.086
Askam	Sand	1	0.078
Askam	Sand and stones	1	0.095
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud and stones	1	0.097
Walney Channel, N of discharge point	Pebbles and sand	1	0.093
Walney Channel, S of discharge point	Mud and sand	2	0.095
Tummer Hill Marsh	Salt marsh	2	0.12
Roa Island	Shell	1	0.090
Roa Island	Shell and stones	1	0.099
Greenodd Salt Marsh	Grass and mud	1	0.080
Greenodd Salt Marsh	Grass	1	0.079
Sand Gate Marsh	Grass and mud	3	0.084
Sand Gate Marsh	Grass	1	0.083
Kents Bank 2	Grass and salt marsh	1	0.093
Kents Bank 2	Grass	3	0.088
High Foulshaw	Grass and mud	1	0.073
High Foulshaw	Grass	3	0.080
Arnside 1	Mud	2	0.083
Arnside 1	Mud and sand	2	0.082
Arnside 2	Grass and salt marsh	1	0.096
Arnside 2	Grass	3	0.093
Lancashire and Merseyside			
Morecambe Central Pier	Mud and sand	1	0.077
Morecambe Central Pier	Sand	1	0.072
Heysham pipelines	Sand	1	0.082
Heysham pipelines	Sand and stones	1	0.082
Half Moon Bay	Mud	1	0.088
Half Moon Bay	Sand and stones	1	0.069
Middleton Sands	Sand	2	0.078
Sunderland Point	Mud	2	0.091
Sunderland Point	Mud and salt marsh	2	0.095
Sunderland	Salt marsh	4	0.11
Colloway Marsh	Salt marsh	2	0.13
Colloway Marsh	Grass and salt marsh	2	0.14
Lancaster	Grass	4	0.083

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lancashire and Merseyside			
Aldcliffe Marsh	Mud	1	0.14
Aldcliffe Marsh	Grass and mud	1	0.13
Aldcliffe Marsh	Salt marsh	1	0.10
Aldcliffe Marsh	Grass and salt marsh	1	0.10
Conder Green	Mud and salt marsh	1	0.090
Conder Green	Mud and grass	1	0.098
Conder Green	Salt marsh	1	0.092
Conder Green	Grass and salt marsh	1	0.094
Pilling Marsh	Grass and salt marsh	1	0.097
Pilling Marsh	Grass	3	0.10
Knott End	Mud and sand	1	0.081
Knott End	Sand	1	0.10
Heads - River Wyre	Salt marsh and mud	1	0.11
Heads - River Wyre	Grass and mud	3	0.11
Height o' th' hill - River Wyre	Salt marsh and grass	1	0.12
Height o' th' hill - River Wyre	Grass	3	0.12
Hambleton	Mud and salt marsh	1	0.12
Hambleton	Grass and mud	3	0.12
Skippool Creek 1	Mud and salt marsh	2	0.10
Skippool Creek 1	Wood	2	0.11
Skippool Creek 2	Salt marsh	4	0.11
Skippool Creek 2	Grass and mud	1	0.11
Skippool Creek 2	Grass and salt marsh	2	0.12
Skippool Creek 2	Grass	1	0.12
Skippool Creek boat 2	Wood	4	0.10
Skippool Creek boat 2 - in vicinity of boats	Mud	1	0.090
Skippool Creek boat 2 - in vicinity of boats	Mud and salt marsh	2	0.095
Skippool Creek boat 2 - in vicinity of boats	Grass and mud	1	0.092
Fleetwood Marsh Nature Park	Salt marsh	4	0.13
Fleetwood shore 1	Sand	3	0.082
Blackpool	Sand	4	0.072
Crossens Marsh	Salt marsh	4	0.095
Ainsdale	Sand	4	0.065
Rock Ferry	Mud	1	0.099
Rock Ferry	Mud and sand	3	0.091
New Brighton	Sand	4	0.067
West Kirby	Mud and sand	1	0.071
West Kirby	Sand	3	0.071
Little Neston Marsh 1	Grass and mud	1	0.091
Little Neston Marsh 1	Grass and salt marsh	1	0.088
Little Neston Marsh 2	Salt marsh	2	0.072
Flint 1	Mud and salt marsh	1	0.091
Flint 1	Mud and grass	1	0.097
Flint 2	Salt marsh	2	0.11
Scotland			
Piltanton Burn	Salt marsh	4	0.061
Garlieston	Mud	4	0.080
Innerwell	Mud	4	0.083
Bladnoch	Mud	4	0.089
Carsluith	Mud	4	0.091
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.077
Kirkcudbright	Salt marsh	4	0.081
Cutters Pool	Winkle bed	4	0.085
Rascarrel Bay	Winkle bed	4	0.095
Gardenburn	Salt marsh	1	0.081
Palnackie Harbour	Mud	1	0.066
Kippford - Slipway	Mud	4	0.10
Kippford - Merse	Salt marsh	1	0.11
Southerness	Winkle bed	4	0.067
Kirkconnell Marsh	Salt marsh	1	0.097
Isle of Man			
Ramsey	Pebbles and sand	1	0.092

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Wales			
Prestatyn	Sand	2	0.066
Rhyl	Mud and salt marsh	1	0.085
Rhyl	Grass and mud	1	0.082
Llandudno	Pebbles and sand	1	0.089
Llandudno	Pebbles and rock	1	0.092
Caerhun	Mud and grass	2	0.089
Llanfairfechan	Sand and shells	1	0.082
Llanfairfechan	Salt marsh	1	0.081
Northern Ireland			
Lishally	Mud	1	0.066
Eglington	Shingle	1	0.058
Carrichue	Mud	1	0.069
Bellerena	Mud	1	0.061
Benone	Sand	1	0.061
Castlerock	Sand	1	0.063
Portstewart	Sand	1	0.066
Portrush, Blue Pool	Sand	1	0.064
Portrush, White Rocks	Sand	1	0.060
Portballintrae	Sand	1	0.058
Giant's Causeway	Sand	1	0.068
Ballycastle	Sand	1	0.060
Cushendun	Sand	1	0.063
Cushendall	Sand and stones	1	0.069
Red Bay	Sand	1	0.072
Carnlough	Sand	1	0.058
Glenarm	Sand	1	0.056
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.057
Drains Bay	Sand	1	0.055
Larne	Sand	1	0.061
Whitehead	Sand	1	0.068
Carrickfergus	Sand	1	0.058
Jordanstown	Sand	1	0.065
Helen's Bay	Sand	1	0.058
Groomsport	Sand	1	0.071
Millisle	Sand	1	0.067
Ballywalter	Sand	1	0.067
Ballyhalbert	Sand	1	0.064
Cloghy	Sand	1	0.076
Portaferry	Shingle and stones	1	0.097
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.092
Ards Maltings	Mud	1	0.085
Island Hill	Mud	1	0.072
Nicky's Point	Mud	1	0.071
Strangford	Shingle and stones	1	0.093
Kilclief	Sand	1	0.079
Ardglass	Mud	1	0.089
Killough	Mud	1	0.086
Rocky Beach	Sand	1	0.074
Tyrella	Sand	1	0.080
Dundrum	Sand	1	0.092
Newcastle	Sand	1	0.092
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.090
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.082
Rostrevor	Sand	1	0.10
Narrow Water	Mud	1	0.097

Table 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2008

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
M	Nets	4	0.065
	Rope	4	0.041
S	Nets	4	0.044
	Pots	4	<0.039
T	Gill nets	4	0.059
	Pots	4	0.046
W	Gill nets	2	0.024
	Pots	2	0.033
X	Gill nets	4	0.050
	Pots	4	0.058
Z	Nets	4	0.086

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2008

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, μSv h^{-1}
Whitehaven - outer harbour	Sand	1	*
Whitehaven - outer harbour	Pebbles and sand	3	0.040
St Bees	Sand	3	<0.073
St Bees	Pebbles and sand	1	*
Sellafield pipeline	Pebbles and sand	1	0.040
Ravenglass - Raven Villa	Mud and salt marsh	1	0.060
Ravenglass - Raven Villa	Salt marsh	2	0.060
Ravenglass - Raven Villa	Grass and salt marsh	1	0.020
Tarn Bay	Sand	2	<0.010

* *Not detected by the method used*

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria								
Silloth	Seaweed	2	<0.90		<1.3	<0.65	430	<5.5
Harrington Harbour	Seaweed	2	<0.80		<1.3	<0.53	760	<4.8
St Bees	*Porphyra*[a]	4[F]	<0.19	0.21	<0.36	<0.46	1.3	<3.4
St Bees	Seaweed	2	<1.0	<2.0	<1.5	<0.61	790	<5.1
Braystones South	*Porphyra*	4[F]	0.32		<0.45	<0.85		5.0
Sellafield	*Rhodymenia* spp.	2[F]	0.36		<0.81	<1.2		<3.0
Sellafield	Seaweed	2	<1.4	<1.3	<1.2	<0.53	3000	<4.7
Seascale	*Porphyra*[b]	53[F]	<0.36		<0.51	<0.30		<5.5
Ravenglass	Samphire	1[F]	<0.06		<0.17	<0.19	0.59	<0.62
Ravenglass	Seaweed	2	<0.96		<1.5	<0.59	560	<5.5
Lancashire								
Half Moon Bay	Seaweed	2	<0.90		<1.4	<0.67	250	<5.8
Marshside Sands	Samphire	1[F]	<0.03		<0.14	<0.22		<0.28
Cockerham Marsh	Samphire	1[F]	<0.07		<0.23	<0.29		<0.69
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10		<0.34	<0.49	55	<0.65
Lerwick	*Fucus vesiculosus*	1[S]	<0.10		<0.15	<0.17	2.6	<0.38
Lewis	*Fucus vesiculosus*	1[S]	<0.10		<0.95	<3.0	44	<0.91
Islay	*Fucus vesiculosus*	1[S]	<0.10		<0.21	<0.28	84	<0.46
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10		<0.20	<0.46	180	<0.67
Port William	*Fucus vesiculosus*	4[S]	<0.14		<0.40	<0.76	450	<0.66
Garlieston	*Fucus vesiculosus*	4[S]	<0.17		<0.30	<0.58	240	<0.56
Auchencairn	*Fucus vesiculosus*	4[S]	0.30		<0.35	<0.52	570	<0.57
Isle of Man	*Fucus vesiculosus*	4	<1.2		<1.6	<0.87	410	<7.1
Wales								
Cemaes Bay	Seaweed	2	<0.75		<1.1	<0.52	120	<4.5
Porthmadog	Seaweed	2	<0.63		<1.0	<0.52	18	<4.2
Lavernock Point	Seaweed	2	<0.93		<1.4	<0.68	4.0	<6.1
Fishguard	Seaweed	2	<0.81		<1.2	<0.58	34	<5.0
South Wales, manufacturer A	Laverbread	4[F]	<0.13		<0.53	<0.87		<1.3
South Wales, manufacturer C	Laverbread	4[F]	<0.10		<0.38	<0.73		<0.93
South Wales, manufacturer D	Laverbread	4[F]	<0.11		<0.62	<0.49		<1.2
South Wales, manufacturer E	Laverbread	1[F]	<0.10		<0.22	<0.18		<0.95
Northern Ireland								
Portrush	*Fucus* spp.	4[N]	<0.10		<0.49	<0.98		<0.97
Strangford Lough	*Rhodymenia* spp.	4[N]	<0.13		<0.94	<2.4	6.9	<1.4
Ardglass	*Ascophyllum nodosum*	1[N]	<0.06		<0.18	<0.19		<0.54
Ardglass	*Fucus vesiculosus*	3[N]	<0.18		<0.91	<0.44	770	<1.9
Carlingford Lough	*Fucus* spp.	4[N]	<0.14		<0.80	<0.31	120	<1.4
Isles of Scilly	*Fucus vesiculosus*	1	<1.1		<1.4	<0.76	13	<6.4

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu
Cumbria									
Silloth	Seaweed	2	<0.79	<2.2	<0.66	6.5	<2.4		
Harrington Harbour	Seaweed	2	<0.73	<2.1	<0.60	4.8	<2.4		
St Bees	*Porphyra*[a]	4[F]	<0.19	<0.29	<0.11	0.98	<0.40	<0.32	<0.17
St Bees	Seaweed	2	<0.85	<2.4	<0.66	4.5	<2.4		
Braystones South	*Porphyra*	4[F]	<0.18	<0.47	<0.09	1.3	<0.38	<0.27	<0.16
Sellafield	*Rhodymenia* spp.	2[F]	<0.36	<0.49	<0.19	6.9	<1.0	<0.59	<0.42
Sellafield	Seaweed	2	<0.71	<2.0	<0.57	5.4	<2.2		
Seascale	*Porphyra*[b]	53[F]	<0.53	<0.93	<0.32	1.4	<1.4	<0.93	<0.68
Ravenglass	Samphire	1[F]	<0.10	<0.13	<0.06	0.81	<0.22	<0.17	<0.08
Ravenglass	Seaweed	2	<0.83	<2.3	<0.69	9.6	<2.8		
Lancashire									
Half Moon Bay	Seaweed	2	<0.91	<2.4	<0.73	5.3	<2.9		
Marshside Sands	Samphire	1[F]	<0.06	<0.07	<0.03	0.49	<0.19	<0.09	<0.08
Cockerham Marsh	Samphire	1[F]	<0.12	<0.14	<0.07	0.58	<0.23	<0.20	<0.09
Scotland									
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10	<0.17	<0.10	0.10	<0.41	<0.10	<0.10
Lerwick	*Fucus vesiculosus*	1[S]	<0.10	<0.10	<0.10	<0.10	<0.26	<0.10	<0.10
Lewis	*Fucus vesiculosus*	1[S]	<0.17	<0.23	<0.10	1.3	<0.71	<0.12	<0.25
Islay	*Fucus vesiculosus*	1[S]	<0.10	<0.13	<0.10	0.26	<0.32	<0.10	<0.10
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10	<0.17	<0.10	0.88	<0.44	<0.10	<0.11
Port William	*Fucus vesiculosus*	4[S]	<0.12	<0.14	<0.10	1.5	<0.42	<0.11	<0.17
Garlieston	*Fucus vesiculosus*	4[S]	<0.11	<0.18	<0.10	1.8	<0.36	<0.10	<0.16
Auchencairn	*Fucus vesiculosus*	4[S]	<0.12	<0.33	<0.10	3.9	<0.39	<0.11	<0.18
Isle of Man	*Fucus vesiculosus*	4	<1.1	<2.9	<0.89	<1.3	<3.1	<6.1	<1.6
Wales									
Cemaes Bay	Seaweed	2	<0.70	<2.0	<0.59	<0.66	<2.4		
Porthmadog	Seaweed	2	<0.68	<1.9	<0.55	<1.3	<2.2		
Lavernock Point	Seaweed	2	<0.91	<2.4	<0.74	<0.79	<3.0	<5.1	<1.4
Fishguard	Seaweed	2	<0.75	<2.1	<0.64	<0.65	<2.3		
South Wales, manufacturer A	Laverbread	4[F]	<0.23	<0.26	<0.13	0.29	<0.47	<0.38	<0.19
South Wales, manufacturer C	Laverbread	4[F]	<0.17	<0.19	<0.10	0.19	<0.32	<0.29	<0.13
South Wales, manufacturer D	Laverbread	4[F]	<0.22	<0.25	<0.12	<0.18	<0.56	<0.34	<0.23
South Wales, manufacturer E	Laverbread	1[F]	<0.16	<0.21	<0.10	0.36	<0.31	<0.32	<0.14
Northern Ireland									
Portrush	*Fucus* spp.	4[N]	<0.21	<0.22	<0.10	<0.15	<0.50	<0.34	<0.24
Strangford Lough	*Rhodymenia* spp.	4[N]	<0.28	<0.28	<0.14	0.51	<0.55	<0.41	<0.20
Ardglass	*Ascophyllum nodosum*	1[N]	<0.11	0.21	<0.06	0.41	<0.35	<0.19	<0.17
Ardglass	*Fucus vesiculosus*	3[N]	<0.35	<0.46	<0.19	0.72	<0.93	<0.53	<0.39
Carlingford Lough	*Fucus* spp.	4[N]	<0.26	<0.28	<0.15	0.49	<0.50	<0.41	<0.21
Isles of Scilly	*Fucus vesiculosus*	1	<1.0	<3.5	<0.84	<0.77	<2.6	<8.4	<1.2

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Cumbria									
Silloth	Seaweed	2				<2.0			
Harrington Harbour	Seaweed	2				3.6			
St Bees	*Porphyra*[a]	4[F]	0.46	2.5	20	5.9	0.018	0.0035	160
St Bees	Seaweed	2	1.4	6.9		3.9			
Braystones South	*Porphyra*	4[F]	0.37	2.0	15	5.5	*	0.0081	
Sellafield	*Rhodymenia* spp.	2F	0.76	3.8		9.2	*	0.021	
Sellafield	Seaweed	2	2.1	10		5.1			
Seascale	*Porphyra*[b]	53[F]				<4.7			
Ravenglass	Samphire	1[F]				2.0			
Ravenglass	Seaweed	2				31			
Lancashire									
Half Moon Bay	Seaweed	2				<1.1			
Marshside Sands	Samphire	1[F]				0.22			
Cockerham Marsh	Samphire	1[F]				0.31			78
Scotland									
Aberdeen	*Fucus vesiculosus*	1[S]				<0.12			
Lerwick	*Fucus vesiculosus*	1[S]				<0.10			
Lewis	*Fucus vesiculosus*	1[S]				0.25			
Islay	*Fucus vesiculosus*	1[S]				0.15			
Campbeltown	*Fucus vesiculosus*	1[S]				<0.12			
Port William	*Fucus vesiculosus*	4[S]				1.4			
Garlieston	*Fucus vesiculosus*	4[S]				2.0			
Auchencairn	*Fucus vesiculosus*	4[S]				3.3			
Isle of Man	*Fucus vesiculosus*	4				<1.2			
Wales									
Cemaes Bay	Seaweed	2				<0.83			
Porthmadog	Seaweed	2				<0.79			
Lavernock Point	Seaweed	2				<1.0			
Fishguard	Seaweed	2				<0.78			
South Wales, manufacturer A	Laverbread	4[F]				<0.28			
South Wales, manufacturer C	Laverbread	4[F]				<0.18			
South Wales, manufacturer D	Laverbread	4[F]				<0.24			140
South Wales, manufacturer E	Laverbread	1[F]				0.29			
Northern Ireland									
Portrush	*Fucus* spp.	4[N]				<0.29			
Strangford Lough	*Rhodymenia* spp.	4[N]	0.047	0.25		0.33	*	0.00061	
Ardglass	*Ascophyllum nodosum*	1[N]				0.14			
Ardglass	*Fucus vesiculosus*	3[N]				<0.46			
Carlingford Lough	*Fucus* spp.	4[N]				<0.11			
Isles of Scilly	*Fucus vesiculosus*	1				<0.98			

* *Not detected by the method used*

[a] *The concentration of ^{14}C was 51 Bq kg^{-1}*

[b] *Counted fresh*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

All other measurements are made on behalf of the Environment Agency

Table 2.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Sellafield 14[b]	Cabbage	1		<0.04	<0.14	<0.15	68	<0.43	<0.09
Sellafield 14[b]	Leeks	1		<0.06	<0.17	<0.19	6.5	<0.57	<0.13
Sellafield 14[b]	Onions	1		<0.08	<0.23	<0.28	1.8	<0.76	<0.16
Sellafield 14[b]	Potatoes	1		<0.04	<0.14	<0.20	7.3	<0.37	<0.09
Sellafield 14[b]	Soil	1		2.4	<1.6	<1.4	700	<5.4	<1.8
Sellafield 474[b]	Kohl Rabi	1		<0.06	<0.52	<1.3	<0.17	<0.69	<0.14
Sellafield 474[b]	Parsnips	1		<0.06	<0.24	<0.29	<0.35	<0.61	<0.15
Sellafield 474[b]	Potatoes	1		<0.04	<0.20	<0.35	<0.33	<0.36	<0.08
Sellafield 474[b]	Sweet red potatoes	1		<0.05	<0.21	<0.33	<0.36	<0.42	<0.10
Sellafield 474[b]	Turnips	1		<0.07	<0.26	<0.32	<0.32	<0.66	<0.17
Sellafield 474[b]	Soil	1		<0.15	<0.88	<1.5	<1.7	<1.8	<0.45
Hinkley	Carrots	1	8.8	<0.06	<0.14	<0.12		<0.58	<0.13
Hinkley	Leeks	1	16	<0.06	<0.15	<0.12		<0.55	<0.12
Hinkley	Soil	1	12	<0.41	<3.5	<7.2		<4.9	<1.2

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Sellafield 14[b]	Cabbage	1	<0.04	0.15	<0.20	<0.13	<0.09	<0.09
Sellafield 14[b]	Leeks	1	<0.06	<0.05	<0.21	<0.18	<0.08	<0.04
Sellafield 14[b]	Onions	1	<0.07	<0.07	<0.27	<0.22	<0.10	<0.05
Sellafield 14[b]	Potatoes	1	<0.04	0.15	<0.24	<0.13	<0.11	<0.11
Sellafield 14[b]	Soil	1	<0.67	60	<3.3	<1.6	<1.6	39
Sellafield 474[b]	Kohl Rabi	1	<0.06	<0.05	<0.36	<0.19	<0.13	<0.12
Sellafield 474[b]	Parsnips	1	<0.07	<0.06	<0.36	<0.21	<0.16	<0.16
Sellafield 474[b]	Potatoes	1	<0.04	0.06	<0.18	<0.12	<0.07	<0.04
Sellafield 474[b]	Sweet red potatoes	1	<0.04	<0.04	<0.21	<0.15	<0.08	<0.05
Sellafield 474[b]	Turnips	1	<0.07	<0.06	<0.30	<0.25	<0.12	<0.08
Sellafield 474[b]	Soil	1	<0.22	4.5	<1.5	<0.45	<0.67	<0.78
Hinkley	Carrots	1	<0.06	<0.05	<0.27	<0.18	<0.12	<0.12
Hinkley	Leeks	1	<0.06	<0.05	<0.21	<0.19	<0.09	<0.05
Hinkley	Soil	1	<0.64	5.2	<3.8	<1.3	<1.8	<2.6

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

Table 2.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2008

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[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]		4	<4.9	18	<0.20	0.040	<0.35	<0.25	<0.0070	<1.2	<0.39	<0.0096
Milk	max		8.0	20	<0.21	0.056	<0.38	<0.27			<0.41	<0.012
Apples		1	<5.0	11	<0.20	0.085	<0.30	<0.30	<0.020	<1.6	<0.60	<0.026
Barley		1	<7.0	60	<0.20	0.32	<0.40	<0.30	<0.023	<1.7	<0.50	<0.044
Beef kidney[e]		1	<10	25	<0.10	0.13	<0.30	<0.20	<0.023	<1.5	<0.60	<0.029
Beef liver		1	<9.0	34	<0.10	0.078	<0.20	<0.10	<0.025	<0.80	<0.20	<0.040
Beef muscle		1	8.0	23	<0.20	0.024	<0.20	<0.10	<0.018	<0.80	<0.20	<0.056
Blackberries		1	<4.0	15	<0.20	0.28	<0.40	<0.30	<0.020	<1.0	<0.30	<0.031
Broad beans[f]		1							<0.028			
Cabbage		1	<4.0	<3.0	<0.20	0.24	<0.20	<0.20	<0.021	<0.90	<0.30	<0.027
Carrots		1	<4.0	6.0	<0.20	0.16	<0.20	<0.20	<0.027	<1.0	<0.30	<0.031
Honey		1	<7.0	61	<0.20	0.053	<0.30	<0.20	<0.019	<1.0	<0.40	<0.019
Lettuce[g]		1							<0.026			
Pheasants		1	<5.0	25	<0.20	0.024	<0.20	<0.20	<0.023	<1.0	<0.30	<0.052
Potatoes		1	<5.0	16	<0.20	0.090	<0.30	<0.20	<0.025	<1.5	<0.40	<0.030
Runner beans		1	<4.0	16	<0.20	0.12	<0.30	<0.20	<0.024	<1.2	<0.40	<0.026
Sheep muscle		2	<6.0	40	<0.20	0.025	<0.25	<0.20	<0.022	<1.0	<0.30	<0.031
Sheep muscle	max			52			<0.30		<0.024	<1.1		<0.033
Sheep offal		2	<6.5	19	<0.10	0.15	<0.30	<0.20	<0.032	<1.1	<0.35	<0.031
Sheep offal	max		<7.0	26		0.24	<0.40		<0.038		<0.40	<0.034
Grass		2							<0.040			
Grass	max								0.055			
Soil[h]		1										

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			Total Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		4		<0.83	<0.00010	<0.00014	<0.029	<0.00015
Milk	max			<0.93		<0.00020	<0.033	<0.00018
Apples		1	0.13	<0.90	<0.00010	0.00060	<0.14	0.0015
Barley		1	0.24	<1.1	0.00030	0.0037	<0.082	0.0047
Beef kidney[e]		1	0.39	<1.4	0.00050	0.0035	<0.096	0.034
Beef liver		1	0.36	<0.50	0.020	0.098	0.73	0.11
Beef muscle		1	0.60	<0.50	<0.00030	0.00050	<0.058	0.00080
Blackberries		1	0.10	<0.90	0.00020	0.00050	<0.12	0.0015
Broad beans[f]		1						
Cabbage		1	0.19	<0.60	<0.00010	0.00030	<0.077	0.00070
Carrots		1	0.22	<0.50	<0.00020	0.00030	<0.066	0.00060
Honey		1	0.45	<1.4	0.00030	0.0013	<0.084	0.0028
Pheasants		1	0.38	<0.60	<0.00010	0.00020	<0.11	0.00030
Potatoes		1	0.20	<0.80	<0.00020	0.00030	<0.082	<0.00030
Runner beans		1	0.12	<0.70	0.00010	0.00020	<0.12	0.00070
Sheep muscle		2	3.8	<0.55	<0.00015	<0.00025	<0.084	0.00090
Sheep muscle	max		6.3	<0.60	<0.00020	<0.00030	<0.11	0.0011
Sheep offal		2	3.2	<0.75	0.00075	0.0070	<0.089	0.0034
Sheep offal	max		5.8	<0.90	0.00080	0.0090	<0.12	0.0035

[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 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 <0.19 (max <0.20) and <0.21 (max <0.23) Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0041, <0.00060 and 0.0043 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0022, <0.00060 and <0.0014 Bq kg^{-1} respectively*

[g] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.020, <0.00070 and 0.018 Bq kg^{-1} respectively*

[h] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 12, 0.48 and 11 Bq kg^{-1} respectively*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2008

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}								
		^{3}H	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+$ ^{240}Pu	Gross alpha	Gross beta
Ehen Spit beach	4	320	<0.39	<0.055	<0.32	<0.51	<0.012	<0.011	<3.0	12
River Ehen (100m downstream of sewer outfall)	4	15	<0.32	<0.055	<0.26	<0.26	<0.013	<0.0095	<0.037	<0.24
River Calder (downstream)	4	<4.3	<0.36	<0.053	<0.30	<0.28	<0.011	<0.0070	<0.11	0.51
River Calder (upstream)	4	<4.0	<0.28	<0.052	<0.24	<0.24	<0.0082	<0.0060	<0.030	<0.098
Wast Water	1	<4.0	<0.29			<0.24			<0.020	<0.10
Ennerdale Water	1	<4.0	<0.11		<0.08	<0.10			<0.020	<0.10
Devoke Water	1	<4.0	<0.12		<0.09	<0.10			<0.020	<0.10
Thirlmere	1	<4.0	<0.32			<0.25			<0.020	<0.10

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2008

Location	No. of sampling observ-ations	Mean 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	<0.39	<5.0	<0.45	300	3.0	23	21
Seascale SS 233	1	<0.39	<2.0	<0.38	170	2.1	18	16
Seascale SS 209	1	<0.35	<5.0	<0.28	24	1.4	5.9	9.3
Seascale SS 232	1	<1.4	<3.0	<1.1	62	2.5	12	14
Seascale SS 231	1	<0.62	<2.0	<0.58	41	4.1	17	23
Whitehaven SS 201	1	<2.8	<4.0	<2.6	32	<0.40	1.7	2.7

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2004-2008

Group	Exposure, mSv per year				
	2004	2005	2006	2007	2008
Isle of Man	0.007	0.008	0.007	0.006	0.007
Northern Ireland	0.010	0.020	0.018	0.015	0.017
Dumfries and Galloway	0.038	0.031	0.037	0.060	0.047
Whitehaven	0.013	0.008	0.011	0.009	0.009
Sellafield (average consumption 2004-8)	0.22	0.22	0.23	0.24	0.23
Morecambe Bay	0.068	0.063	0.038	0.037	0.042
Fleetwood	0.018	0.019	0.018	0.013	0.016
North Wales	0.012	0.015	0.016	0.014	0.018

Table 2.18. Individual radiation exposures, Sellafield, 2008

Exposed population group[a]	Exposure, mSv per year						
	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 2004-08)	0.62[d]	0.20	0.39	-	0.032	-	-
Local seafood consumers (habits for 2008)	0.59[e]	0.19	0.36	-	0.036	-	-
Whitehaven seafood consumers	0.009	0.009	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.047	0.037	-	-	0.010	-	-
Morecambe Bay seafood consumers	0.042	0.013	-	-	0.029	-	-
Fleetwood seafood consumers	0.016	0.016	-	-	-	-	-
Isle of Man seafood consumers	0.007	0.007	-	-	-	-	-
Northern Ireland seafood consumers	0.017	0.013	-	-	<0.005	-	-
North Wales seafood consumers	0.018	0.011	-	-	0.007	-	-
Other groups							
Ravenglass Estuary, nature warden	0.046	-	-	-	0.039	0.006	-
Fishermen handling nets or pots[c]	0.049	-	-	-	0.049	-	-
Bait diggers and shellfish[c] collectors	0.026	-	-	-	0.026	-	-
Ribble Estuary houseboats	0.13	-	-	-	0.13	-	-
Local consumers at Ravenglass[b]	0.014	-	-	0.014	-	-	-
Local consumers of vegetables grown on land with seaweed added[b]	0.009	-	-	0.009	-	-	-
Local consumers at Drigg[b]	0.013	-	-	0.013	-	-	
Local consumers in the Isle of Man[b]	0.009	-	-	0.009	-	-	
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.027	-	-	0.027	-	-	<0.005
Dumfries and Galloway wildfowlers	0.005	<0.005	-	-	<0.005	-	-
Groups with average consumption or exposure							
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Average consumer of locally grown food	0.010	-	-	0.010	-	-	-
Typical visitor to Cumbria	0.005	<0.005	<0.005	-	<0.005	-	-
Recreational user of beaches							
North Cumbria	0.012	-	-	-	0.012	-	-
Sellafield	0.012	-	-	-	0.012	-	-
Lancashire	0.008	-	-	-	0.008	-	-
North Wales	0.007	-	-	-	0.007	-	-
Isle of Man	0.011	-	-	-	0.011	-	-
Recreational user of mud/saltmarsh areas							
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-
North Cumbria	0.009	-	-	-	0.009	-	-
Sellafield	0.020	-	-	-	0.020	-	-
Lancashire	0.009	-	-	-	0.009	-	-
North Wales	0.005	-	-	-	0.005	-	-
All sources[f]	0.47	-	-	-	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1 yr*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *The total dose due to nuclear industry discharges was 0.23 mSv*
[e] *The total dose due to nuclear industry discharges was 0.23 mSv*
[f] *The* total dose *due to discharges and direct radiation. See Appendix 4. The doses from man-made and naturally occurring radionuclides were 0.18 and 0.29 mSv respectively.*
The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the Drigg site into the same area

3. Research establishments

Key points

- Discharges, environmental concentrations, dose rates and doses in 2008 were broadly similar to those in 2007
- Radiation doses from all sources were less than 8 per cent of the dose limit

Dounreay, Highland

- The Dounreay authorisations were transferred from UKAEA to Dounreay Site Restoration Limited (DSRL) in April 2008. They were varied in June 2008
- A detailed assessment of the effects of radioactive particles in the environment was published by the Dounreay Particles Advisory Group (DPAG) in November 2008
- Local consumers' diet and occupancy rates were reviewed and updated to improve dose assessments
- Gamma dose rates increased at some intertidal locations
- The dose from terrestrial food consumption was affected by the presence of caesium-137 in game

Winfrith, Dorset, Harwell, Oxfordshire and Windscale, Cumbria

- Research Sites Restoration Limited is the new site licence company for Harwell and Winfrith
- GE Healthcare voluntarily surrendered one of its licences on the Harwell site in February 2009, the Windscale licence was transferred from UKAEA to Sellafield Limited, and Winfrith's limit for gaseous tritium was increased

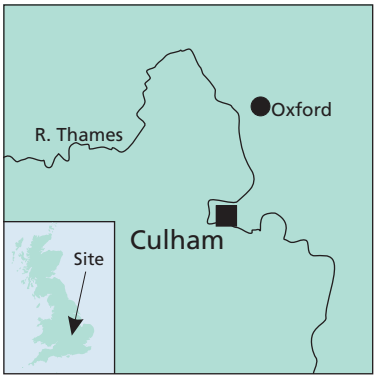
This section considers the effects of discharges from research establishments that hold nuclear site licences.

The NDA has ownership of the majority of such sites, with licensed nuclear sites at Harwell, Windscale and Winfrith in England, and Dounreay in Scotland. The NDA also owns the non-nuclear site at Culham, on behalf of the European Fusion Development Agreement. Until recently Harwell, Winfrith and Dounreay sites were operated by UKAEA. Research Sites Restoration Limited (RSRL) and Dounreay Site Restoration Limited (DSRL) (both wholly-owned subsidiaries of UKAEA) became the site licence companies for Harwell and Winfrith, and Dounreay respectively. Sellafield Limited currently operates Windscale. 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 Nuvia 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 located on the 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, the Scottish Universities' Environmental Research Centre and Culham.

3.1 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 2008. Locations and data are shown in Figure 3.1 and Table 3.2 respectively. In recent years, the main effect of the site's operation was increased tritium found in grass collected near the site perimeter. In 2008, measurements of tritium were either very close to or less than the LoD (as in 2007). The Environment Agency will continue to monitor the situation in 2009. Overall, no effects due to site operation were detected. 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.

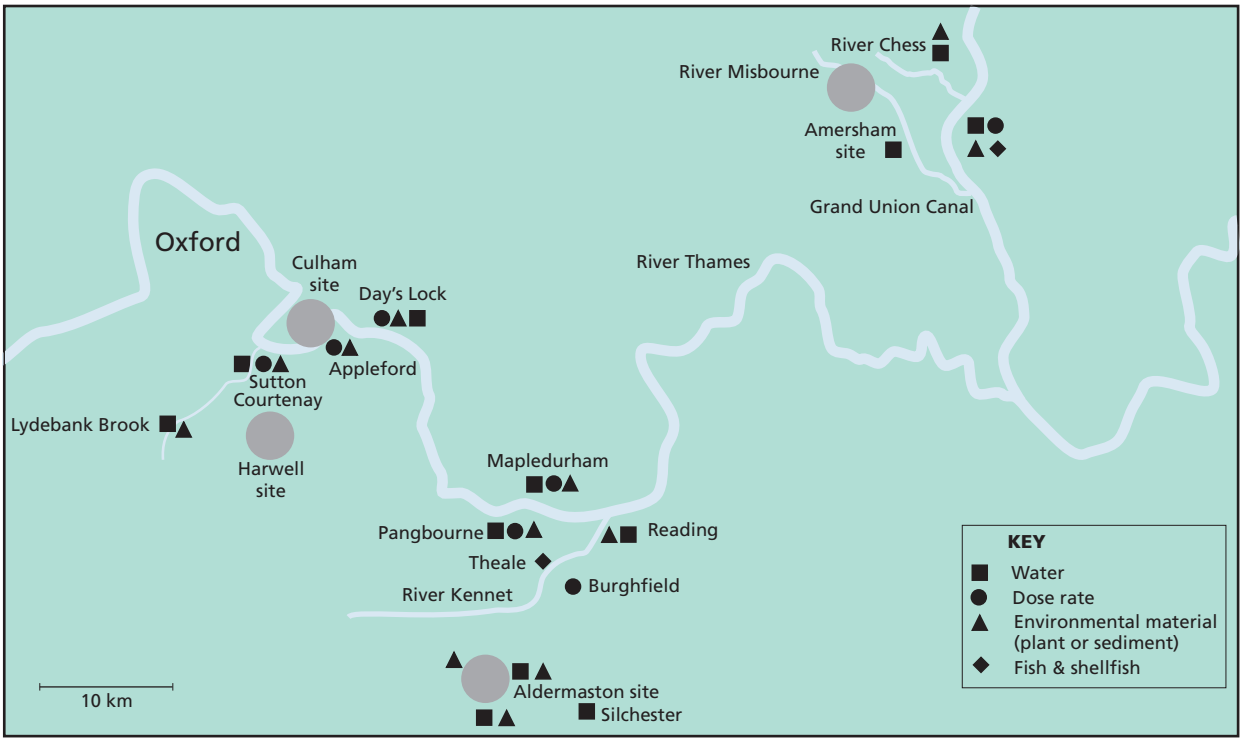
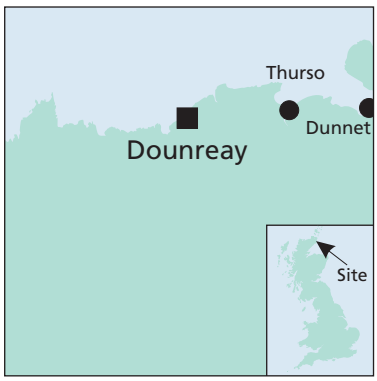


Figure 3.1. Monitoring locations at Thames sites, 2008 (not including farms)

The exposure of high-rate consumers was less than 0.005 mSv, which was less than 0.5 per cent of the annual dose limit for members of the public of 1 mSv. This dose is similar to 2007, but reduced from the conservative estimate of 0.027 mSv in 2006 (in which the assessment assumed that all terrestrial foods contained an elevated concentration of OBT). The annual dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2008 was estimated to be much less than 0.005 mSv (Table 3.1).

3.2 Dounreay, Highland



The Dounreay site was opened in 1955 to develop research reactors. Three reactors were built on the site; the Prototype Fast Reactor, the Dounreay Fast Reactor and the Dounreay Materials Test Reactor. All three are now closed and undergoing decommissioning.

From 2005, the NDA became responsible for the UK's civil nuclear liabilities that included those at UKAEA Dounreay, and UKAEA became a contractor to the NDA. In common with other NDA sites, UKAEA prepared a long term decommissioning plan known as the Lifetime Plan. The NDA's ministerially agreed strategy included a timetable for putting the Parent Body Agreement of the decommissioning sites out to competitive tender. Part of this process required the transfer of the three existing radioactive waste disposal authorisations from UKAEA to a new site license company (Dounreay Site Restoration Limited, DSRL), before DSRL took over the site management contract.

As part of the determination of the transfer application, SEPA conducted three inspections (October and November 2007, and February 2008) at Dounreay. These inspections sought to satisfy SEPA that DSRL can meet the criteria set down in Section 16A(7) of RSA 93, that DSRL will have operational control over the disposal of wastes and that DSRL is able and willing to comply with the terms and conditions of the authorisations that it was seeking to have transferred. These criteria were found to be satisfied. SEPA concluded its determination of the application in March 2008 and the RSA authorisations were transferred with an effective date of 1 April 2008 along with all of the other environmental permits, which was concurrent with HSE transferring the Nuclear Site Licence from UKAEA to DSRL. There is no change in the limitations and conditions of the authorisations.

The outcome of the transfer application determination inspections identified a number of areas within the Environmental Management System requiring improvement. As part of DSRL's demonstration that it would be able to comply with the terms and conditions of the transferred Authorisations, DSRL committed to undertake these improvements and submitted a programme for the completion of this work. In June 2008, SEPA varied the authorisations to place improvement conditions within the authorisations to require DSRL to undertake the improvements in line with its proposed programme. The issuing of the Notices of Variation was a separate legal process from the transfer process.

The Dounreay Cementation Plant restarted in April 2008, following the completion of the clean up required after the spillage of raffinate which occurred in 2005. Construction of the new ventilation extract facility at the Fuel Cycle Area progressed.

Active commissioning of the bulk Sodium/Potassium (NaK) destruction plant commenced. In September 2008 a leak of radioactive liquor occurred within the ion exchange plant of the NaK destruction plant. Although there was no release to the environment, the NaK destruction plant was shut down whilst a number of plant improvements were undertaken. The active commissioning of the NaK destruction plant was restarted in March 2009.

Work on grouting around the Dounreay Shaft to isolate the 65 metre deep facility from the surrounding groundwater was completed in spring 2008.

DSRL applied to SEPA for an authorisation to dispose of waste to a Low Level Radioactive Waste Disposal facility adjacent to the site.

UKAEA/DSRL have intercepted contaminated surface water and diverted it to their authorised discharge route. The source of the contamination has been identified and this has been incorporated into DSRL's contaminated land strategy.

SEPA conducted several inspections of the progress of the improvement conditions, relating to the Environmental Management System.

SEPA conducted an inspection of the facility level documents, which underpin the identification and consignment of solid radioactive waste.

SEPA had a significant involvement in scrutinising the Best Practicable Means case for the operation of the new Effluent Treatment plant at the Prototype Fast Reactor.

In 2008, radioactive waste discharges from Dounreay were made by UKAEA under authorisations granted by SEPA. The quantities of both gaseous and liquid discharges in 2008 were generally similar to those in 2007 (Appendix 2). Sampling locations for the terrestrial and marine monitoring programme are shown in Figure 3.2 (north of Scotland) and Figure 3.3 (Dounreay).

In August 2008, a habits survey of consumption and occupancy, by members of the public, was completed at Dounreay. Three potentially critical pathways for public radiation exposure in the aquatic environment were confirmed. A decrease in the fish consumption rate and increases in crustacean and mollusc consumption rates have been observed in comparison with those of the previous survey in 2003. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

This facility is authorised to discharge gaseous wastes to the local environment via stacks to the atmosphere. Monitoring conducted in 2008 included sampling of grass and soil and terrestrial foods including meat, vegetables and cereals. As there are no dairy cattle herds in the Dounreay area, no milk samples were collected from cattle. However, monitoring for radionuclides in goats' milk was included in 2008. The results for terrestrial samples and radioactivity in air are given in Tables 3.3(a) and (c) and generally show low concentrations of radioactivity. Low concentrations of strontium-90, caesium-137, europium-155, uranium, plutonium and americium-241 were reported in samples. In 2008, a concentration of caesium-137 was found in rabbit (110 Bq kg^{-1}), which had not been sampled in recent years. Caesium-137 levels in lamb muscle and mushrooms were reduced in 2008, in comparison to the slightly elevated levels in 2007. Concentrations of caesium-137 in the terrestrial environment in the Dounreay area will have been affected by fallout from weapons testing in the 1960s and from the Chernobyl reactor accident in 1986.

Liquid waste discharges and aquatic monitoring

Low level liquid waste is routed via a Low Level Liquid Effluent Treatment Plant (LLLETP). The effluent is discharged to sea (Pentland Firth) via a pipeline terminating 600 metres offshore at a depth of about 24 metres. The discharges also include groundwater pumped from the Dounreay Shaft, surface water runoff, leachate from the low level solid waste disposal facility, and a minor contribution from the adjoining reactor site (Vulcan NRTE), which the Defence Procurement Agency operates.

Routine marine monitoring included sampling of seafood around the Dounreay outfall in the North Atlantic and other materials from further afield, as well as the measurement of beta and gamma dose rates. Seafood samples from within the zone covered by a FEPA* Order are collected under consent granted in 1998 by the Scottish Office.

Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. The results for marine samples and gamma dose rates (Tables 3.3(a) and (b)) generally show low concentrations of radioactivity in 2008 and are generally similar to those in recent years, although gamma dose rates were overall slightly higher in 2008. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield, but were generally slightly lower than in 2007. Beta dose measurements were less than the LoD (Table 3.3(b)).

During 2008, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA.

* *The FEPA Order was made in 1997 following the discovery of 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.*

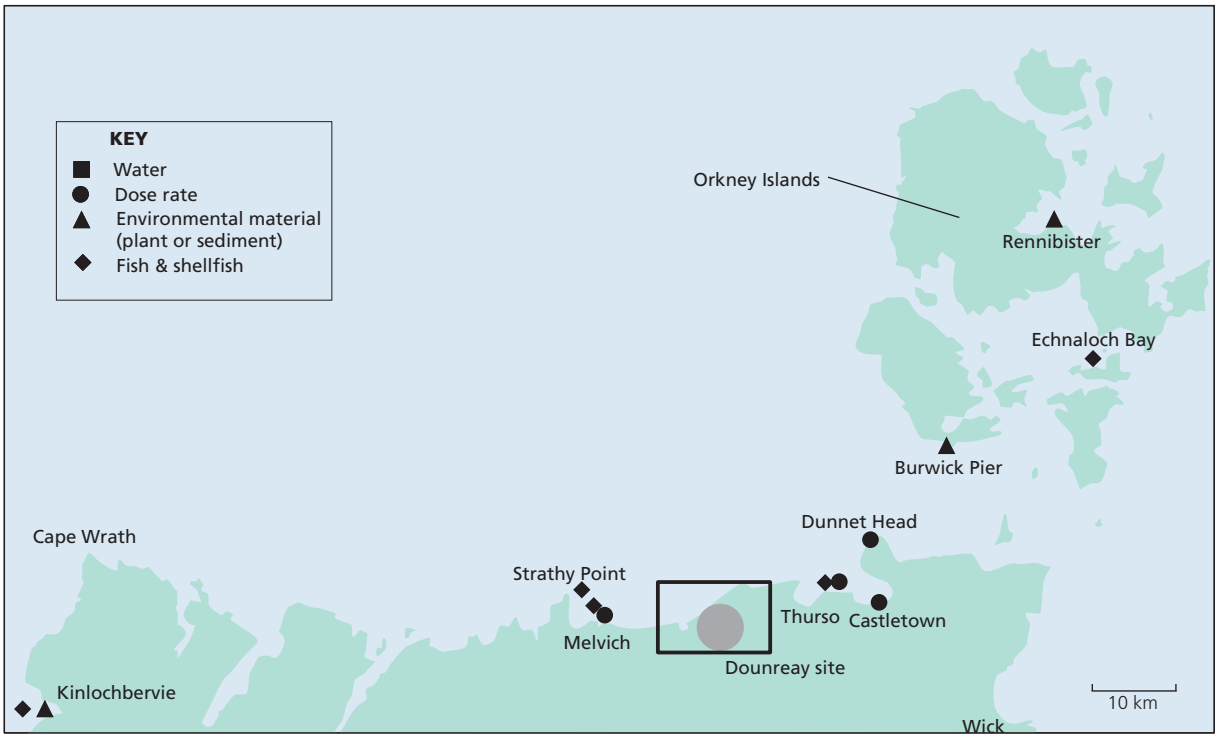


Figure 3.2. Monitoring locations in the north of Scotland, 2008 (not including farms)

At one of the beaches, monitoring for radioactive fragments is undertaken via an agreement between UKAEA Dounreay and the landowner. In 2008, access was periodically withdrawn and as a result monitoring was interrupted during the year.

In 2008, 14 fragments were recovered from Sandside Bay and 4 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 9.2 kBq and 240 kBq (similar to ranges observed in 2007).

In August 2008, particle retrieval operations to recover fragments from the seabed using a remotely operated vehicle commenced. The retrieval operations undertaken during August and September recovered 55 fragments from the offshore seabed.

The previously conducted offshore survey 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 DPAG's† Fourth Report, published in November 2008 (Dounreay Particles Advisory Group, 2008).

In 2007, the Food Standards Agency reviewed the Dounreay FEPA Order. A risk assessment, peer-reviewed by HPA, indicated that the food chain risk was very small (Food Standards Agency, 2009). The FEPA Order was reviewed with regard to ongoing work to remove radioactive particles from the seabed and the food chain risk. On 11 March 2009, FSA Scotland announced that the FEPA Order would remain in place, and be reviewed again when the seabed remediation work was complete.

Doses to the public

The dose from the consumption of local terrestrial foodstuffs, including a contribution due to weapon test fallout, was estimated to be 0.036 mSv, which was less than 4 per cent of the annual dose limit for members of the public of 1 mSv (Table 3.1). This includes an assessment of the effects for non-food pathways from discharges to air (see Appendix 1). In 2008, the critical age group was adults, as opposed to 1-year-old infants. The change in dose to the critical group (0.047 mSv in 2007) was due to a combination of factors (both increasing and decreasing dose), which combined, resulted in an overall decrease in exposure between the different age groups. The significant contributors that decreased dose were lower LoDs for americium-241 and ruthenium-106 in goats' milk, and lower LoDs for iodine-129 in potato samples. A significant contributor that increased dose in 2008 was the inclusion of the concentration of caesium-137 found in rabbit (game), which had not been sampled in recent years. The annual dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

The marine monitoring programme relates to the existence of three potential exposure pathways at Dounreay. Individual radiation exposures are provided in Table 3.1 and details are given in Appendix 1.

† *DPAG was set up in 2000 to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments.*

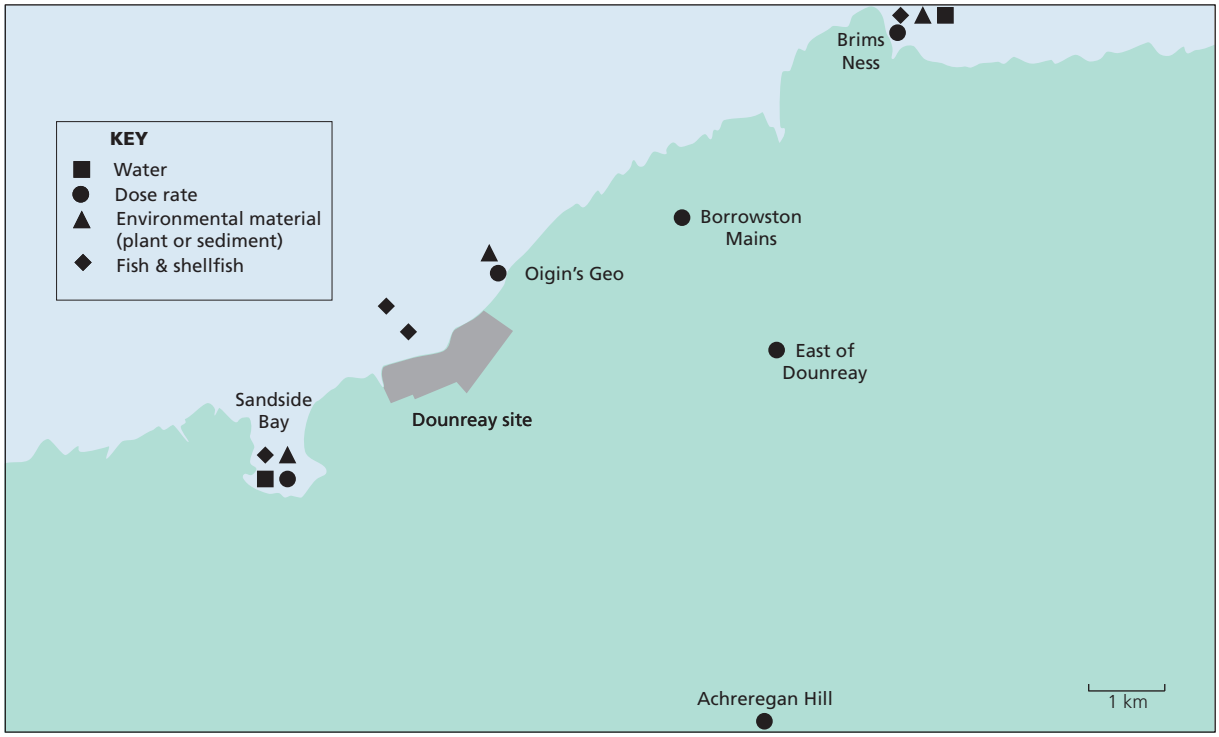


Figure 3.3. Monitoring locations at Dounreay, 2008 (not including farms)

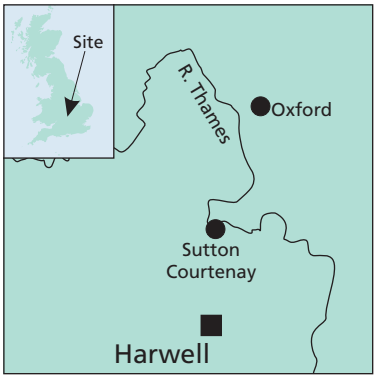
The first potential pathway involves the consumption of locally collected fish and shellfish, and includes external exposure from occupancy over local beaches. The estimated dose to the critical group was 0.010 mSv or 1 per cent of the dose limit for members of the public of 1 mSv. The increase in dose from less than 0.005 mSv in 2007 was attributed to a general increase in gamma dose rates in 2008.

The second potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore (Geo occupants). The radiation dose to the public from these rocky areas was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv.

The third 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 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 estimated dose based on these beta measurements (Table 3.3(b)) was of no radiological significance.

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.078 mSv or approximately 8 per cent of the dose limit. This is an increase from 0.059 mSv in 2007, and was largely attributable to increased consumption of game. There were no measurements of radionuclides in venison in 2008. In view of its importance as a source of game in local diet, doses were estimated from data for 2007.

3.3 Harwell, Oxfordshire



The UKAEA Harwell nuclear licensed site forms part of the Harwell Science and Innovation Campus and is situated approximately 5 km southwest of the town of Didcot. In 2008, UKAEA were the operators under the ownership of the NDA, and GE Healthcare occupied buildings in two small areas embedded within the UKAEA licensed site, each with their own nuclear site licence. One of the buildings is in the process of being decommissioned and the other is an operating radioactive waste management and source refurbishment facility. In February 2009, Research Sites Restoration Limited, (RSRL, a wholly-owned subsidiary of UKAEA) became the site licence company. Also in February 2009, GE Healthcare's authorisation for B10.23 was revoked as a result of the company surrendering its nuclear site licence for the building. The most recent habits survey was conducted during 2007 (Garrod *et al*., 2008).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via stacks to the local environment. The monitoring programme sampled milk and other terrestrial foodstuffs. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.1. The results of the terrestrial programme are shown

in Table 3.4(a). The results of tritium and caesium-137 analyses of terrestrial food samples were all below LoDs.

Liquid waste discharges and aquatic monitoring

Discharges of radioactive wastes from Harwell continued in 2008 under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site. The aquatic monitoring programme was directed at consumers of freshwater fish, sediments and external exposure close to the liquid discharge point.

Concentrations of caesium-137 from liquid discharges were below the LoD close to the outfall at Sutton Courtenay, and slightly enhanced at Lydebank Brook and, but the levels were small in terms of any radiological effect. The concentrations of radionuclides in flounder from the lower reaches of the Thames were below the LoD. Concentrations of transuranic elements were similar to those in 2007.

Doses to the public

The estimated dose to the critical group for terrestrial food consumers was less than 0.005 mSv, including a component due to non-food pathways arising from discharges to air (see Appendix 1), which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 3.1). Neither perch nor crayfish were sampled in 2008 and estimates of activity concentrations have been used from previous data for pike, taking recent variations in sediment concentrations into account. On this basis, the radiation dose to anglers in 2008 was 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 3.1), and similar to the dose in 2007. 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.

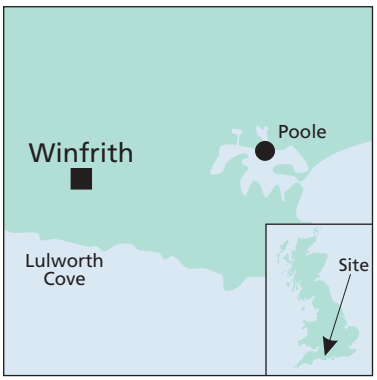
In 2008, the *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.020 mSv or 2 per cent of the dose limit.

3.4 Windscale, Cumbria

Windscale is located on the Sellafield site and comprises three reactors, two of which were shut down in 1957 and the third in 1981. Most of the radioactive wastes derive from decontamination and decommissioning operations, some of which are of the early Windscale reactor buildings. From 1 April 2008, the Windscale authorisation was transferred from UKAEA to Sellafield Limited, and combined with the Sellafield site licence. Gaseous wastes are authorised from specific stacks on the Windscale site; liquid radioactive wastes are disposed of, after appropriate treatment, to the Irish Sea via the Sellafield site pipelines. Both gaseous and liquid discharges are included as part of the authorised Sellafield discharges (Appendix 2). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from the rest of the Sellafield site.

Regular monitoring of the environment by the Environment Agency and the Food Standards Agency is conducted 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 2.3.

3.5 Winfrith, Dorset



A new authorisation was effective in 2008, increasing the gaseous limit of tritium from 4 TBq to 50 TBq (Appendix 2). Discharges of radioactive wastes from this site continued in 2008, at the low rates typical of recent years, and with further reductions in both gaseous and liquid tritium in comparison to 2007. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. Gaseous wastes are disposed of from various stacks on site.

The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and environmental materials. Sampling locations at Winfrith are shown in Figure 3.4. Data are presented in Tables 3.5(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. Low concentrations of tritium were found in surface water to the north of the site, similar to previous years. In all cases the gross alpha and beta activities were below the WHO's screening levels for drinking water. In 2008, the estimated dose from terrestrial food consumption was less than 0.005 mSv. After making an allowance for radionuclides in air, using the methods and data given in Appendix 1, the critical group dose in 2008 was less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 3.1). 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 2008 at much less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members

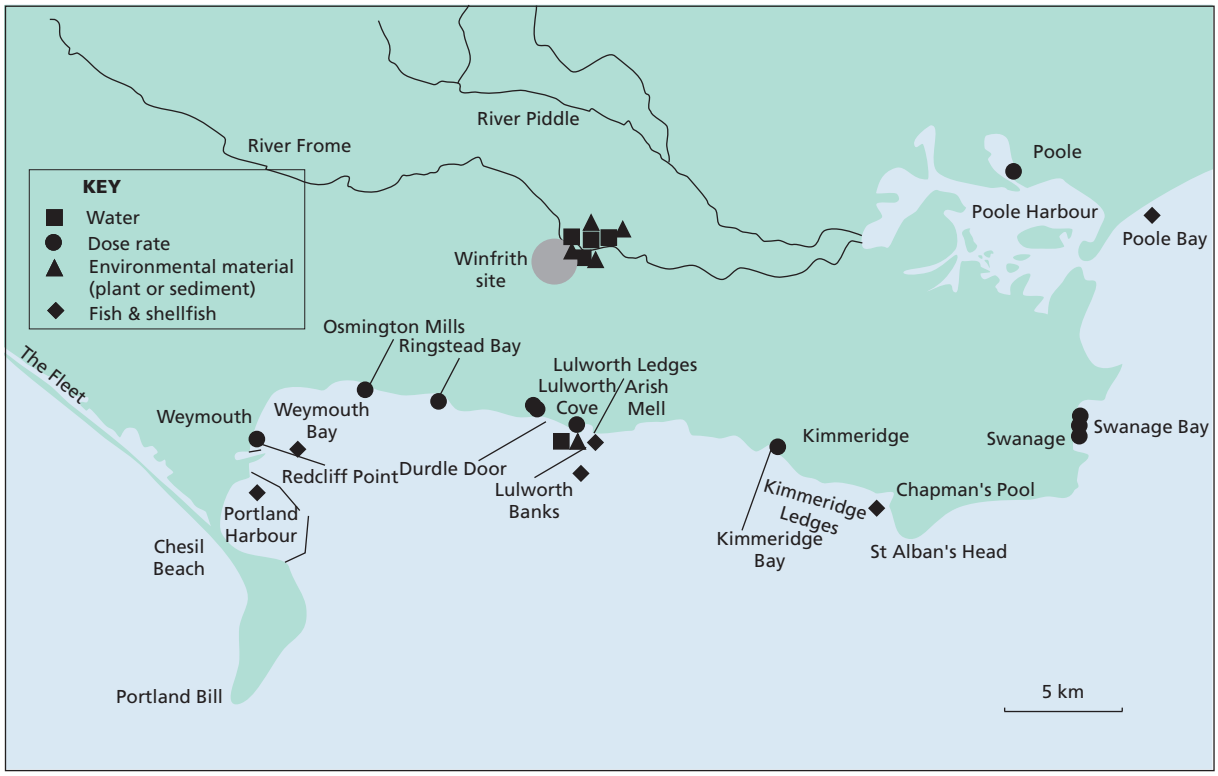


Figure 3.4. Monitoring locations at Winfrith, 2008 (not including farms)

of the public. Trends in doses in the area of the south coast (and the Severn Estuary) are shown in Figure 6.4. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv or 0.5 per cent of the dose limit.

3.6 Minor sites

Two minor licensed sites with very low radioactive discharges 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 2008 due to operation of these sites.

3.6.1 Imperial College Reactor Centre, Ascot, Berkshire

The Reactor Centre provided facilities for the University and other educational institutions for teaching and research in many fields of nuclear science and technology. Imperial College undertook a review of the future of the Reactor Centre at Silwood Park in 2007, which resulted in the temporary closure of commercial operations with the anticipation of decommissioning. It is now proposed that the reactor will maintain operational ability for commercial, training and educational operations.

In 2008, gaseous discharges were very low (further reduced from 2007 as a result of the temporary closure) and aqueous discharges were nil (Appendix 2). The environmental monitoring of their effects comprises analysing two grass samples by gamma-ray spectrometry. Both sets of results in 2008 were either close to or less than the limits of detection.

3.6.2 Scottish Universities' Environmental Research Centre, South Lanarkshire

The small research reactor at this site has been decommissioned, with the waste disposed of under the authorisations granted by SEPA in 2001 for its decommissioning. The site continues to hold a nuclear site licence and is currently progressing de-licensing of this site. Routine laboratory work continues at the site, resulting in the authorised disposal of small quantities of radioactive substances, although no discharges were made from the premises during the calendar year 2008. In 2008, SEPA issued a registration for the keeping and use of radioactive sources to cover their on-going use following the revocation of the nuclear site licence.

Table 3.1. Individual radiation exposures - research sites, 2008

Site	Exposed population group[a]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Culham	Drinkers of river water	<0.005	-	-	-	<0.005	-
Dounreay	Seafood consumers	0.010	<0.005	-	0.008	-	-
	Geo occupants	<0.005	-	-	<0.005	-	-
	Consumers of locally grown food	0.036	-	0.036	-	-	<0.005
	All sources[c]	0.078	-	-	-	-	-
Harwell	Anglers	0.005	<0.005	-	0.005	-	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-	<0.005
	All sources[c,d]	0.020	-	-	-	-	-
Winfrith	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-	<0.005
	All sources[c]	<0.005	-	-	-	-	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *The* total dose *due to discharges and direct radiation. See Appendix 4*
[d] *Prenatal children*

Table 3.2. Concentrations of radionuclides in the environment near Culham, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Freshwater	River Thames (upstream)	2	<4.0				<0.28	<0.035	0.29
Freshwater	River Thames (downstream)	2	<5.5				<0.25	<0.055	0.25
Grass	1 km East of site perimeter	1	23	40	6.4	<3.0	<1.5		230
Sediment	River Thames (upstream)	2					12		
Sediment	River Thames (downstream)	2					22		
Soil	1 km East of site perimeter	1	<25	<25	9.1	<1.0	4.0		490

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

Table 3.3(a). Concentrations of radionuclides in food and the environment near Dounreay, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{65}Zn	^{90}Sr	^{99}Tc	^{110m}Ag	^{134}Cs	^{137}Cs
Marine samples										
Crabs	Pipeline inner zone	4		<0.13	<0.35	<0.10	0.58	<0.15	<0.13	<0.13
Crabs	Pipeline	4		<0.15	<0.44			<0.17	<0.13	<0.15
Crabs	Strathy	3		<0.32	<0.86			<0.32	<0.29	<0.33
Crabs	Kinlochbervie	4		<0.13	<0.31		<0.50	<0.14	<0.13	<0.10
Crabs	Melvich Bay	3		<0.31	<0.82		1.3	<0.32	<0.30	<0.31
Winkles	Brims Ness	4		<0.15	<0.41	<0.10	8.0	<0.16	<0.14	<0.16
Winkles	Sandside Bay	4		<0.13	<0.32	<0.10	21	<0.13	<0.13	<0.25
Mussels	Echnaloch Bay	4		<0.15	<0.42			<0.17	<0.15	<0.17
Mussels	Thurso East Mains	4		<0.16	<0.42			<0.17	<0.16	<0.29
Fucus vesiculosus	Kinlochbervie	4		<0.10	<0.26		41	<0.11	<0.11	<0.18
Fucus vesiculosus	Brims Ness	4		<0.10	<0.18			<0.10	<0.10	<0.14
Fucus vesiculosus	Sandside Bay	4		<0.10	<0.20		55	<0.10	<0.10	0.19
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.27		24	<0.10	<0.10	<0.13
Sediment	Oigins Geo	2		<0.11	<0.48			<0.16	<0.14	4.1
Sediment	Brims Ness	1		<0.10	<0.23			<0.10	<0.10	1.2
Sediment	Sandside Bay	1		<0.10	<0.22			<0.10	<0.10	2.5
Sediment	Rennibister	1		<0.10	<0.25			<0.10	<0.10	15
Seawater	Brims Ness	4	<1.0	<0.10	<0.10			<0.10	<0.10	<0.10
Seawater	Sandside Bay	4	<1.0	<0.10	<0.12			<0.10	<0.10	<0.10
Spume	Oigins Geo	3		<2.6	<1.7			<0.81	<0.54	88

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples									
Crabs	Pipeline inner zone	4	<0.14	<0.23	0.0044	0.016	<0.10	2.0	98
Crabs	Pipeline	4	<0.19	<0.26			<0.18		
Crabs	Strathy	3	<0.35	<0.69			<0.37		
Crabs	Kinlochbervie	4	<0.15	<0.27	0.0022	0.0058	0.0064		
Crabs	Melvich Bay	3	<0.32	<0.61	<0.00057	0.0072	0.0076		
Winkles	Brims Ness	4	<0.19	<0.33	0.036	0.14	0.15		
Winkles	Sandside Bay	4	<0.15	<0.28	0.045	0.18	0.31		
Mussels	Echnaloch Bay	4	<0.19	<0.35	0.016	0.080	0.057		
Mussels	Thurso East Mains	4	<0.17	<0.28			<0.22		
Fucus vesiculosus	Kinlochbervie	4	<0.11	<0.15			<0.12		
Fucus vesiculosus	Brims Ness	4	<0.10	<0.13			<0.14	<3.0	430
Fucus vesiculosus	Sandside Bay	4	<0.10	<0.12			<0.25	<3.7	480
Fucus vesiculosus	Burwick Pier	4	<0.10	<0.16			<0.11		
Sediment	Oigins Geo	2	<0.24	1.1	2.3	9.4	5.4		
Sediment	Brims Ness	1	0.32	<0.26	2.8	9.4	10		
Sediment	Sandside Bay	1	0.41	<0.23	3.8	16	17		
Sediment	Rennibister	1	<0.12	0.77	0.11	0.58	<0.26		
Seawater	Brims Ness	4	<0.10	<0.10			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.11			<0.10		
Spume	Oigins Geo	3	<2.8	<2.9	35	160	170		

Table 3.3(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{110m}Ag	^{129}I	^{134}Cs	^{137}Cs
Terrestrial samples											
Beef muscle		1	<5.0	<0.05	<0.10	<0.08	<0.38	<0.05	<0.081	<0.05	0.10
Beef offal		1	<5.0	<0.05	<0.10	<0.08	<0.37	<0.05	<0.089	<0.05	0.12
Cabbage		1	<5.0	<0.05	2.7	<0.05	<0.29	<0.05	<0.014	<0.05	0.36
Elderberries		1	<5.0	<0.05	0.25	<0.08	<0.45	<0.05	<0.017	<0.05	<0.05
Goats' milk		1	<5.0	<0.05	<0.10	<0.08	<0.36	<0.05	<0.010	<0.05	<0.05
Lamb muscle		1	<5.0	<0.05	<0.10	<0.08	<0.40	<0.05	<0.071	<0.05	0.12
Maize		1	<5.0	<0.05	0.34	<0.07	<0.37	<0.05	<0.014	<0.05	0.15
Mushrooms		1	<5.0	<0.05	<0.10	<0.05	<0.18	<0.05	<0.015	<0.05	0.55
Nettles		1	<5.0	<0.05	2.1	<0.05	<0.32	<0.05	<0.019	<0.05	0.30
Potatoes		1	<5.0	<0.05	<0.10	<0.05	<0.30	<0.05	<0.016	<0.05	0.13
Rabbit		1	<5.0	<0.05	<0.10	<0.05	<0.52	<0.06	<0.11	<0.05	110
Rosehips		1	<5.0	<0.05	0.65	<0.06	<0.48	<0.07	<0.018	<0.05	1.4
Turnips		1	<5.0	<0.05	0.19	<0.05	<0.23	<0.05	<0.016	<0.05	0.18
Grass		6	<5.0	<0.05	0.59	<0.32	<0.36	<0.05	<0.010	<0.05	0.22
Grass	max				1.1	<0.57	<0.44	<0.06	<0.011		0.50
Soil		6	<5.5	<0.09	0.93	<0.55	<0.83	<0.14	<0.069	<0.11	25
Soil	max		8.1	<0.12	1.3	<1.2	<1.1	<0.18	<0.083	<0.14	33

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{144}Ce	^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples										
Beef muscle		1	<0.23		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Beef offal		1	<0.25		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cabbage		1	<0.19					<0.050	<0.050	<0.050
Elderberries		1	<0.27					<0.050	<0.050	<0.050
Goats' milk		1	<0.20							<0.06
Lamb muscle		1	<0.24		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Maize		1	<0.28					<0.050	<0.050	<0.050
Mushrooms		1	<0.12					<0.050	<0.050	<0.050
Nettles		1	<0.22					<0.050	<0.050	<0.050
Potatoes		1	<0.19					<0.050	<0.050	<0.050
Rabbit		1	<0.39					<0.050	<0.050	<0.050
Rosehips		1	<0.32					<0.050	<0.050	<0.050
Turnips		1	<0.14					<0.050	<0.050	<0.050
Grass		6	<0.26		<0.12	<0.050	<0.12	<0.050	<0.050	<0.050
Grass	max		<0.32		0.29		0.29			
Soil		6	<0.77	1.5	27	1.2	25	<0.062	0.46	<0.18
Soil	max		<0.97	1.8	51	2.0	46	0.094	0.84	0.37

[a] *Except for seawater and goats' milk 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 3.3(b). Monitoring of radiation dose rates near Dounreay, 2008

Location	Material or ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.052
Sandside Bay	Winkle bed	2	0.11
Oigin's Geo	Spume/sludge	4	0.14
Brims Ness	Shingle and stones	2	0.095
Melvich	Salt Marsh	2	0.073
Melvich	Sand	2	0.069
Strathy	Sand	2	0.069
Thurso	Riverbank	2	0.079
Achreregan Hill	Soil	2	<0.051
Thurso Park	Soil	2	0.079
Borrowston Mains	Soil	2	0.084
East of Dounreay	Soil	2	0.083
Castletown Harbour	Sand	2	0.083
Dunnet	Sand	2	0.054
Mean beta dose rates			μSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Thurso	Riverbank	2	<1.0
Castletown Harbour	Surface sediment	2	<1.0

Table 3.3(c). Radioactivity in air near Dounreay, 2008

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	5	<0.010	<0.0068	0.092
Reay	11	<0.010	<0.0053	0.10
Balmore	12	<0.010	<0.0064	0.11

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			^{3}H	^{60}Co	^{137}Cs	^{238}Pu
Freshwater samples						
Flounder	Beckton	1	<25	<0.13	<0.13	
Sediment	Appleford	4[E]		<0.32	11	<0.40
Sediment	Outfall (Sutton Courtenay)	4[E]		<1.5	<5.6	<0.70
Sediment	Day's Lock	4[E]		<1.4	<6.4	<0.70
Sediment	Lydebank Brook	4[E]		<1.7	5.6	<0.40
Freshwater	Day's Lock	4[E]	<4.8	<0.30	<0.25	
Freshwater	Lydebank Brook	4[E]	<4.0	<0.30	<0.24	
Freshwater	R Thames (above discharge point)	4[E]	<4.0	<0.36	<0.31	
Freshwater	R Thames (below discharge point)	4[E]	<4.0	<0.33	<0.29	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Freshwater samples						
Flounder	Beckton	1		<0.28		
Sediment	Appleford	4[E]	<0.70	1.6	<140	310
Sediment	Outfall (Sutton Courtenay)	4[E]	0.78	1.4	240	410
Sediment	Day's Lock	4[E]	<0.50	<2.0	<170	390
Sediment	Lydebank Brook	4[E]	0.44	1.5	150	330
Freshwater	Day's Lock	4[E]			<0.055	0.22
Freshwater	Lydebank Brook	4[E]			<0.047	0.16
Freshwater	R Thames (above discharge point)	4[E]			<0.050	0.23
Freshwater	R Thames (below discharge point)	4[E]			<0.062	0.24

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			Organic ^{3}H	^{3}H	^{137}Cs
Terrestrial samples					
Milk		4	<4.9	4.9	<0.20
Milk	max		<6.3	<6.3	<0.23
Apples		1	<5.0	<5.0	<0.20
Beetroot		1	<5.0	<5.0	<0.20
Blackberries		1	<5.0	<5.0	<0.20
Cabbage		1	<5.0	5.0	<0.20
Honey		1		<8.0	<0.20
Potatoes		1	<5.0	<5.0	<0.30

[a] *Except for milk where units are Bq l^{-1}, and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean 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 3.4(b). Monitoring of radiation dose rates near Harwell, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Grass and mud	2	0.069
Sutton Courtenay	Mud	1	0.077
Sutton Courtenay	Grass and mud	1	0.080
Day's Lock	Grass and mud	2	0.071

Table 3.5 (a). Concentrations of radionuclides in food and the environment near Winfrith, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples							
Plaice	Weymouth Bay	2		<0.04		0.10	
Bass	Weymouth Bay	2		<0.06		0.23	
Crabs	Chapman's Pool	1		0.14		0.04	<0.0017
Crabs	Lulworth Banks	1	26	0.16		<0.06	0.00033
Pacific Oysters	Poole	1		<0.11		<0.10	
Cockles	Poole	1		0.15		0.07	
Whelks	Poole Bay	1		<0.15		0.14	0.00035
Whelks	Lyme Regis	1		<0.05		<0.05	0.00011
Scallops	Lulworth Ledges	1		<0.08		<0.06	0.00045
Clams	Portland Harbour	1		<0.11		0.10	
Seaweed	Lulworth Cove	1[E]		<1.0	9.4	<0.74	
Seaweed	Bognor Rock	2[E]		<0.91	6.4	<0.67	
Seawater	Lulworth Cove	1[E]		<0.42		<0.32	

Material	Location	No. of sampling ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Weymouth Bay	2		<0.07				
Bass	Weymouth Bay	2		<0.06				
Crabs	Chapman's Pool	1	0.0036	<0.0013	*	*		
Crabs	Lulworth Banks	1	0.0019	0.0038	*	0.000025		
Pacific Oysters	Poole	1		<0.22				
Cockles	Poole	1		<0.11				
Whelks	Poole Bay	1	0.0019	0.0022	*	0.000041		
Whelks	Lyme Regis	1	0.0010	0.00060	0.000033	0.000013		
Scallops	Lulworth Ledges	1	0.0035	0.00097	*	*		
Clams	Portland Harbour	1		<0.21				
Seaweed	Lulworth Cove	1[E]		<0.80				
Seaweed	Bognor Rock	2[E]		<0.90				
Seawater	Lulworth Cove	1[E]		<0.38			<3.0	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		4	<4.6	<4.6	18	<0.19	<0.20		
Milk	max		<4.8	<4.8	19	<0.20			
Apples		1	<5.0	<5.0	13	<0.30	<0.20		
Beetroot		1	<5.0	<5.0	11	<0.30	<0.20		
Blackberries		1	<4.0	<4.0	15	<0.10	0.20		
Chard		1	<5.0	<5.0	5.0	<0.30	<0.20		
Honey		1		<7.0	60	<0.20	5.4		
Potatoes		1	<7.0	7.0	19	<0.20	<0.20		
Grass		2	<11	11	28	<0.20	<2.1		
Grass	max		<13	13	34		3.8		
Sediment	North of site (Stream A)	1[E]				<0.25	5.5	<100	<100
Sediment	R Frome (upstream)	1[E]				<1.2	<1.3	170	180
Sediment	R Frome (downstream)	1[E]				<0.32	2.5	230	220
Sediment	R Win, East of site	1[E]				<0.21	<0.21	<100	<100
Freshwater	North of site (Stream A)	2[E]		21		<0.29	<0.25	<0.030	<0.10
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.30	<0.24	<0.030	0.11
Freshwater	R Frome (downstream)	2[E]		<4.0		<0.34	<0.27	<0.030	0.11
Freshwater	R Win, East of site	2[E]		<5.0		<0.34	<0.29	<0.040	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 3.5(b). Monitoring of radiation dose rates near Winfrith, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand and shingle	1	0.054
Red Cliffe Point to Black Head	Shingle	1	0.053
Osmington Mills	Rock	1	0.064
Ringstead Bay	Sand	1	0.052
Durdle Door	Shingle	1	0.053
Lulworth Cove	Sand and pebbles	1	0.068
Kimmeridge Bay	Pebbles and rock	1	0.069
Swanage Bay 1	Sand	1	0.059
Swanage Bay 2	Sand	1	0.060
Swanage Bay 3	Sand	1	0.056
Poole Harbour	Sand	1	0.052

4. Nuclear power stations

Key points

- Electricity production continued in 2008 at two Magnox stations (Oldbury and Wylfa) and all the British Energy power stations
- In 2008, Magnox North Limited became the operator for Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa. Magnox South Limited became the operator for Berkeley, Bradwell, Dungeness A, Hinkley Point A and Sizewell A
- In 2009, British Energy Generation Limited became a subsidiary of EDF
- Discharges, environmental concentrations, dose rates and doses in 2008 were broadly similar to those in 2007
- Concentrations of radiocaesium and transuranic elements were enhanced around some sites. These were mainly due to discharges from Sellafield and fallout from Chernobyl and/or former weapons testing
- Radiation doses from all sources were mostly less than 10 per cent of the dose limit (exceptions stated below)

Berkeley, Gloucestershire and Oldbury, South Gloucestershire

- There were small increases in radiation doses due to increased gamma dose rates in intertidal areas

Dungeness, Kent

- Gaseous tritium discharges increased from Dungeness B. Aqueous discharges of tritium decreased from Dungeness A and of tritium, sulphur-35 and cobalt-60 decreased from Dungeness B
- There were small increases in radiation doses due to increased gamma dose rates in intertidal areas
- *Total dose* from all sources was approximately 40 per cent of the dose limit. This was mainly due to direct radiation from the power station

Bradwell, Essex

- There were small decreases in radiation doses due to reductions in gamma dose rates on beaches

Chapelcross, Dumfries and Galloway

- Concentrations of tritium in milk have dropped since closure of the tritium plant in 2005

Hartlepool, Cleveland

- A new survey of local consumers' diet and occupancy was conducted to reduce uncertainties in risk assessments
- Radiation doses from marine pathways increased to 2 per cent of the dose limit because of improved assessment information from the survey

Heysham, Lancashire

- Gaseous discharges increased from Heysham 1
- There were small increases in radiation doses due to increased gamma dose rates in intertidal areas

Hinkley Point, Somerset

- Gaseous discharges of sulphur-35 and carbon-14 increased from Hinkley B
- There were small increases in radiation doses due to increased gamma dose rates in intertidal areas

Hunterston, North Ayrshire

- Gaseous discharges from Hunterston B increased
- Concentrations of technetium-99 in lobster were increased
- Radiation doses to terrestrial food consumers decreased due to lower strontium-90 LoD in milk

Sizewell, Suffolk

- Gaseous discharges of tritium from Sizewell A and B decreased

Wylfa, Isle of Anglesey

- Liquid discharges of tritium decreased

This section considers the effects of discharges from nuclear power stations during 2008. 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), three in Scotland (Chapelcross, Hunterston and Torness) and two in Wales (Trawsfynydd and Wylfa).

Eleven of the 19 nuclear power stations are older Magnox power stations, owned by the NDA. From April 2005, the NDA was formed and became responsible for the UK's civil nuclear liabilities. The NDA is a non-departmental public body with a remit to secure the decommissioning and clean-up of the UK's civil public sector nuclear sites. In 2009, the NDA published their plan which summarises the programme of work that

they intend to deliver both within the NDA and at each of their sites during 2009/12 (Nuclear Decommissioning Authority, 2009).

On 1 October 2008, Magnox Electric Limited (the nuclear site licence holder) split into two Site Licence Companies: Magnox North Limited and Magnox South Limited. Magnox North Limited became the operator for Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa and Magnox South Limited became the operator for Berkeley, Bradwell, Dungeness A, Hinkley Point A and Sizewell A. Calder Hall is operated by Sellafield Limited. In 2008, only two of these Magnox stations (Oldbury and Wylfa) continued to generate electricity, others are in the process of decommissioning. Discharges from one of the Magnox stations (Calder Hall) are considered in Section 2 because it is located at Sellafield.

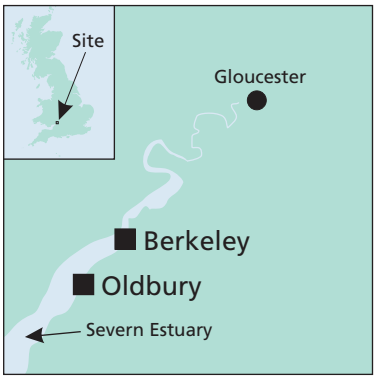
Seven advanced gas-cooled reactor (AGR) power stations and one pressurised water reactor (PWR) power station were owned and operated by British Energy Generation Limited in 2008. British Energy plc (the parent company) was subject to a merger and takeover negotiations in 2008, and Électricité de France (EDF) Energy has acquired a controlling interest in British Energy Group plc. British Energy Generation Limited, which operates Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B and Sizewell B power stations in England, and Hunterston B and Torness power stations in Scotland, became a subsidiary of EDF in early 2009. This takeover made no impact on the operation of these power stations in 2008. All of these were generating electricity during 2008.

Gaseous and liquid discharges from each of the power stations are authorised by the Environment Agency for England and Wales, and by SEPA for Scotland. In 2008, gaseous and liquid discharges were below authorised limits for each of the power stations (see Appendix 2). Independent monitoring of the environment around each of the power stations is conducted by the Food Standards Agency and the Environment Agency for England and Wales, and by SEPA for Scotland.

Estimates of dose discussed in this Section (and summarised in Table 4.1) do not always include a component from direct radiation from the site (unless specifically stated that they do include direct radiation). Separate estimates of *total dose* around the power stations taking into account direct radiation are available for all of the power stations. These are provided at the end of each sub-section. The sites are grouped in the Section according to whether they are in England, Scotland or Wales.

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station is situated on the eastern bank of the River Severn. Berkeley was the first commercial power station in the UK to enter into decommissioning, when it ceased electricity generation in March 1989. Decommissioning is still in progress and radioactive wastes are still generated by these 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, located on the south bank of the River Severn close to the village of Oldbury-on-Severn, 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.

Oldbury was expected to shut down on 31 December 2008, due to a planned decision by Magnox North Limited and the NDA, but has since received the go-ahead to continue generating (not expected to continue beyond June 2011). The most recent habits survey undertaken for the Berkeley and Oldbury sites was in 2007 (Clyne *et al*., 2008b).

Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Local freshwater samples were also analysed. Data for 2008 are presented in Table 4.2(a). 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 concentrations slightly above background values, although this may be due to natural variation. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

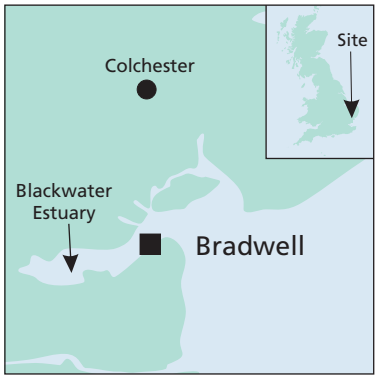
Liquid radioactive wastes are discharged to the Severn estuary. Analyses of seafood and marine indicator materials and

measurements of external radiation over muddy intertidal areas were conducted. 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 6). Data for 2008 are presented in Tables 4.2(a) and (b). Where comparisons can be drawn concentrations in the aquatic environment were generally similar to those in recent years, although gamma dose rates are generally slightly higher in 2008. 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 reasonably consistent for the last decade (Figure 4.1), with a suggestion of a small peak in 2004 and subsequently decreasing with time. 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.

Doses to the public

The estimated dose from consumption of terrestrial foodstuffs was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air, (see Appendix 1), the critical group dose in 2008 for Berkeley and Oldbury sites was still below 0.005 mSv, which was less than 0.5 per cent of the dose limit. The dose to the critical group of fish and shellfish consumers was estimated to be 0.029 mSv, which was less than 3 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This includes external radiation, a component due to the tritium originating from GE Healthcare, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The dose in 2007 was 0.018 mSv, and the increase in 2008 was due to an overall increase in the gamma dose rates. Recent trends in doses in the area of the Severn Estuary are shown in Figure 6.4. The *total dose* (Berkeley and Oldbury combined) in 2008 from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.041 mSv or approximately 4 per cent of the dose limit. This was almost entirely due to direct radiation.

4.2 Bradwell, Essex



The Bradwell site is located on the south side of the Blackwater Estuary. This Magnox power station ceased electricity production in March 2002 after 40 years of operation and is now undergoing defuelling prior to decommissioning. The most recent habits survey was undertaken in 2007 (Tipple *et al*., 2008).

Gaseous discharges and terrestrial monitoring

This power station is authorised to discharge gaseous wastes to the local environment via stacks to the atmosphere. 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. Data for 2008 are presented in Table 4.3(a). Concentrations of activity were low in terrestrial food samples, though some enhancements of carbon-14 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. The gross beta activity in water from the coastal ditch continued to be enhanced above background levels, and in 2008 both gross alpha and beta were in excess of the WHO screening levels for drinking water (0.5 Bq $l^{-1}$and 1 Bq l^{-1}, respectively). Overall, tritium concentrations in coastal ditches were increased in 2008 but were still substantially below the EU reference level for tritium of 100 Bq l^{-1}. The water in the ditches is not known to be used as a source of drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged to the estuary of the River Blackwater. 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. In comparison to 2007, discharges were slightly increased for caesium-137 and other radionuclides, but significantly less than in 2006. Measurements for 2008 are summarised in Tables 4.3(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 2007, however, there is evidence for a small decline in caesium-137 concentrations in biota from reduced discharges in recent years (Table 4.3(a)), and overall decline in sediments (Figure 4.1). The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity. Gamma dose rates on beaches were difficult to distinguish from natural background.

Doses to the public

The dose from consumption of locally grown foodstuffs and other terrestrial pathways was estimated to be less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The critical

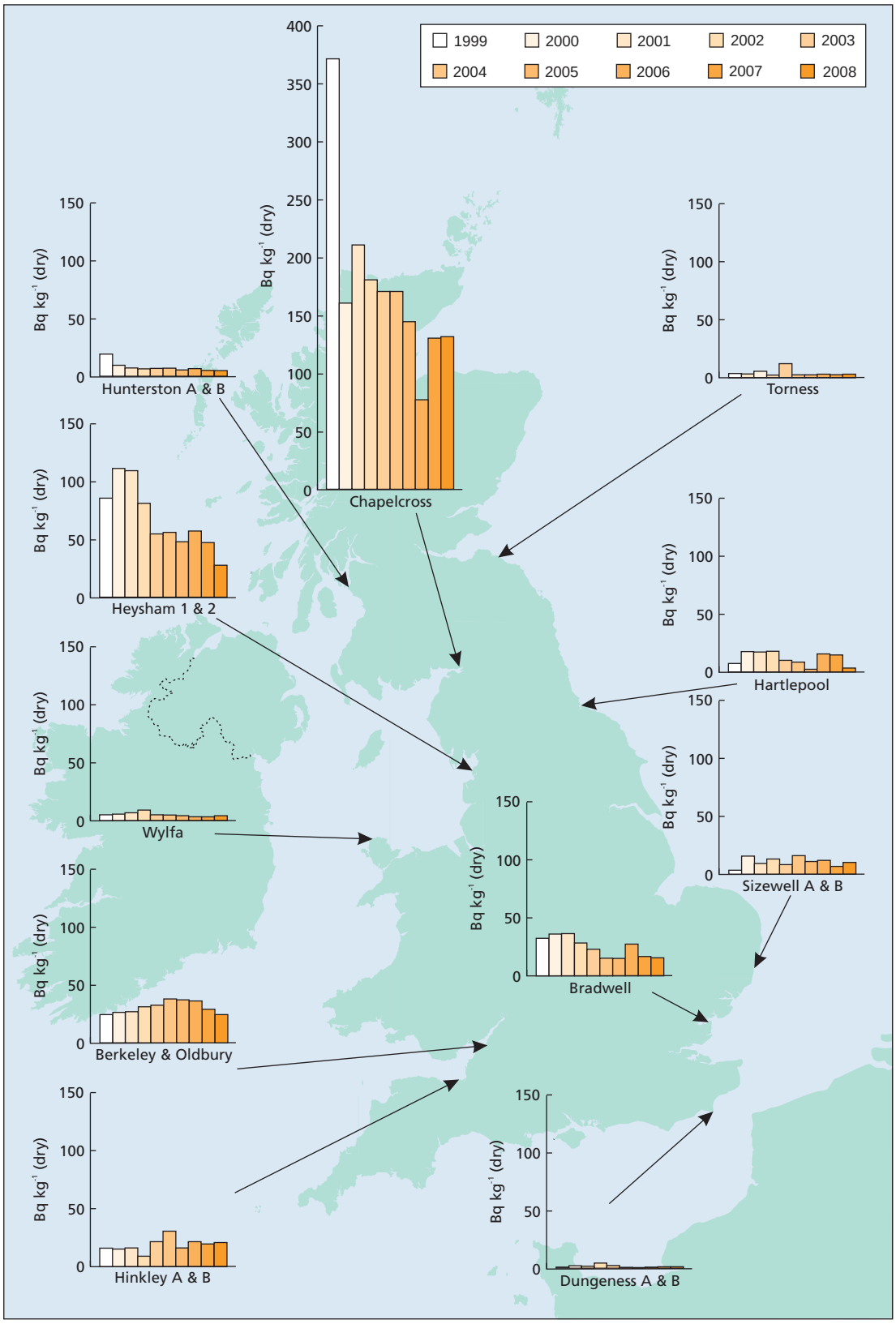
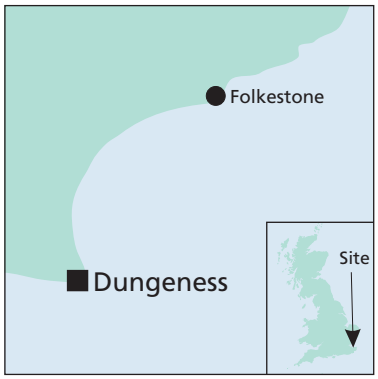


Figure 4.1. Caesium-137 concentration in marine sediments near nuclear power stations between 1999-2008

group of seafood consumers received less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose in 2007 was 0.017 mSv and the decrease in 2008 was due to a reduction in the beach gamma dose rate. The trend in marine doses at Bradwell and at power stations generally is shown in Figure 4.2. The variability in dose estimated at Bradwell is predominantly due to the normal variability expected in concentrations and dose rates in the environment. In addition, during 2000 and 2001, no information was available for assessment of doses from external radiation from beaches at the time of writing. If this had been assessed it is expected that the full dose to the critical

groups would have been similar to those values in other years. In 2008, the *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.070 mSv, or 7 per cent of the dose limit. This was almost entirely due to direct radiation

4.3 Dungeness, Kent



Located on the Dungeness headland in the south east of Kent, there are two separate A and B nuclear power stations on this site; the A station was 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. Dungeness A ceased generating electricity on the 31 December 2006 and will be decommissioned. It is estimated that Dungeness B will end power generation by 2018. The most recent habits survey was conducted during 2005 (McTaggart *et al.*, 2006).

Gaseous discharges and terrestrial monitoring

Discharges of tritium were increased from Dungeness B, in comparison to releases in 2007. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. The results of monitoring for 2007 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the limits of detection. Concentrations of carbon-14 were generally within the range of observed background activity concentrations. Low concentrations of sulphur-35 were detected in some samples. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium were decreased from Dungeness A, and discharges of tritium, sulphur-35 and cobalt-60 were decreased from Dungeness B, in comparison to releases in 2007. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2008 are given in Tables 4.4(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 and Cap de la Hague. Apportionment is difficult at these low levels. The small concentrations of transuranic nuclides in scallops and sediment were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma dose rates were generally difficult to distinguish from the natural background.

Doses to the public

As in 2007, the infant age group received the maximum dose due to gaseous disposals. Their dose in 2008 was estimated to be 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public. This is a similar value to 2007, and a decrease compared with 0.13 mSv in 2006 in which the age group was adult. For seafood consumers, local bait diggers who also eat fish and shellfish represented the critical group. Their radiation dose was 0.012 mSv, which was approximately 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from 0.007 mSv (in 2007) was attributed to slightly higher dose rates at Rye Bay in 2008, compared to 2007. The trend in marine doses at Dungeness and at other power stations more generally is shown in Figure 4.2. The variability in dose seen at Dungeness is predominantly due to the normal variability expected in concentrations and dose rates in the environment. From available data in 2008, with no gamma dose rate being measured at Rye Harbour, the external radiation dose for local houseboat occupants was estimated to be 0.012 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.40 mSv, or 40 per cent of the dose limit. This was almost entirely due to direct radiation.

4.4 Hartlepool, Cleveland

Hartlepool Power Station is situated on the mouth of the Tees estuary and is powered by twin AGRs. It is estimated that its power generation will end by 2018. A habits survey was conducted in May 2008. Two potential critical groups for public exposure in the aquatic environment were identified: sea coal collectors and seafood consumers. No consumption of mollusc was identified within the Paddy's Hole area. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. In 2008, gaseous discharges were generally lower than in 2007. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. Samples of water are also taken from a borehole and public supplies. Data for 2008 are presented in Table 4.5(a). The effects of gaseous disposals from the site were

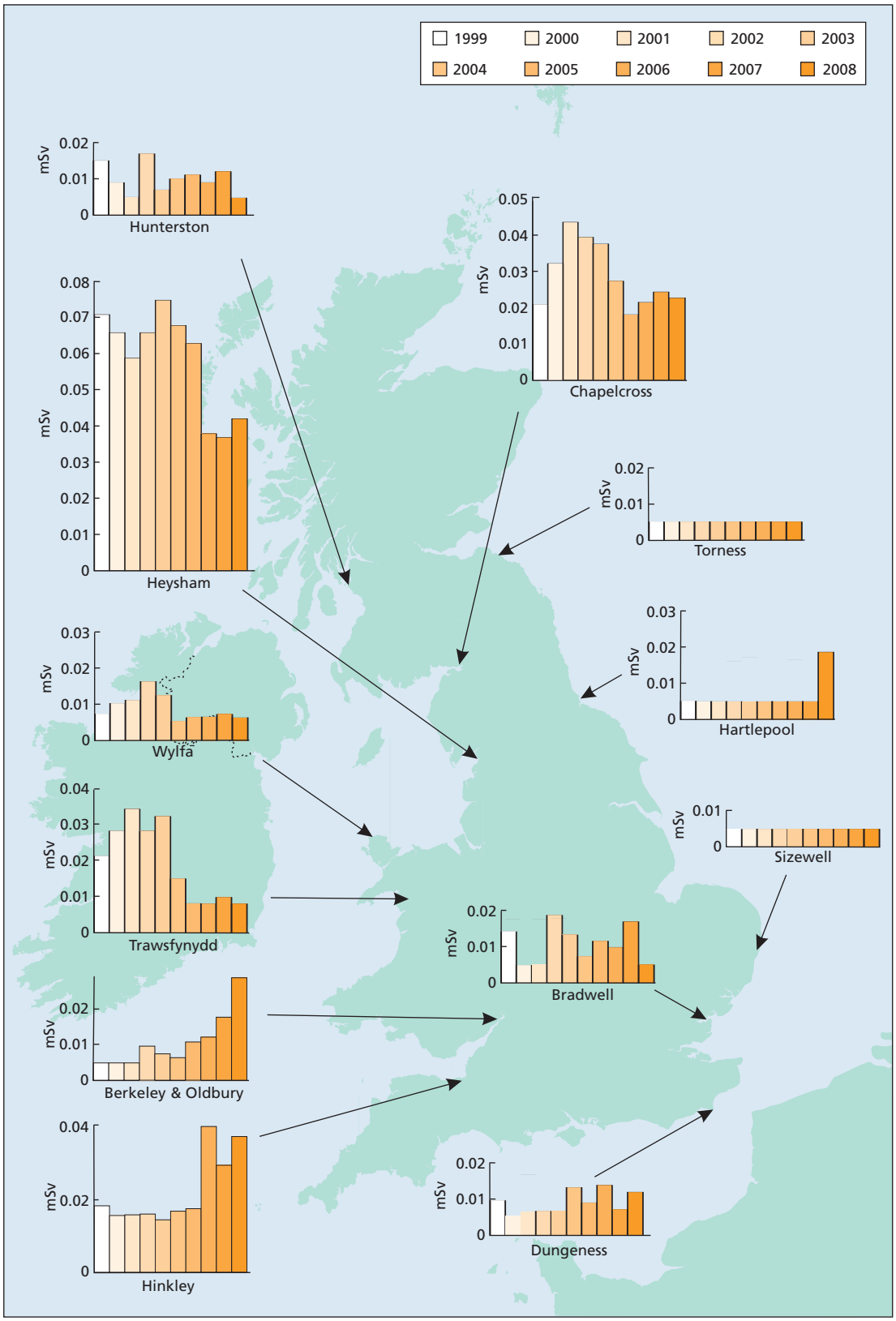


Figure 4.2. Individual radiation exposures at nuclear power stations from aquatic pathways for artificial radionuclides, 1999-2008 (Small doses less than or equal to 0.005mSv are recorded as being 0.005mSv)

not easily detectable in foodstuffs, though some enhancements of carbon-14 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Tritium and sulphur-35 discharges were significantly reduced in 2008, in comparison to 2007. Technetium-99 analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield.

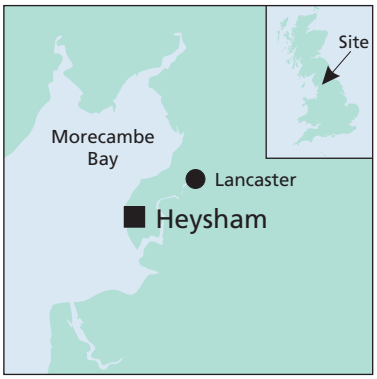
Results of the aquatic monitoring programme conducted in 2008 are shown in Tables 4.5(a) and (b). Tritium activity in seawater was less than the LoD, consistent with reduced discharges in 2008. Concentrations of carbon-14 were enhanced above a background of approximately 25 Bq kg^{-1} expected for seafood (see Appendix 1). This is most likely to be due to carbon-14 discharges from a non-nuclear site since carbon-14 discharges from the power station are low. Concentrations of technetium-99 in seaweed (*Fucus vesiculosus*) were similar to 2007 and less than the peak observed in 1998 (see also Figure 2.19). They are less than 1 per cent of the equivalent concentrations near Sellafield. Iodine-131 was not detected in seaweed around the bottom of the River Tees Estuary (detection in previous years is believed to originate from the therapeutic use of this radionuclide in a local hospital). Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. In 2008, the lead-210 and polonium-210 levels were close to natural background. In previous years, sampling in Paddy's Hole has revealed a local enhancement which was believed to be due to wastes from iron and steel industries. In comparison to 2007 data, gamma dose rates were slightly increased in 2008.

Doses to the public

The dose from consumption of locally grown foodstuffs was estimated to be less than 0.005 mSv, including a component due to non-food pathways arising from discharges to air (see Appendix 1) and was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The decrease in dose from 0.006 mSv (in 2007) was attributed to a lower LoD for sulphur-35 in milk.

The radiation dose to local fish and shellfish consumers, including external radiation was 0.011 mSv which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from less than 0.005 mSv (in 2007) was attributed to increased gamma dose rates, particularly at Seaton Carew and Seaton Sands. In 2008, a new assessment was conducted to determine the external exposure for sea coal collectors at Carr House. The estimated dose was 0.019 mSv for this activity. There had been no significant trend in doses from marine pathways previous to 2008 (Figure 4.2). The *total dose* from all sources including direct radiation was assessed, using methods in Appendix 4, to have been 0.026 mSv or less than 3 per cent of the dose limit.

4.5 Heysham, Lancashire



Heysham Power Station is situated on the Lancashire coast to the south of Morecambe and near the port of Heysham. This establishment comprises two separate nuclear power stations both powered by AGRs. It is estimated that Heysham 1 and 2 will end power generation by 2014 and 2023, respectively. 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 most recent habits survey was conducted in 2006 (McTaggart *et al.*, 2007).

Gaseous discharges and terrestrial monitoring

Discharges from Heysham 1 were generally lower in comparison to releases in 2007. The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. Data for 2008 are presented in Table 4.6(a). The effects of gaseous disposals were also difficult to detect in 2008, and measured activities of cobalt-60 were below the LoD. Small enhancements of concentrations of carbon-14 and sulphur-35 were apparent in some samples.

Liquid waste discharges and aquatic monitoring

The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates and for completeness the data considered in this section include all of those for Morecambe Bay. A substantial part of the programme is in place in order to monitor the effects of Sellafield disposals. The results for 2008 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2007 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in flounder 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, caused by discharges from Sellafield. Concentrations of caesium-137 in sediments were also largely due to Sellafield but they are in decline

(Figure 4.1). In 2008, gamma dose rates were slightly higher at the Heysham pipelines and Half Moon Bay, in comparison to 2007.

Doses to the public

The estimated dose for terrestrial food consumers was 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air (see Appendix 1), the dose was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This is similar to the value in 2007 and both largely attributable to the inclusion of the LoD for cobalt-60 analysis in the assessments. The radiation dose in 2008 to the critical group of fishermen, including a component due to external radiation, was 0.042 mSv, which is approximately 4 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This is an increase from the value for 2007 (0.037 mSv) and attributable to slightly increased gamma dose rates at the Heysham pipeline and Half Moon Bay. Trends in aquatic doses from power stations are shown in Figure 4.2. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.046 mSv or less than 5 per cent of the dose limit. The increase in dose from 0.038 mSv in 2007 is attributable to a general increase in gamma dose rates in 2008.

4.6 Hinkley Point, Somerset

Hinkley Point power stations are situated on the Somerset coast, west of the River Parrett estuary. 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. The station began defuelling in 2002 and completed this in 2004. It is estimated that Hinkley Point B will end power generation by 2016. Environmental monitoring covers the effects of the two power stations together. The most recent habits survey was undertaken in 2006 (Clyne *et al*., 2007).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Discharges of cabon-14 and sulphur-35 at Hinkley Point B were increased in comparison to releases in 2007, but remained lower than in 2006. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. The use of seaweeds as fertilisers and soil conditioners was assessed to investigate transfer of radionuclides from sea to land. Data for 2008 are presented in Table 4.7(a), including measurements for cobalt-60 which was added in the revised discharge authorisation in 2007. Activity concentrations of tritium and gamma emitters in terrestrial materials were below or close to the limits of detection. Concentrations of sulphur-35 showed the effects of Hinkley Point B, and these effects were slightly increased, in comparison to 2007, due to the higher discharges. Some of the concentrations of carbon-14 were higher than the default values used to represent background levels (Appendix 1). Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water. Sea to land transfer data for vegetables and soil which had seaweed added as a compost showed no evidence for uptake of activity concentrations in foodstuffs.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent from both power stations are made via separate outfalls into the Bristol Channel. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were conducted. 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 2008 are presented in Tables 4.7 (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 2007 (see also Figure 4.1). Concentrations of tritium and carbon-14 in cod and shrimps were similar to their levels in recent years. Further information on tritium concentrations in seawater from the Bristol Channel is given in Section 8. 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 to the aquatic environment are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl fallout. Apportionment is generally difficult at the low concentrations 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 were similar to measurements in 2007. The rates at one location (Stolford, mud and rock) in 2008 were marginally increased in comparison to 2007, but similar to rates in 2006.

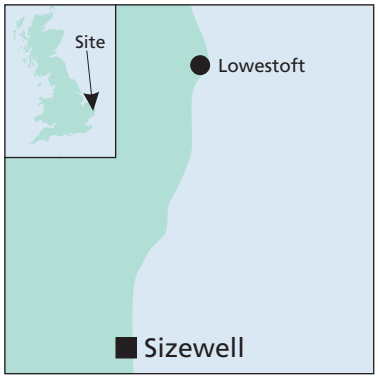
Doses to the public

The estimated dose for terrestrial food consumers was 0.006 mSv, including a component due to non-food pathways arising from discharges to air (see Appendix 1). This was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This represents a small increase in the dose in comparison to the value obtained in 2007 (less than 0.005 mSv). The increase in dose in 2008 was largely attributed to the inclusion of an LoD result for cobalt-60 in milk. Assuming that high-rate vegetable consumers obtain all

of their supplies from monitored plots near Hinkley, the dose in 2008 from the use of seaweeds as fertilisers and soil conditioners was estimated to be much less than 0.005 mSv.

The critical group of local fishermen was estimated to receive a dose (including a component due to external radiation) of 0.037 mSv, which was less than 4 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This estimate also includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1). The increase in dose, from 0.029 mSv (in 2007), was due to the slightly enhanced gamma dose rates, but the dose value and dose rates were similar to those in 2006. There is no site related reason to account for the variation in dose rates and the change may be due to variations in natural radiation. Trends in doses in the area of the Severn Estuary are shown in Figure 6.4. The increase in dose in 2006 was largely due to an increase in occupancy observed from new habits survey information. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.045 mSv or less than 5 per cent of the dose limit. The increase in dose from 0.035 mSv in 2007 was attributable to a general increase in gamma dose rates in 2008.

4.7 Sizewell, Suffolk



The two Sizewell power stations are located on the Suffolk coast, near Leiston. The A station has two Magnox reactors whilst the B station is the UK's only commercial PWR power station. The B station began operation in 1995 and it is estimated that it will end power generation by 2035. Sizewell A power station ceased to be an electricity generator on 31 December 2006 and is due to be decommissioned. The most recent habits survey was undertaken in 2005 (Clyne *et al.*, 2006).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. In 2008, discharges of tritium were significantly reduced in comparison to 2007. The results of the terrestrial monitoring in 2008 are shown in Table 4.8 (a). Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit generally showed very low concentrations of artificial radionuclides near the power stations in 2008. Concentrations of activity in local freshwater were all low.

Liquid waste discharges and aquatic monitoring

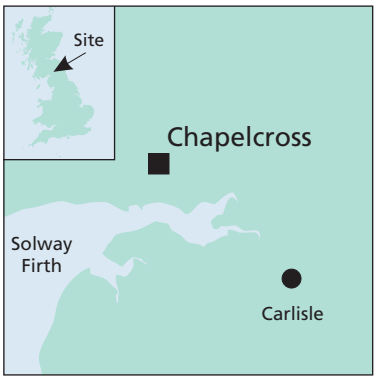
Authorised discharges of radioactive liquid effluent are made via outfalls to the North Sea. In 2008, discharges from Sizewell A were reduced, particularly for tritium, in comparison to 2007. Sizewell B's discharges were increased for tritium, resulting overall in a slight increase from the site. In the aquatic programme, analysis of seafood, sediment, sand and seawater, and measurements of gamma dose rates in intertidal areas were conducted. Data for 2008 are presented in Tables 4.8(a) and (b). Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium concentrations in seafood were all below the limits of detection. Measured gamma dose rates in intertidal areas were difficult to distinguish from the natural background, including at Sizewell beach where direct radiation from the A station is known to have had a local effect in recent years.

Doses to the public

The estimated dose from consumption of locally grown foodstuffs was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air, (see Appendix 1), the critical group dose in 2008 was the same at less than 0.005 mSv which is less than 0.5 per cent of the dose limit for members of the public of 1 mSv. In 2008, the radiation dose to local fish and shellfish consumers was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). There has been no significant variation in doses to seafood consumers in recent years (Figure 4.2). They have remained consistently below 0.005 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.031 mSv or approximately 3 per cent of the dose limit. This has reduced due to cessation of power generation at Sizewell A in 2006, when the *total* dose was 0.091mSv.

SCOTLAND

4.8 Chapelcross, Dumfries and Galloway



Chapelcross was Scotland's first commercial nuclear power station and has Magnox reactors located near the town of Annan in Dumfries and Galloway. After 45 years of continuous operation, electricity generation ceased in June 2004 and the station has been preparing for decommissioning. Defuelling

of the four reactors began in 2008 and completion is expected during 2011.

The 2007 application for a revised authorisation for the disposal of radioactive waste arising from the decommissioning of Chapelcross was sent to statutory consultees in 2008. Public consultation on the application is expected to commence in 2009.

The end of the effluent pipeline is fully submerged at high water and for a period prior to and after high water. The pipeline remains exposed during the rest of the time. The pipeline is subject to groundwater ingress and constantly discharges to the Solway Firth. Samples of effluent from the end of the site's pipeline, whilst fully exposed, were taken by SEPA and these showed that the levels of tritium are consistent with that measured by the site operator in rainwater and below the levels previously measured in surface water close to the site. The levels of caesium-137 whilst low are not in accordance with the requirement to discharge around high water. Full control of liquid disposals will need to be achieved with the improvements that are being progressed by the site operator as discussed later in this section.

Discussions between SEPA and the site operators took place regarding the disposal of tritiated groundwater building up in the reactor cable basements. The cable basements are subject to groundwater ingress. Samples were taken from the cable basements to check on the operator's measurements, which underpinned SEPA's agreement to permit the discharge of liquid waste from the cable basement outwith the tidal conditions set down in the authorisation. Tritium and caesium-137 concentrations in the reactor basement water were measurable but relatively low. The waste was disposed of to the Solway under SEPA's dispensation regarding the tidal conditions set down in the authorisation. To better understand the legacy of gaseous tritium disposals from the site and to inform on future disposals a programme of surface water sampling in the locality of the premises is being undertaken in 2009.

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2005 (Sherlock *et al*., 2006). 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. In 2007, a habits survey of consumption and occupancy, by members of the public, was completed on the Dumfries and Galloway coast (Clyne *et al*., 2008a). The results of the survey are used to determine the potential exposure pathways relating to authorised liquid discharges from the Sellafield nuclear site in Cumbria (see Section 2.3.4).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Argon-41 was not discharged in 2008, as in recent years, following the end of power generation. Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit and crops, as well as grass and soil samples, for a range of radionuclides. Air samples at three locations were also monitored to investigate the inhalation pathway.

The results of terrestrial food and air monitoring in 2008 are presented in Tables 4.9(a) and (c). The activity concentrations of radionuclides in milk and grass were generally similar to those observed in 2007. The maximum concentration of tritium in milk decreased from 20 Bq l^{-1} in 2007 to below the LoD (<12 Bq l^{-1}) in 2008, the latter value being the lowest since electricity generation ceased in 2004. The results for terrestrial foods show the effects of discharges from Chapelcross in the concentrations of tritium and sulphur-35 in a range of foods, and these are generally low. Measured concentrations of radioactivity in air samples, at locations near to the site, were very low.

Liquid waste discharges and aquatic monitoring

Radioactive liquid effluents are discharged to the Solway Firth. Samples of seawater and *Fucus vesiculosus*, as environmental indicators, were collected in addition to seafood, sediments and dose rates. Data for 2008 are presented in Tables 4.9(a) and (b), which include results for the sampling of the cable basement and from the end of the pipeline. Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years. Progressive reductions in concentrations of technetium-99 in biota were observed again in 2008. In comparison to 2007 data, gamma dose rates slightly decreased in some intertidal areas. Measurements of the contact beta dose rate on stake nets were below the LoD.

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. Magnox North Limited monitor this area frequently. In 2008, three particles with activity above background were detected during routine monitoring. In comparison, one particle with activity above background was detected in 2007, with a total of 127 particles during the period 2000 to 2007. The relatively high number found in 2005 (95 particles) was 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 North Limited and taken back to Chapelcross for analysis and appropriate disposal. During 2007 attempts were made to de-scale the inside of the effluent pipeline, however this was judged to be only

partially successful. The quantity of scale generated caused operational difficulties and no liquid disposals were possible between January and the end of May 2008. Consequently the de-scaling plans were abandoned in favour of providing a new pipeline within the existing pipeline by a technique routinely used within the water industry known as "slip lining". These plans are at an advanced stage. This should have the benefit of eliminating the ingress of groundwater to, and isolating any scale from, the new pipeline whilst isolating the current pipeline from discharging to the Solway.

Doses to the public

The annual dose from terrestrial food consumption was estimated to be 0.023 mSv in 2008. The dose in 2007 was similar at 0.021 mSv, but with minor variations in contributors in 2008 (an increased value for the maximum carbon-14 activity in milk offset by a decreased value for the LoD of strontium-90 in milk). The dose from consumption of terrestrial foods includes contributions due to weapons testing and Chernobyl fallout. After making an allowance for non-food pathways arising from discharges to air (see Appendix 1), the critical group dose from gaseous discharges in 2008 was 0.023 mSv, which was approximately 2 per cent of the dose limit for members of the public of 1 mSv. As no argon-41 was discharged in 2008, this dose was mostly due to the consumption of local foodstuffs. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.022 mSv in 2008, which was approximately 2 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The decrease in dose from 0.024 mSv in 2007 was due to slight decreases in gamma dose rate measurements. 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.

The total exposure to consumers of wildfowl, including their external dose from occupancy over salt marsh was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The decrease from 0.008 mSv (in 2007) was due to slightly decreased gamma dose rates in some intertidal areas. The dose from consumption of wildfowl was less than 0.005 mSv. Trends in aquatic doses from power stations are shown in Figure 4.2. The reduction of the dose at Chapelcross, commencing in 2004, was due to lower gamma dose rates reported. In recent years, the observed trend is due to differences in measured gamma dose rates from normal variability in the environment. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.021 mSv, or approximately 2 per cent of the dose limit.

4.9 Hunterston, North Ayrshire

Hunterston power station is located on the Ayrshire coast near West Kilbride. At this location there are two separate nuclear power stations – Hunterston A and Hunterston B. Hunterston B is owned by EDF and operated by British Energy Generation Limited, while Hunterston A is operated by Magnox North Limited and owned by the NDA. Hunterston A was powered by twin Magnox reactors and Hunterston B is powered by a pair of AGRs. Hunterston A ceased electricity power production at the end of March 1990, and it is estimated that Hunterston B will end power generation by 2018. Environmental monitoring in the area considers the effects of both sites together.

Reactors at Hunterston B returned to 70 per cent operation in May 2008 following a prolonged outage to repair faults found in the boiler tubes. The station had accumulated a substantial backlog of contaminated waste oil, which had not been disposed of due to staff resource issues. In compliance with the Water Environment (Oil Storage) (Scotland) Regulations 2006, a programme to address the backlog was instituted, and the backlog of waste oil had been disposed of via the station's dedicated waste oil burner by October 2008.

In October 2008 SEPA varied the authorisation for Hunterston A, to reflect the change of operator at the low level waste repository near Drigg in Cumbria.

Two potential pathways have been identified in the recent habits survey: seafood consumers and terrestrial food consumers. The most recent habits survey was undertaken in 2007 (Sherlock *et al.*, 2008).

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. Discharges from Hunterston B were increased in comparison to 2007. 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 results of terrestrial food and air monitoring in 2008 are presented in Tables 4.10(a) and (c). The concentrations of radionuclides in air, milk, crops and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. Measured concentrations of radioactivity in air at locations near to the site were very low (Table 4.10(c)).

Liquid waste discharges and aquatic monitoring

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. 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.

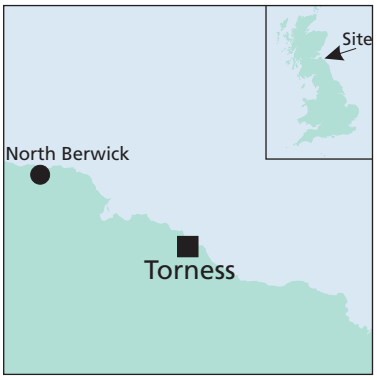
A new modular active effluent treatment plant has been designed and installed at Hunterston A to provide improved treatment of effluent prior to discharge. The plant has been undergoing commissioning and non-active trials during the year before it comes into full operation.

The results of aquatic monitoring in 2008 are shown in Tables 4.10(a) and (b). 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 around Hunterston were similar to those in 2007. The technetium-99 concentration in the common lobster increased in 2008, in comparison to 2007 and 2006, but is still lower than in preceding years. Small concentrations of activation products such as manganese-54 that are likely to have originated from the site were also detected in seaweed but were of negligible radiological significance. Gamma dose rates were similar to those in 2007.

Doses to the public

In 2008, the estimated dose for consumption of terrestrial food, including a contribution due to weapon testing and Chernobyl fallout, was 0.006 mSv. The dose in 2007 was larger at 0.023 mSv. The decrease in dose was largely contributed to a relatively high LoD for strontium-90 in milk in 2007, compared to 2008. In 2008, the dose from non-food pathways (arising from discharges to air, see Appendix 1) slightly increased in comparison to 2007, due to small increases in discharges from Hunterston B. Taking the food and non-food pathways together, the critical group dose in 2008 was 0.007 mSv which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. As in 2007, the contribution to dose from consumption of fish and shellfish was less than 0.005 mSv. This includes a contribution from the Sellafield-derived technetium-99 in shellfish. The dose to the critical group of fishermen who consume seafood and are exposed to radiation over intertidal areas was 0.005 mSv in 2008, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). Trends in aquatic doses at power stations are shown in Figure 4.2. In recent years, the observed trend is due to differences in measured gamma dose rates from normal variability in the environment. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.077 mSv, or approximately 8 per cent of the dose limit.

4.10 Torness, East Lothian



Torness power station is located near Dunbar on the east coast of Scotland. This station, which is powered by two AGRs, began operation at the end of 1987 and it is estimated that its power generation will end by 2023. Disposals and discharges of radioactive waste from the site are made in accordance with the Radioactive Substances Act authorisation issued to the site by SEPA in 2007. The liquid and gaseous discharges from the site are given in Appendix 2. There were no amendments made to the authorisation during 2008.

SEPA carried out additional monitoring in response to a notification from the station that there had been a leak of carbon dioxide. The leak was minor and not considered to be either an off-site or on-site emergency. The monitoring results showed no elevated levels of radioactivity in any of the samples taken.

The most recent habits survey was conducted in 2006 (Tipple *et al.*, 2007b). The scope of the monitoring programme at this site was enhanced in 2000 and further in 2004.

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops and fruit as well as grass and soil samples, were measured for a range of radionuclides. Air sampling at two locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2008 are presented in Tables 4.11(a) and (c). The effects of discharges from the power station were observed in low concentrations of sulphur-35 in terrestrial foods and environmental indicator materials. Measured concentrations of radioactivity in air at locations near to the site were very low (Table 4.11(c)).

Liquid waste discharges and aquatic monitoring

Samples of seawater and *Fucus vesiculosus*, as useful environmental indicators, were collected in addition to seafood. 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 the aquatic monitoring in 2008 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides

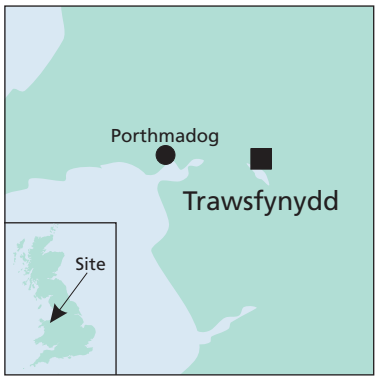
were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout. As in recent years, very low concentrations of activation products were detected which were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2007. Beta radiation from fishermen's nets and pots was below the LoD. A relatively high value was measured for tritium in seawater (130 Bq l^{-1}) in 2008. This is likely to be due to sample collection coinciding with a routine discharge. Gamma dose rates on beaches were generally indistinguishable from natural background, although slightly higher rates were measured at Thornton Loch in 2008, in comparison to LoD values reported in recent years.

Doses to the public

The estimated dose from terrestrial food consumption, including a contribution due to weapon testing and Chernobyl fallout, was 0.006 mSv. This represents a small decrease in the dose in comparison to the value obtained in 2007 (0.008 mSv), due to a lower LoD for strontium-90 in goat's milk for 2008. After making an allowance for non-food pathways, arising from radionuclides in air (see Appendix 1), the critical group dose in 2008 was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. The dose to the critical group of fish and shellfish consumers, including a component due to external radiation, was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). There has been no significant trend in doses from marine pathways in recent years (Figure 4.2). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.022 mSv or approximately 2 per cent of the dose limit.

WALES

4.11 Trawsfynydd, Gwynedd



Trawsfynydd power station is located in the heart of Snowdonia National Park, North Wales. At this establishment, there are twin Magnox reactors. Defuelling of the reactors was completed in 1995 and the station is being decommissioned. Low-level discharges continued during 2008 under an authorisation granted by the Environment Agency. Monitoring is conducted on behalf of the Welsh Assembly Government. The most recent habits survey was undertaken in 2005 (Tipple *et al.,* 2006a).

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, including those for local milk, crops and animal samples, are shown in Table 4.12(a). Concentrations of activity in all terrestrial foods were low. Caesium-137 was detected in some of the terrestrial foods (apples, blackberries and potatoes), at concentrations just above the LoD. The most likely source 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 conducted 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 lake shore contributing to increased exposure from transuranic radionuclides in 2008.

Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. The aquatic monitoring programme was 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. Freshwater and sediment samples are also analysed. Habits surveys have established that species of fish regularly consumed are brown and rainbow trout. 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.

Data for 2008 are presented in Tables 4.12(a) and (b). Concentrations of radiocaesium in fish in 2008 were similar to those in 2007. The activity concentrations in sediments, and 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 transuranics are also detected, particularly in lake sediments (in recent years' monitoring, it has been demonstrated that these increase with depth beneath the sediment surface). However, the transuranic concentrations in fish are very low and it is the effects of caesium-137 that dominate the fish consumption and external radiation pathways.

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 2007. The predominant radionuclide is caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.3. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. Over the last decade, the observed levels now are

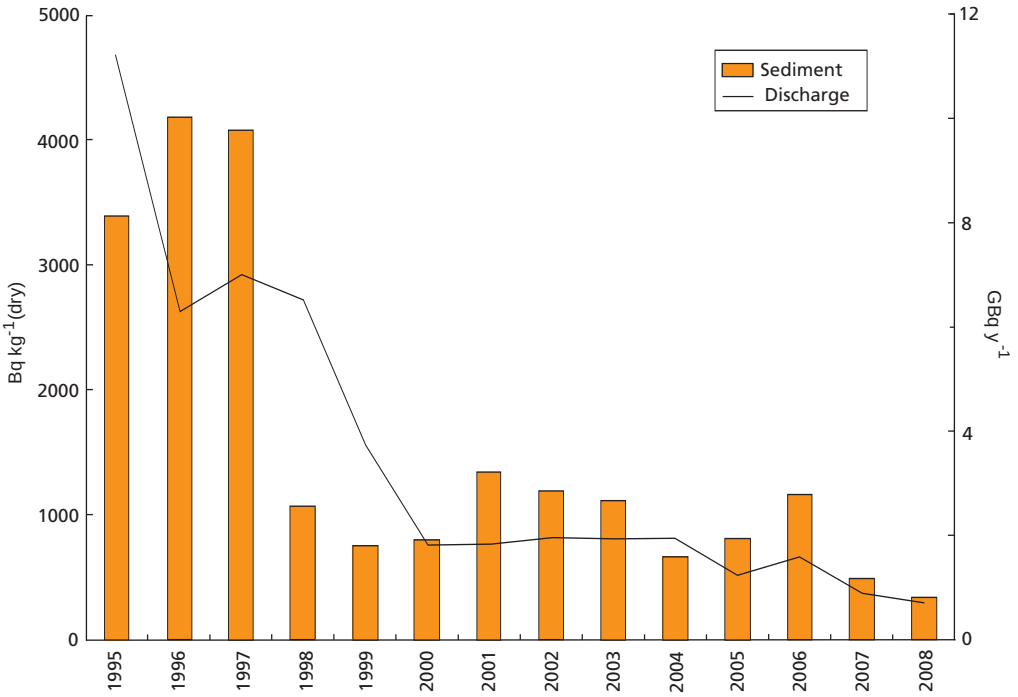


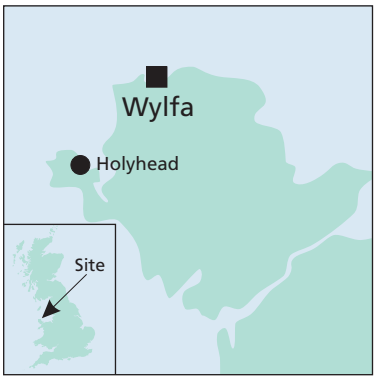
Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2008

mainly affected by sample variability, with the lowest levels reported in recent years.

Doses to the public

Consumers of terrestrial foods at Trawsfynydd in 2008 received doses of less than 0.005 mSv. The infant age group received the maximum dose from milk consumption. This dose is similar in comparison to the value obtained in 2007. After making an allowance from non-food pathways, arising from discharges to air (see Appendix 1), the dose to the critical group was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to the critical group of anglers was 0.008 mSv in 2008, which was less than 1 per cent 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. The decrease from the estimate of 0.010 mSv in 2007 was due to slightly reduced caesium-137 concentrations in lake sediments (Figure 4.3). Trends in doses at power stations are shown in Figure 4.2. The reduction of the dose in 2004 at Trawsfynydd was due to a reduction in the observed concentrations in lake sediments. There has been no significant trend in doses from aquatic pathways in recent years. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.031 mSv or approximately 3 per cent of the dose limit.

4.12 Wylfa, Isle of Anglesey



Wylfa power station is located on the north coast of Anglesey and generates electricity from two Magnox reactors. The end of power generation is scheduled for 2010. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is conducted on behalf of the Welsh Assembly Government. The most recent habits survey was conducted in 2004 (Clyne *et al*., 2005).

Gaseous discharges and terrestrial monitoring

The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Local surface water samples were also taken and analysed. Data for 2008 are presented in Table 4.13(a). Sulphur-35 was detected at very low concentrations in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, and although carbon-14 discharges increased from 1.0 TBq in 2007 to 1.5 TBq in 2008, concentrations were mostly those expected for background levels. Caesium-137 levels in food samples were below the LoD (with the exception of honey, detected close to the LoD). Overall the effects of

discharges are very low. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

In April 2008, the site operators at Wylfa reported that the weekly advisory levels for carbon-14 and tritium had been exceeded. The Food Standards Agency conducted extra analyses of carbon-14 and tritium in milk samples from two local farms, but found no elevated concentrations of these radionuclides (Table 4.13(a)).

Liquid waste discharges and aquatic monitoring

In 2008, discharges of tritium and other radionuclides were significantly reduced in comparison to 2007. The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates. The results of the programme in 2008 are given in Tables 4.13 (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 2007, and continued to show the effects of technetium-99 from Sellafield. Gamma dose rates, measured using portable instruments, were similar to those found in 2007.

Doses to the public

The dose received by terrestrial food consumption was 0.005 mSv. The increase in dose from less than 0.005 mSv (in 2007) was attributed to a small increase in carbon-14 in milk, and the inclusion of the detectable activity of caesium-137 in line with the rules on use of results for dose calculations. After making an allowance for non-food pathways, arising from discharges to air (see Appendix 1), the critical group dose in 2008 was 0.006 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to the critical group of high-rate fish and shellfish consumers was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). Trends in doses at power stations are shown in Figure 4.2. The reduction of the dose in 2004 at Wylfa was due to new estimates of consumption and occupancy rates. There has been no significant trend in doses from marine pathways in recent years. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.011 mSv or approximately 1 per cent of the dose limit.

Table 4.1. Individual radiation exposures - nuclear power stations, 2008

Site	Exposed population group[a]	Exposure, mSv per year				
		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	0.029	<0.005	-	0.028	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[b,d]	0.041	-	-	-	-
Bradwell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005
	All sources[d,e]	0.070	-	-	-	-
Dungeness	Seafood consumers	0.012	<0.005	-	0.009	-
	Houseboat occupants	0.012	-	-	0.012	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005
	All sources[d]	0.40	-	-	-	-
Hartlepool	Seafood consumers[c]	0.011	<0.005	-	0.010	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	Sea coal collectors	0.019	-	-	0.019	-
	All sources[d]	0.026	-	-	-	-
Heysham	Seafood consumers	0.042	0.013	-	0.029	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	0.005	-	<0.005
	All sources[d]	0.046	-	-	-	-
Hinkley Point	Seafood consumers	0.037	<0.005	-	0.035	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	0.006	-	<0.005
	Local consumers of vegetables grown on land with seaweed added	<0.005	-	<0.005	-	-
	All sources[d]	0.045	-	-	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[d]	0.031	-	-	-	-
Scotland						
Chapelcross	Seafood consumers	0.022	<0.005	-	0.019	-
	Wildfowlers	0.006	-	<0.005	0.005	-
	Inhabitants and consumers of locally grown food[b]	0.023	-	0.023	-	<0.005
	All sources[b,d]	0.021	-	-	-	-
Hunterston	Seafood consumers	0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.007	-	0.006	-	<0.005
	All sources[d,e]	0.077	-	-	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	0.006	-	<0.005
	All sources[d,e]	0.022	-	-	-	-
Wales						
Trawsfynydd	Anglers	0.008	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[b,d]	0.031	-	-	-	-
Wylfa	Seafood consumers	0.006	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	0.005	-	<0.005
	All sources[d]	0.011	-	-	-	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *Excluding possible enhancement of naturally occurring radionuclides. See Section 4*
[d] *The* total dose *due to discharges and direct radiation. See Appendix 4*
[e] *Prenatal children*

Table 4.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25			<0.08	<0.13	
Bass	River Severn	2	260			<0.12	2.4	
Elvers	River Severn	1	<25			<0.12	<0.10	
Shrimps	Guscar	2	260	38		<0.06	0.44	0.00040
Seaweed	Pipeline	2[E]			3.5	<0.84	<0.90	
Sediment	Hills Flats	2[E]					18	
Sediment	1 km south of Oldbury	2[E]				<1.2	26	
Sediment	2 km south west of Berkeley	2[E]				1.2	25	
Sediment	Sharpness	2[E]					21	
Seawater	Local beach	2[E]				<0.25	<0.25	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Salmon	Beachley	2		<0.07				
Bass	River Severn	2		<0.20				
Elvers	River Severn	1		<0.23				
Shrimps	Guscar	2	0.0023	0.0022	*	*		
Seaweed	Pipeline	2[E]		<1.1				
Sediment	Hills Flats	2[E]		<1.3				
Sediment	1 km south of Oldbury	2[E]		<1.2				
Sediment	2 km south west of Berkeley	2[E]		<0.80				
Sediment	Sharpness	2[E]		<1.2				
Seawater	Local beach	2[E]		<0.36			<1.2	4.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{134}Cs	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		8	<4.5	17	<0.37	<0.20	<0.20		
Milk	max		<5.0	20	<0.50				
Apples		1	<5.0	7.0	<0.20	<0.20	<0.20		
Blackberries		1	<5.0	17	<0.20	<0.20	<0.30		
Cabbage		1	<5.0	5.0	0.40	<0.20	<0.20		
Honey		1	<7.0	78	0.40	<0.20	<0.20		
Onions		1	<5.0	6.0	0.40	<0.20	<0.20		
Potatoes		1	<6.0	18	0.50	<0.20	<0.30		
Runner beans		1	<5.0	12	0.40	<0.20	<0.20		
Wheat		1	<8.0	71	0.80	<0.30	<0.20		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<0.95	<0.23	<0.23	<0.060	0.21
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.28	<0.28	<0.075	0.34

* *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 4.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud	1	0.12
1 km south of Oldbury	Salt marsh and mud	1	0.092
2 km south west of Berkeley	Mud and rock	2	0.072
Guscar Rocks	Mud and salt marsh	2	0.084
Lydney Rocks	Mud	1	0.11
Lydney Rocks	Mud and salt marsh	1	0.096
Sharpness	Salt marsh and mud	2	0.081
Hills Flats	Salt marsh and mud	1	0.087
Hills Flats	Mud and rock	1	0.10

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{90}Sr	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+$ ^{240}Pu
Marine samples								
Sole	Bradwell	2			<0.14	0.17		
Bass	Pipeline	1			<0.04	0.79		
Thornback ray	Pipeline	1			<0.07	0.74		
Lobsters	West Mersea	1			<0.07	0.07		
Native oysters	Tollesbury N. Channel	1			<0.12	<0.10	0.00023	0.0014
Pacific oysters	Goldhanger Creek	2			<0.09	0.13		
Winkles	Pipeline	2			<0.14	<0.14		
Winkles	Heybridge Basin	2			<0.16	<0.22		
Seaweed	Bradwell	2[E]		6.8	<0.66	<0.73		
Leaf beet	Tollesbury	1			<0.08	<0.06		
Samphire	Tollesbury	1			<0.05	0.12		
Sediment	Pipeline	2[E]	<2.0			4.7		
Sediment	Waterside	2[E]	<2.5			12		
Sediment	West Mersea Beach Huts	2[E]	<1.5			<0.83		
Sediment	West Mersea Boatyard	2[E]	<1.5			9.8		
Sediment	Maldon	2[E]	<3.5			36		
Sediment	N side Blackwater Estuary	2[E]	<2.5			17		
Seawater	Bradwell	2[E]			<0.28	<0.27		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	$^{243}Cm+$ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Sole	Bradwell	2	<0.17				
Bass	Pipeline	1	<0.10				
Thornback ray	Pipeline	1	<0.06				
Lobsters	West Mersea	1	<0.07				
Native oysters	Tollesbury N. Channel	1	0.0029	*	0.000090		
Pacific oysters	Goldhanger Creek	2	<0.14				
Winkles	Pipeline	2	<0.10				
Winkles	Heybridge Basin	2	<0.19				
Seaweed	Bradwell	2[E]	<0.94				
Leaf beet	Tollesbury	1	<0.27				
Samphire	Tollesbury	1	<0.04				
Sediment	Pipeline	2[E]	<1.0				
Sediment	Waterside	2[E]	<1.8				
Sediment	West Mersea Beach Huts	2[E]	<0.80				
Sediment	West Mersea Boatyard	2[E]	<1.3				
Sediment	Maldon	2[E]	<1.8				
Sediment	N side Blackwater Estuary	2[E]	<1.7				
Seawater	Bradwell	2[E]	<0.37			<4.5	18

Table 4.3(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk			4	<4.8	15		<0.20		
Milk		max		<5.0	16		<0.23		
Apples			1	<5.0	18		<0.20		
Blackberries			1	<5.0	16		<0.20		
Cabbage			1	11	<3.0		<0.20		
Carrots			1	<5.0	12		<0.30		
Lucerne			1	<5.0	16		<0.20		
Potatoes			1	<5.0	22		<0.20		
Rabbit			1	<5.0	22		<0.30		
Wheat			1	<6.0	84		<0.20		
Freshwater	Public supply		2[E]	<4.0		<0.85	<0.25	<0.14	0.39
Freshwater	Coastal ditch 2		1[E]	<4.0		<1.0	<0.26	<1.1	5.9
Freshwater	Coastal ditch 3		1[E]	30		<1.0	<0.30	2.0	15
Freshwater	Coastal ditch 4		1[E]	33		1.7	<0.24	<0.90	24

* *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 4.3(b). Monitoring of radiation dose rates near Bradwell, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Sand and shingle	2	0.080
Beach opposite power station, N side of estuary	Mud	2	0.070
Waterside	Mud	2	0.067
Maldon	Mud	2	0.065
West Mersea Beach Huts	Mud and sand	1	0.051
West Mersea Beach Huts	Sand and shingle	1	0.071
West Mersea	Mud and shingle	1	0.054
West Mersea	Sand and shingle	1	0.055

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Pipeline	2		<25		<0.04			0.20
Bass	Pipeline	1		<25		<0.06			0.36
Sole	Pipeline	2	<25	<25		<0.09			<0.10
Crabs	Eastbourne / Folkestone landed	1				<0.04			<0.04
Shrimps	Pipeline	2	<25	<25	29	<0.12			<0.15
Scallops	Pipeline	2				<0.08	0.056		<0.07
Sea kale	Dungeness Beach	1				<0.07			0.29
Seaweed	Folkestone	2[E]				<0.80		3.4	<0.62
Sediment	Rye Harbour 1	2[E]				<0.98			<1.1
Sediment	Camber Sands	2[E]				<0.26			<0.23
Sediment	Pilot Sands	2[E]				<0.31			<0.23
Seawater	Dungeness South	2[E]		<4.5		<0.30			<0.25

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Cod	Pipeline	2			<0.07				
Bass	Pipeline	1			<0.26				
Sole	Pipeline	2			<0.32				
Crabs	Eastbourne / Folkestone landed	1			<0.10				
Shrimps	Pipeline	2			<0.10				
Scallops	Pipeline	2	0.00076	0.0030	0.0018	*	0.000049		
Sea kale	Dungeness Beach	1			<0.06				
Seaweed	Folkestone	2[E]			<0.90				
Sediment	Rye Harbour 1	2[E]	<0.40	0.57	<1.2				440
Sediment	Camber Sands	2[E]			<0.45				
Sediment	Pilot Sands	2[E]			<0.40				
Seawater	Dungeness South	2[E]			<0.36			<5.5	16

Table 4.4(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<5.4	16	<0.20	<0.18	<0.20		
Milk	max		<5.5						
Blackberries		1	<4.0	16	<0.20	<0.20	<0.20		
Cabbage		1	<4.0	<3.0	0.60	<0.20	<0.20		
Onions		1	<4.0	10	0.50	<0.20	<0.20		
Potatoes		1	<4.0	15	0.50	<0.30	<0.20		
Sea kale		1	<4.0	15	2.6	<0.10	0.50		
Wheat		1	<7.0	80	0.70	<0.20	<0.20		
Grass		1				<0.20	0.20		
Freshwater	Long Pits	2[E]	<4.0		<0.85	<0.30	<0.24	<0.075	0.16
Freshwater	Pumping station Well number 1	1[E]	<4.0		<1.0	<0.39	<0.31	<0.030	0.16
Freshwater	Pumping station Well number 2	1[E]	<4.0		<0.50	<0.30	<0.23	<0.030	0.18
Freshwater	Reservoir	2[E]	<4.0		<0.90	<0.29	<0.24	<0.065	0.17

* *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 4.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and pebbles	1	0.054
Littlestone-on-Sea	Shingle	1	0.069
Greatstone-on-Sea	Sand	2	0.062
Dungeness East	Sand	1	0.067
Dungeness East	Sand and pebbles	1	0.056
Dungeness South	Shingle	1	0.051
Dungeness South	Pebbles	1	0.059
Jury's Gap	Sand and pebbles	1	0.056
Jury's Gap	Shingle	1	0.053
Rye Bay	Sand and shingle	1	0.058
Rye Bay	Sand and pebbles	1	0.056

Table 4.5 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I
Marine samples								
Plaice	Pipeline	2	<25	<25	29	<0.04		*
Cod	Pipeline	2				<0.06		*
Crabs	Pipeline	2			58	<0.07		*
Winkles	South Gare	2	<25	<25		<0.06		*
Mussels	South Gare	2				<0.06		*
Mussels	Seal Sands	1			190			
Seaweed	Pilot Station	2[E]				<0.69	39	<22
Sediment	Old Town Basin	2[E]				<1.3		
Sediment	Seaton Carew	2[E]				<0.26		
Sediment	Paddy's Hole	2[E]				<0.39		
Sediment	North Gare	2[E]				<0.25		
Sediment	Greatham Creek	2[E]				<0.54		
Sea coal	Old Town Basin	2[E]				<0.42		
Sea coal	Carr House Sands	2[E]				<0.41		
Seawater	North Gare	2[E]		<4.0		<0.30		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{210}Pb	^{210}Po	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples							
Plaice	Pipeline	2	0.23				
Cod	Pipeline	2	0.34				
Crabs	Pipeline	2	<0.10			0.00028	0.0021
Winkles	South Gare	2	<0.12	0.97	14	0.0049	0.034
Mussels	South Gare	2	<0.08				
Seaweed	Pilot Station	2[E]	<0.54				
Sediment	Old Town Basin	2[E]	4.7				
Sediment	Seaton Carew	2[E]	<0.23				
Sediment	Paddy's Hole	2[E]	3.0				
Sediment	North Gare	2[E]	<0.23				
Sediment	Greatham Creek	2[E]	5.6				
Sea coal	Old Town Basin	2[E]	<0.73				
Sea coal	Carr House Sands	2[E]	<0.73				
Seawater	North Gare	2[E]	<0.25				

Table 4.5 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Plaice	Pipeline	2	<0.08				
Cod	Pipeline	2	<0.17				
Crabs	Pipeline	2	0.0023	*	*		
Winkles	South Gare	2	0.021	*	0.000041		
Mussels	South Gare	2	<0.13				
Seaweed	Pilot Station	2[E]	<0.73				
Sediment	Old Town Basin	2[E]	<1.2				
Sediment	Seaton Carew	2[E]	<0.45				
Sediment	Paddy's Hole	2[E]	<0.74				
Sediment	North Gare	2[E]	<0.43				
Sediment	Greatham Creek	2[E]	<0.84				
Sea coal	Old Town Basin	2[E]	<0.67				
Sea coal	Carr House Sands	2[E]	<0.66				
Seawater	North Gare	2[E]	<0.37			<3.5	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<5.1	16	<0.24	<0.18	<0.20		
Milk	max		<6.0	18	<0.28	<0.20			
Apples		1	<5.0	11	<0.20	<0.30	<0.20		
Barley		1	<6.0	96	1.0	<0.30	<0.30		
Beetroot		1	<5.0	9.0	<0.20	<0.20	<0.30		
Blackberries		1	<4.0	8.0	<0.20	<0.20	<0.20		
Cabbage		1	<4.0	5.0	<0.30	<0.30	<0.30		
Honey		1	<8.0	61	<0.20	<0.20	<0.20		
Potatoes		1	<5.0	12	0.30	<0.20	<0.20		
Runner beans		1	<4.0	6.0	<0.20	<0.20	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.3	<0.33	<0.30	<0.14	0.14
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<1.6	<0.29	<0.24	<0.14	0.20

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1}, and for sediment and sea coal 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 Hartlepool nuclear power station, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.074
Fish Sands	Sand and rock	1	0.080
Old Town Basin	Mud	1	0.079
Old Town Basin	Mud and sand	1	0.069
Carr House	Sand	2	0.069
Seaton Carew	Sand	1	0.065
Seaton Carew	Sand and pebbles	1	0.076
Seaton Sands	Sand	1	0.067
Seaton Sands	Sand and pebbles	1	0.072
North Gare	Sand	2	0.065
Paddy's Hole	Pebbles and shingle	1	0.17
Paddy's Hole	Stones	1	0.19
Greatham Creek Bird Hide	Mud	1	0.095
Greatham Creek Bird Hide	Salt marsh and mud	1	0.089

Table 4.6 (a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Marine samples									
Flounder	Flookburgh	4			87	<0.14			<1.6
Flounder	Morecambe	4	<25	<25		<0.14	0.068	0.98	<1.7
Whiting	Morecambe	4				<0.06			<0.65
Bass	Morecambe	2				<0.06			<0.70
Whitebait	Sunderland Point	1				<0.06	0.25		<0.62
Shrimps	Flookburgh	4			77	<0.08		1.2	<0.81
Shrimps	Morecambe	2				<0.06			<0.67
Cockles	Middleton Sands	2				0.41			<0.58
Cockles[b]	Flookburgh	4			82	0.36	0.29	2.3	<0.75
Winkles	Red Nab Point	4				0.25			<0.83
Mussels	Morecambe	4	<27	<28	65	<0.13		29	<0.64
Wild fowl	Morecambe	1				<0.08			<0.74
Samphire	Cockerham Marsh	1				<0.07			<0.69
Seaweed	Half Moon Bay	2[E]				<0.90		250	<5.8
Sediment	Half Moon Bay	2[E]				<0.38			
Sediment	Pott's Corner	2[E]				<0.40			
Sediment	Heysham pipelines	1[E]				<0.42			
Sediment	Morecambe Central Pier	2[E]				<0.31			
Sediment	Sunderland Point	4[E]				<0.53			<3.5
Sediment	Conder Green	4[E]				<0.52			<3.6
Sediment	Sand Gate Marsh	4[E]				<0.80			<5.4
Seawater	Heysham Harbour	2[E]		21		<0.34			

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{125}Sb	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples									
Flounder	Flookburgh	4	<0.41	<0.15	11	<0.35	0.00054	0.0031	
Flounder	Morecambe	4	<0.38	<0.16	7.3	<0.30			
Whiting	Morecambe	4	<0.18	<0.07	6.3	<0.19			
Bass	Morecambe	2	<0.18	<0.07	9.7	<0.18			
Whitebait	Sunderland Point	1	<0.17	<0.06	4.6	<0.18	0.039	0.24	2.2
Shrimps	Flookburgh	4	<0.21	<0.08	4.7	<0.21	0.0051	0.031	0.21
Shrimps	Morecambe	2	<0.18	<0.07	4.5	<0.15			
Cockles	Middleton Sands	2	0.20	<0.06	4.0	<0.15	0.40	2.4	
Cockles[b]	Flookburgh	4	<0.21	<0.08	3.7	<0.17	0.34	2.0	12
Winkles	Red Nab Point	4	<0.35	<0.09	3.9	<0.18	0.33	1.8	
Mussels	Morecambe	4	<0.20	<0.07	2.1	<0.13	0.19	1.1	
Wild fowl	Morecambe	1	<0.16	<0.08	0.64	<0.13			
Samphire	Cockerham Marsh	1	<0.14	<0.07	0.58	<0.09			
Seaweed	Half Moon Bay	2[E]	<2.4	<0.73	5.3				
Sediment	Half Moon Bay	2[E]			57		6.6	36	
Sediment	Pott's Corner	2[E]			23				
Sediment	Heysham pipelines	1[E]			21				
Sediment	Morecambe Central Pier	2[E]			9.4				
Sediment	Sunderland Point	4[E]	<1.6	<0.45	59	<1.1			
Sediment	Conder Green	4[E]	<1.6	<0.46	81	<1.2			
Sediment	Sand Gate Marsh	4[E]	<2.7	<0.69	65	<1.3			
Seawater	Half Moon Bay	1		*	0.11				
Seawater	Heysham Harbour	2[E]		<0.27	<0.30				

Table 4.6 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Flounder	Flookburgh	4	0.0074	*	*		
Flounder	Morecambe	4	<0.29				
Whiting	Morecambe	4	<0.22				
Bass	Morecambe	2	<0.17				
Whitebait	Sunderland Point	1	0.38	*	0.00051		
Shrimps	Flookburgh	4	0.055	*	0.000063		
Shrimps	Morecambe	2	<0.12				
Cockles	Middleton Sands	2	6.2	*	0.0040		
Cockles[b]	Flookburgh	4	5.9	*	0.0053		
Winkles	Red Nab Point	4	3.5	0.014	0.0030		
Mussels	Morecambe	4	2.1	*	0.0017		
Wild fowl	Morecambe	1	<0.07				
Samphire	Cockerham Marsh	1	0.31				78
Seaweed	Half Moon Bay	2[E]	<1.1				
Sediment	Half Moon Bay	2[E]	60				
Sediment	Pott's Corner	2[E]	12				
Sediment	Heysham pipelines	1[E]	21				
Sediment	Sunderland Point	4[E]	52			330	650
Sediment	Conder Green	4[E]	70			430	770
Sediment	Sand Gate Marsh	4[E]	49			170	500
Seawater	Heysham Harbour	2[E]	<0.38			<3.5	11

Material	Location or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		7	<5.0	16	<0.33	<0.19	<0.20		
Milk	max		<5.8	19	0.48	<0.20	<0.23		
Apples		1	<5.0	15	<0.20	<0.20	<0.20		
Blackberries		1	<4.0	20	<0.20	<0.10	<0.10		
Cabbage		1	5.0	5.0	<0.30	<0.10	<0.30		
Honey		1	<7.0	64	<0.20	<0.20	1.5		
Onions		1	<5.0	15	0.20	<0.10	<0.20		
Potatoes		1	<5.0	16	0.20	<0.20	<0.20		
Sprouts		1	<4.0	13	1.7	<0.10	<0.20		
Wheat		1	<7.0	73	1.2	<0.30	<0.30		
Freshwater	Lancaster	2[E]	<4.0		<1.3	<0.29	<0.25	<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 15 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 4.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass and mud	1	0.080
Greenodd Salt Marsh	Grass	1	0.079
Sand Gate Marsh	Grass and mud	3	0.084
Sand Gate Marsh	Grass	1	0.083
High Foulshaw	Grass and mud	1	0.073
High Foulshaw	Grass	3	0.080
Arnside 1	Mud	2	0.083
Arnside 1	Mud and sand	2	0.082
Arnside 2	Grass and salt marsh	1	0.096
Arnside 2	Grass	3	0.093
Morecambe Central Pier	Mud and sand	1	0.077
Morecambe Central Pier	Sand	1	0.072
Half Moon Bay	Mud	1	0.088
Half Moon Bay	Sand and stones	1	0.069
Heysham pipelines	Sand	1	0.082
Heysham pipelines	Sand and stones	1	0.082
Middleton Sands	Sand	2	0.078
Sunderland	Salt marsh	4	0.11
Sunderland Point	Mud	2	0.091
Sunderland Point	Mud and salt marsh	2	0.095
Colloway Marsh	Salt marsh	2	0.13
Colloway Marsh	Grass and salt marsh	2	0.14
Lancaster	Grass	4	0.083
Aldcliffe Marsh	Mud	1	0.14
Aldcliffe Marsh	Grass and mud	1	0.13
Aldcliffe Marsh	Salt marsh	1	0.10
Aldcliffe Marsh	Grass and salt marsh	1	0.10
Conder Green	Mud and salt marsh	1	0.090
Conder Green	Mud and grass	1	0.098
Conder Green	Grass and salt marsh	1	0.094
Conder Green	Salt marsh	1	0.092

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{134}Cs
Marine samples										
Cod	Stolford	1	130	120	29	<0.04	<0.04			<0.04
Bass	Stolford	1	54	72	41	<0.06	<0.06			<0.06
Shrimps	Stolford	2	86	98	46	<0.06	<0.05			<0.06
Limpets	Stolford	1		30	29	<0.04	<0.03			<0.04
Porphyra	Stolford	2				<0.10	<0.09			<0.11
Seaweed	Pipeline	2[E]					<0.90		10	<0.70
Carrots[d]	Stolford	1			8.8	<0.06	<0.06			<0.06
Leeks[d]	Stolford	1			16	<0.06	<0.06			<0.06
Soil[d]	Stolford	1			12	<0.60	<0.41			<0.64
Mud	Watchet Harbour	2[E]					<0.45	<1.5		
Sediment	Pipeline	2[E]					<0.42	<1.0		
Sediment	Stolford	2[E]					<0.46	<1.0		
Sediment	Steart Flats	2[E]					<0.89	<2.5		
Sediment	River Parrett	2[E]					<1.0	<3.0		
Sediment	Weston-Super-Mare	2[E]					<0.34	<1.0		
Sediment	Burnham-On-Sea	2[E]					<0.33	<4.0		
Sediment	Kilve	2[E]					<0.82	<1.0		
Sediment	Blue Anchor Bay	2[E]					<0.35	<4.7		
Seawater	Pipeline	2[E]					<0.40	<0.040		<0.33

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Cod	Stolford	1	0.69			<0.10				
Bass	Stolford	1	1.4			<0.06				
Shrimps	Stolford	2	0.31	0.000075	0.00068	0.00062	*	0.000011		
Limpets	Stolford	1	0.30			<0.10				
Porphyra	Stolford	2	1.1			<0.30				
Seaweed	Pipeline	2[E]	<0.77			<1.0				
Carrots[d]	Stolford	1	<0.05			<0.12				
Leeks[d]	Stolford	1	<0.05			<0.05				
Soil[d]	Stolford	1	5.2			<2.6				
Mud	Watchet Harbour	2[E]	7.0			<0.74				
Sediment	Pipeline	2[E]	9.9			<0.66				
Sediment	Stolford	2[E]	18			<0.75				
Sediment	Steart Flats	2[E]	21			<1.3				
Sediment	River Parrett	2[E]	33			<4.0				
Sediment	Weston-Super-Mare	2[E]	2.2			<0.57				
Sediment	Burnham-On-Sea	2[E]	2.6			<0.50				
Sediment	Kilve	2[E]	15			<1.2				
Sediment	Blue Anchor Bay	2[E]	1.7			<0.56				
Seawater	Pipeline	2[E]	<0.33			<0.42			<2.0	9.5

Table 4.7(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{134}Cs	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples										
Milk		6	<4.6	18	<0.30	<0.19	<0.19	<0.20		
Milk	max		<4.8	20	<0.38	<0.20	<0.20			
Apples		1	<5.0	21	<0.20	<0.30	<0.20	<0.20		
Blackberries		1	<4.0	18	0.50	<0.30	<0.20	<0.20		
Carrots		1	<5.0	12	<0.20	<0.20	<0.20	<0.20		
Honey		1	<7.0	69	<0.10	<0.20	<0.20	0.70		
Lettuce		1	<5.0	<3.0	<0.20	<0.20	<0.20	<0.20		
Potatoes		1	<5.0	18	0.50	<0.40	<0.30	<0.30		
Runner beans		1	<5.0	6.0	<0.20	<0.20	<0.20	<0.20		
Wheat		1	<7.0	75	1.1	<0.20	<0.20	<0.20		
Freshwater	Durleigh Reservoir	2[E]	<5.5		<0.80	<0.33	<0.26	<0.26	<0.12	0.73
Freshwater	Ashford Reservoir	2[E]	<4.0		<0.70	<0.39	<0.33	<0.33	<0.050	<0.10

* *Not detected by the method used*

[a] *Except for milk and water 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*

[d] *Used to determine sea to land transfer*

[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 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Mud and sand	1	0.065
Weston-Super-Mare	Sand	3	0.066
Burnham	Mud and sand	1	0.077
Burnham	Sand	3	0.061
River Parrett	Mud and rock	3	0.078
River Parrett	Mud and salt marsh	1	0.084
Steart Flats	Mud	4	0.078
Stolford	Mud and rock	4	0.092
Hinkley Point	Mud and rock	3	0.096
Hinkley Point	Sand	1	0.093
Kilve	Rock and mud	3	0.089
Kilve	Rock	1	0.083
Watchet Harbour	Mud	1	0.082
Watchet Harbour	Mud and sand	1	0.095
Watchet Harbour	Mud and rock	2	0.10
Blue Anchor Bay	Mud and sand	2	0.077
Blue Anchor Bay	Sand	1	0.059
Blue Anchor Bay	Pebbles and sand	1	0.066

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{238}Pu
Marine samples							
Cod	Sizewell	2	<25		<0.04	0.30	
Sole	Sizewell	1	<25		<0.06	0.22	
Skates / rays	Sizewell	1	<25		<0.04	0.41	
Crabs	Sizewell	2		19	<0.05	<0.11	0.00012
Lobsters	Sizewell	1			<0.04	0.15	0.00015
Native oysters	Blyth Estuary	1			<0.07	0.05	
Pacific oysters	Butley Creek	1			<0.07	<0.06	
Mussels	River Alde	2	<25		<0.12	<0.14	
Sediment	Rifle range	2[E]				<0.59	
Sediment	Aldeburgh	2[E]				<0.20	
Sediment	Southwold	2[E]				9.8	
Seawater	Sizewell	2[E]	<7.2		<0.26	<0.27	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Cod	Sizewell	2		<0.08				
Sole	Sizewell	1		<0.06				
Skates / rays	Sizewell	1		<0.10				
Crabs	Sizewell	2	0.00091	0.0014	*	0.000046		
Lobsters	Sizewell	1	0.00066	0.0014	*	*		
Native oysters	Blyth Estuary	1		<0.05				
Pacific oysters	Butley Creek	1		<0.13				
Mussels	River Alde	2		<0.15				
Sediment	Rifle range	2[E]		<0.73				
Sediment	Aldeburgh	2[E]		<0.37				
Sediment	Southwold	2[E]		<1.7				910
Seawater	Sizewell	2[E]		<0.37			<3.5	14

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk			6	<5.0	16	<0.40	<0.20		
Milk		max		<6.3	18	<0.78			
Apples			1	<4.0	19	<0.20	<0.20		
Blackberries			1	<5.0	14	0.20	<0.20		
Cabbage			1	<5.0	9.0	<0.30	<0.20		
Honey			1	<8.0	74	<0.20	0.10		
Onions			1	<4.0	9.0	0.20	<0.20		
Potatoes			1	<5.0	24	0.60	<0.30		
Runner beans			1	<5.0	7.0	<0.20	<0.10		
Wheat			1	<8.0	89	2.1	<0.20		
Freshwater	Nature Reserve		2[E]	<4.0		<0.80	<0.25	<0.080	0.30
Freshwater	The Meare		2[E]	<4.0		<0.90	<0.25	<0.035	0.29
Freshwater	Leisure Park		2[E]	<4.0		<0.70	<0.25	<0.050	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*

[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 4.8(b). Monitoring of radiation dose rates near Sizewell, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	1	0.049
Sizewell Beach	Pebbles and sand	1	0.055
Dunwich	Sand and shingle	1	0.056
Dunwich	Shingle	1	0.055
Rifle Range	Sand and shingle	1	0.055
Rifle Range	Pebbles and sand	1	0.053
Aldeburgh	Shingle	1	0.051
Aldeburgh	Pebbles and sand	1	0.052
Southwold Harbour	Mud	2	0.068

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{99}Tc
Marine samples								
Flounder	Inner Solway	4		56	<0.10	<0.15	<0.10	1.4
Shrimps	Inner Solway	2	<5.0		<0.10	<0.24	<0.10	1.1
Cockles	North Solway	2			1.2	<0.21		
Mussels	North Solway	4	<5.0	47	0.26	<0.15	0.35	100
Winkles	Southerness	4	<5.0		0.34	<0.29	0.23	58
Fucus vesiculosus	Pipeline	4			0.26	<0.20		120
Fucus vesiculosus	Browhouses	4			0.18	<0.18		
Sediment	Pipeline	4	<5.0		1.7	<0.39		
Sediment	Southerness	1			0.35	<0.26		
Seawater	Pipeline	4	2.3		<0.10	<0.13		
Seawater	Southerness	4	3.9		<0.10	<0.11		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Marine samples								
Flounder	Inner Solway	4	<0.48	<0.10	<0.17	<0.10	14	<0.10
Shrimps	Inner Solway	2	<0.81	<0.13	<0.24	<0.10	2.6	<0.13
Cockles	North Solway	2	<0.72	<0.11	<0.21	<0.10	9.8	<0.10
Mussels	North Solway	4	<0.49	<0.11	<0.21	<0.10	2.4	<0.11
Winkles	Southerness	4	<1.0	<0.15	<0.31	<0.11	1.6	<0.13
Fucus vesiculosus	Pipeline	4	<0.57	<0.11	<0.19	<0.10	9.0	<0.10
Fucus vesiculosus	Browhouses	4	<0.53	<0.10	<0.14	<0.10	10	<0.10
Sediment	Pipeline	4	<1.7	<0.17	1.9	<0.13	230	0.95
Sediment	Southerness	1	<0.67	<0.11	<0.19	<0.10	32	<0.16
Seawater	Pipeline	4	<0.38	<0.10	<0.12	<0.10	<0.11	<0.10
Seawater	Southerness	4	<0.34	<0.10	<0.11	<0.10	<0.11	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	$^{239}Pu+$ ^{240}Pu	^{241}Pu	^{241}Am	Gross Alpha	Gross Beta
Marine samples									
Flounder	Inner Solway	4	<0.17	0.0047	0.035		0.072		
Shrimps	Inner Solway	2	<0.23	0.0079	0.054		0.027		
Cockles	North Solway	2	<0.19	1.5	8.7		19		
Mussels	North Solway	4	<0.15	0.50	2.4	7.9	5.2		
Winkles	Southerness	4	<0.24	0.27	1.6	<2.5	3.0		
Fucus vesiculosus	Pipeline	4	<0.22	0.83	4.4		7.3	17	380
Fucus vesiculosus	Browhouses	4	<0.18				7.3	16	300
Sediment	Pipeline	4	<1.0	15	86		150		
Sediment	Southerness	1	0.68	5.4	32		54		
Seawater	Pipeline	4	<0.11				<0.10		
Seawater	Southerness	4	<0.11	0.00058	0.0031		0.0049		

Table 4.9(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial samples								
Milk		12	<6.3	<17	<0.54	<0.05	<0.10	<0.17
Milk	max		<12	32	<0.60			<0.36
Apples		2	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Barley		1	<5.0	78	<0.70	<0.06	0.41	<0.06
Blackberries		1	<5.0	18	<0.50	<0.08	0.28	<0.12
Cabbage		1	<5.0	<15	<0.50	<0.05	0.17	<0.05
Crab Apples		1	<5.0	21	<0.50	<0.05	0.13	<0.05
Honey		1	6.9	53		<0.05		<0.06
Maize		1	<5.0	48	<0.50	<0.05	<0.10	<0.05
Mallard		1	<5.0	29	<0.50	<0.05	<0.10	<0.06
Rabbit		1	<5.0	16	<0.50	<0.05	<0.10	<0.06
Rosehips		1	<5.0	<15	<0.50	<0.05	1.0	<0.05
Rowan berries		1	13	23	<0.50	<0.05	0.27	<0.05
Teal		1	<5.0	21	<0.50	<0.05	<0.10	<0.06
Turnips		1	<5.0	15	<0.50	<0.05	0.10	<0.08
Wheat		1	<5.0	57	<0.50	<0.06	1.1	<0.09
Widgeon		1	<5.0	25	<0.50	<0.05	<0.10	<0.06
Grass		4	<6.7	<17	<0.51	<0.06	<0.16	<0.41
Grass	max		12	20	<0.55	<0.07	0.20	<0.49
Soil		4	<7.6	<15	<1.1	<0.07	0.94	<0.15
Soil	max		15		<1.3	<0.11	1.1	<0.25
Freshwater	Reactor basement 1	1	140					
Freshwater	Reactor basement 2	1	21					
Freshwater	Reactor basement 3	1	40					

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{106}Ru	^{137}Cs	^{155}Eu	^{241}Am	Gross Alpha	Gross Beta
Terrestrial samples								
Milk		12	<0.35	<0.05		<0.06		
Milk	max		<0.38					
Apples		2	<0.22	<0.05		<0.07		
Apples	max		<0.25			<0.09		
Barley		1	<0.42	0.07		<0.15		
Blackberries		1	<0.74	<0.08		<0.14		
Cabbage		1	<0.24	<0.05		<0.06		
Crab Apples		1	<0.27	<0.05		<0.10		
Honey		1	<0.39	0.12		<0.15		
Maize		1	<0.27	<0.05		<0.08		
Mallard		1	<0.24	0.49		<0.08		
Rabbit		1	<0.36	22		<0.12		
Rosehips		1	<0.21	<0.05		<0.07		
Rowan berries		1	<0.15	<0.05		<0.05		
Teal		1	<0.39	0.10		<0.13		
Turnips		1	<0.29	<0.05		<0.09		
Wheat		1	<0.43	<0.05		<0.13		
Widgeon		1	<0.39	0.59		<0.14		
Grass		4	<0.54	<0.08		<0.10	0.72	280
Grass	max		<0.68	0.16		<0.14	1.2	350
Soil		4	<0.59	14	1.3	<0.60	190	1200
Soil	max		<0.99	15	1.7	1.6	210	1500
Freshwater	Reactor basement 1	1	<4.9		<1.2			
Freshwater	Reactor basement 2	1	<3.8	15				
Freshwater	Reactor basement 3	1		9.8				

[a] *Except for milk and water 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 4.9(b). Monitoring of radiation dose rates near Chapelcross, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.067
Glencaple Harbour	Mud and sand	4	0.079
Priestside Bank	Salt marsh	4	0.065
Powfoot Merse	Mud	4	0.070
Pipeline	Sand	4	0.084
Pipeline	Salt marsh	4	0.082
Battlehill	Sand	4	0.077
Dornoch Brow	Mud and sand	4	0.076
Dornoch Brow	Salt marsh	4	0.077
Browhouses	NA	4	0.077
Redkirk	NA	4	0.071
Mean beta dose rates			
Pipeline 500m east	NA	4	<3.3
Pipeline 500m west	NA	4	<3.3
Pipeline	Stake nets	3	<1.0

NA *Not available*

Table 4.9(c). Radioactivity in air near Chapelcross, 2008

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.010	<0.0062	0.15
Kirtlebridge	11	<0.011	<0.0057	0.10
Brydekirk	12	<0.011	<0.0054	0.11

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{125}Sb
Marine Samples								
Cod	Millport	2		<0.10	<0.10		<0.10	<0.13
Hake	Millport	1		<0.10	<0.10		<0.10	<0.17
Crabs	Millport	2		<0.10	<0.10	1.6	<0.11	<0.17
Nephrops	Millport	2		<0.10	<0.10		<0.10	<0.12
Lobsters	Largs	1		<0.10	<0.10	280	<0.10	<0.12
Squat lobsters	Largs	4		<0.12	<0.12	0.42	<0.12	<0.27
Winkles	Pipeline	2		<0.10	0.37		<0.44	<0.22
Scallops	Largs	4		<0.12	<0.12		<0.12	<0.24
Oysters	Hunterston	1		<0.10	<0.10		<0.10	<0.12
Fucus vesiculosus	N of pipeline	2		0.47	0.23		<0.10	<0.15
Fucus vesiculosus	S of pipeline	2		<0.51	0.40		<0.13	<0.21
Sediment	Millport	1		<0.10	<0.10		<0.10	<0.14
Sediment	Gull's Walk	1		<0.10	<0.10		<0.10	<0.10
Sediment	Ardneil Bay	1		<0.10	<0.10		<0.10	<0.13
Sediment	Fairlie	1		<0.10	<0.10		<0.10	<0.10
Seawater	Pipeline	2	3.8					

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine Samples								
Cod	Millport	2	1.4	<0.27	<0.14			<0.13
Hake	Millport	1	1.3	<0.36	<0.19			<0.20
Crabs	Millport	2	0.28	<0.34	<0.17	0.0021	0.0085	<0.12
Nephrops	Millport	2	1.0	<0.26	<0.13			<0.16
Lobsters	Largs	1	0.46	<0.26	<0.14			0.41
Squat lobsters	Largs	4	0.28	<0.58	<0.25	0.0024	0.020	0.023
Winkles	Pipeline	2	0.46	<0.46	<0.21	0.027	0.14	0.063
Scallops	Largs	4	0.41	<0.51	<0.23	0.0021	0.015	0.0078
Oysters	Hunterston	1	0.27	<0.26	<0.13			<0.14
Fucus vesiculosus	N of pipeline	2	0.55	<0.38	<0.13			<0.14
Fucus vesiculosus	S of pipeline	2	1.1	<0.48	<0.16			<0.14
Sediment	Millport	1	4.6	<0.42	<0.21			0.31
Sediment	Gull's Walk	1	5.6	<0.38	<0.20			0.64
Sediment	Ardneil Bay	1	2.5	<0.38	<0.19			<0.18
Sediment	Fairlie	1	6.2	<0.44	<0.21			0.50

Table 4.10(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples								
Milk		6	<5.1	<16	<0.52	<0.05	<0.10	<0.14
Milk	max		<5.3	<18	<0.53			<0.16
Beef mince		1	<5.0	27	<0.73	<0.05	<0.10	<0.05
Cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Carrots		1	<5.0	<15	<0.50	<0.05	0.17	<0.05
Cauliflower		1	<5.0	<15	0.53	<0.05	<0.10	<0.07
Crab apples		1		20	<0.50	<0.05	0.25	<0.05
Eggs		1	<5.0	22	<0.50	<0.05	<0.10	<0.05
Leeks		1	<5.0	<15	<0.50	<0.05	<0.10	<0.06
Nettles		1	<5.0	16	5.1	<0.05	1.3	<0.05
Pheasant		2	<5.0	25	<1.7	<0.05	<0.10	<0.07
Pheasant	max			26	2.5			<0.08
Pork muscle		1	<5.0	17	<0.50	<0.05	<0.10	<0.05
Potatoes		1	<5.0	18	<0.50	<0.05	<0.10	<0.05
Rosehips		1	<5.0	25	<0.50	<0.05	1.6	<0.07
Rowan berries		1	<5.0	21	<0.50	<0.05	<0.10	<0.05
Grass		3	<5.0	<16	1.3	<0.05	0.35	<0.13
Grass	max			16	2.0		0.42	<0.16
Soil		3	<5.0	<15	<0.55	<0.05	0.74	<0.05
Soil	max				<0.66		1.1	<0.06

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		6	<0.05	<0.06		<0.05		
Milk	max			0.11		<0.06		
Beef mince		1	<0.05	0.30		<0.08		
Cabbage		1	<0.05	<0.05		<0.07		
Carrots		1	<0.05	<0.05		<0.09		
Cauliflower		1	<0.05	<0.05		<0.13		
Crab apples		1	<0.05	0.05		<0.11		
Eggs		1	<0.05	<0.05		<0.05		
Leeks		1	<0.05	<0.05		<0.09		
Nettles		1	<0.05	0.06				
Pheasant		2	<0.06	0.67		<0.12		
Pheasant	max			0.93		<0.15		
Pork muscle		1	<0.05	0.11		<0.15		
Potatoes		1	<0.05	0.26		<0.11		
Rosehips		1	<0.05	<0.05		<0.12		
Rowan berries		1	<0.05	<0.05		<0.08		
Grass		3	<0.05	0.11		<0.11	0.75	250
Grass	max			0.18		<0.13	1.5	270
Soil		3	<0.06	15	0.50	<0.19	140	740
Soil	max			21	0.57	<0.20	150	1000

[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 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	Stones	2	0.062
Kilchatten Bay	Sand	2	<0.044
Millport	Sand	2	0.048
Gulls Walk	Mud	2	0.053
0.5 km north of pipeline	Sand	2	0.056
0.5 km south of pipeline	Sand and stones	2	0.066
Ardneil Bay	NA	2	0.044
Ardrossan Bay	NA	2	0.054
Beta dose rates			µSv h^{-1}
Millport	Sand	1	<1.0
Fairlie	Sand	1	<1.0

NA *Not available*

Table 4.10(c). Radioactivity in air near Hunterston, 2008

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	12	<0.011	<0.0066	0.14
West Kilbride	11	<0.010	<0.0069	0.12
Crosbie Mains	6	<0.012	<0.0065	0.089

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag
Marine Samples								
Cod	White Sands	1			<0.10	<0.10		<0.10
Cod	Pipeline	2			<0.10	<0.10		<0.11
Crabs	Cove	2		26	<0.10	<0.10	2.4	<0.10
Lobsters	Cove	1			<0.19	<0.14	1.5	<0.18
Nephrops	Dunbar	2			<0.10	<0.10		<0.10
Winkles	Pipeline	2			<0.21	<0.28		14
Fucus vesiculosus	Pipeline	2			<0.53	0.68		3.1
Fucus vesiculosus	Thornton Loch	2			0.57	0.23	75	0.74
Fucus vesiculosus	White Sands	2			<0.11	<0.10		<0.11
Fucus vesiculosus	Pease Bay	2			<0.11	<0.10		<0.11
Fucus vesiculosus	Coldingham Bay	2			<0.10	<0.10		<0.10
Sediment	Dunbar	1			<0.10	<0.10		<0.12
Sediment	Barns Ness	1			<0.10	<0.10		<0.11
Sediment	Thornton Loch	1			<0.10	<0.10		<0.10
Sediment	Heckies Hole	1			<0.10	<0.10		<0.15
Sediment	Eyemouth	1			<0.10	<0.10		<0.10
Salt marsh	Belhaven Bay	1			<0.10	<0.10		<0.10
Seawater	Pipeline	2	130		<0.10	<0.10		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine Samples									
Cod	White Sands	1	0.43	<0.15			<0.10		
Cod	Pipeline	2	0.46	<0.22			<0.14		
Crabs	Cove	2	<0.14	<0.17			<0.11		
Lobsters	Cove	1	<0.18	<0.45			<0.28		
Nephrops	Dunbar	2	0.22	<0.20	<0.0028	0.0099	0.013		
Winkles	Pipeline	2	<0.34	<0.33			<0.19	3.0	140
Fucus vesiculosus	Pipeline	2	0.17	<0.16			<0.17		
Fucus vesiculosus	Thornton Loch	2	0.15	<0.12			<0.10		
Fucus vesiculosus	White Sands	2	0.15	<0.17			<0.14		
Fucus vesiculosus	Pease Bay	2	<0.12	<0.13			<0.12		
Fucus vesiculosus	Coldingham Bay	2	<0.11	<0.11			<0.11		
Sediment	Dunbar	1	3.2	0.89			<0.26		
Sediment	Barns Ness	1	2.0	0.58			0.29		
Sediment	Thornton Loch	1	0.99	0.11			<0.17		
Sediment	Heckies Hole	1	8.9	1.4			0.74		
Sediment	Eyemouth	1	2.0	0.39			<0.23		
Salt marsh	Belhaven Bay	1	0.83	<0.22			<0.19		
Seawater	Pipeline	2	<0.10	<0.10			<0.10		

Table 4.11(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples								
Milk		1	<5.0	<18	<0.59	<0.05	<0.10	<0.13
Goats' milk		1	<5.0	<15	<0.50	<0.05	<0.10	<0.10
Apples		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Blackberries		1	<5.0	17	<0.50	<0.05	0.13	<0.08
Broad beans		1	<5.0	16	0.73	<0.05	<0.10	<0.05
Brussels sprouts		1	<5.0	16	<0.63	<0.05	0.11	<0.08
Cabbage		1	<5.0	<15	0.78	<0.05	<0.10	<0.05
Eggs		1	<5.0	23	<0.50	<0.05	<0.10	<0.05
Nettles		1	<5.0	<15	1.4	<0.05	3.2	<0.06
Onions		1	<5.0	<15	<0.50	<0.05	0.072	<0.05
Potatoes		1	<5.0	22	<0.50	<0.05	<0.10	<0.05
Rosehips		1	<5.0	23	<1.1	<0.05	<0.10	<0.05
Rowan berries		1	<5.0	23	<0.50	<0.05	0.13	<0.05
Wheat		1	<5.0	84	<0.50	<0.05	0.22	<0.05
Grass		3	<5.0	20	<0.79	<0.05	0.24	<0.20
Grass	max			23	0.94		0.28	<0.24
Soil		3	<5.0	<15	<0.83	<0.06	0.81	<0.32
Soil	max				<1.2		1.3	<0.36

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		1	<0.05	<0.05		<0.06		
Goats' milk		1	<0.04	<0.05		<0.06		
Apples		1	<0.05	<0.05		<0.06		
Blackberries		1	<0.05	<0.05		<0.05		
Broad beans		1	<0.05	<0.05		<0.06		
Brussels sprouts		1	<0.05	<0.05		<0.08		
Cabbage		1	<0.05	<0.05				
Eggs		1	<0.05	<0.05		<0.07		
Nettles		1	<0.05	0.06		<0.09		
Onions		1	<0.05	<0.05		<0.08		
Potatoes		1	<0.05	<0.05				
Rosehips		1	<0.05	<0.05		<0.05		
Rowan berries		1	<0.05	<0.05		<0.08		
Wheat		1	<0.05	<0.05		<0.06		
Grass		3	<0.05	<0.05		<0.09	0.65	330
Grass	max					<0.11	0.96	440
Soil		3	<0.09	6.3	1.3	<0.23	170	750
Soil	max			10	1.7	<0.27	180	860

[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 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Sediment	2	0.070
Dunbar Inner Harbour	Sand	2	0.088
Belhaven Bay	Salt marsh	2	<0.050
Barns Ness	Mud, sand and stones	2	0.057
Skateraw	Sand	2	0.052
Thornton Loch	Sand	2	0.071
Pease Bay	Sand	2	0.065
St Abbs Head	Mud	2	0.093
Coldingham Bay	Sand	2	<0.049
Eyemouth	Mud	2	0.062
Mean beta dose rates on fishing gear			µSv h^{-1}
Cove	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2008

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	11	<0.01	<0.0063	0.099
Cockburnspath	12	<0.01	<0.0063	0.12

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6			<0.09	1.5	<0.10	42	<0.30
Rainbow trout	Trawsfynydd Lake	6			<0.10		<0.11	1.5	<0.32
Perch	Trawsfynydd Lake	6			<0.19	0.57	<0.20	81	<0.59
Pike	Trawsfynydd Lake	1			<0.12		<0.15	89	<0.46
Sediment	Lake shore	2[E]			<0.81	<2.0	<0.78	250	
Sediment	Bailey Bridge	2[E]			<4.9		<5.5	110	
Sediment	Fish farm	2[E]			4.3	7.0	<2.0	1100	
Sediment	Footbridge	2[E]			<0.51	<2.0	<0.42	52	
Sediment	Cae Adda	2[E]			<1.5	7.0	<1.3	210	
Freshwater	Public supply	2[E]	<4.0	<1.2	<0.32		<0.28	<0.27	
Freshwater	Gwylan Stream	2[E]	<4.0	<0.75	<0.34		<0.29	<0.26	
Freshwater	Hot Lagoon	2[E]	<4.0	<1.4	<0.39		<0.31	<0.30	
Freshwater	Afon Prysor	2[E]	<4.0	<1.3	<0.40		<0.34	<0.35	
Freshwater	Trawsfynydd Lake	2[E]	<4.0	<1.3	<0.11		<0.10	<0.10	
Freshwater	Afon Tafarn-helyg	2[E]	<4.0	<1.4	<0.32		<0.28	<0.27	
Freshwater	Gellilydan	1[E]	<4.0	<1.0	<0.29		<0.30	<0.25	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6	0.00021	0.00086	0.0019	0.000012	0.000016		
Rainbow trout	Trawsfynydd Lake	6			<0.17				
Perch	Trawsfynydd Lake	6	0.00015	0.00059	0.0014	*	0.000029		
Pike	Trawsfynydd Lake	1			<0.59				
Sediment	Lake shore	2[E]	<0.55	<0.56	1.6				
Sediment	Bailey Bridge	2[E]	<0.90	3.2	5.4				
Sediment	Fish farm	2[E]	3.3	11	13				
Sediment	Footbridge	2[E]	<0.65	<0.70	1.4				
Sediment	Cae Adda	2[E]	<0.40	0.50	1.0				
Freshwater	Public supply	2[E]						<0.035	<0.10
Freshwater	Gwylan Stream	2[E]						<0.035	<0.10
Freshwater	Hot Lagoon	2[E]						<0.065	<0.15
Freshwater	Afon Prysor	2[E]						<0.065	<0.15
Freshwater	Trawsfynydd Lake	2[E]						<0.13	<0.19
Freshwater	Afon Tafarn-helyg	2[E]						<0.065	<0.13
Freshwater	Gellilydan	1[E]						<0.030	<0.10

Table 4.12(a). continued

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs
Terrestrial Samples							
Milk		2	<6.1	18	<0.21	0.044	
Milk	max		<6.3		<0.25	0.063	
Apples		1	<4.0	11	<0.20		0.20
Blackberries		1	<4.0	16	<0.20		0.40
Eggs		1	<5.0	31	<0.10		<0.20
Marrow		1	<5.0	<3.0	<0.20		<0.20
Potatoes		1	<5.0	19	<0.20		0.30
Sheep muscle		2	<6.0	22	<0.25	0.029	
Sheep muscle	max			24	<0.30	0.033	
Sheep offal		2	<7.5	25	<0.15	0.47	
Sheep offal	max		<8.0	29	<0.20	0.53	
Swede		1	<5.0	4.0	<0.30		<0.20

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples						
Milk		2	0.15			
Milk	max		0.17			
Apples		1		0.00010	<0.00020	0.00040
Blackberries		1		<0.00010	<0.00010	0.00030
Eggs		1		<0.00010	<0.00010	0.00030
Marrow		1				
Potatoes		1		<0.00010	0.00010	0.00020
Sheep muscle		2	0.91	<0.00025	<0.00035	0.00035
Sheep muscle	max		1.1	0.00040	<0.00060	0.00040
Sheep offal		2	0.78	<0.00015	<0.00030	0.00040
Sheep offal	max		0.87	<0.00020	0.00040	
Swede		1		0.00010	<0.00020	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] *The concentration of ^{14}C was 31 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 4.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Grass and mud	1	0.096
Footbridge	Pebbles	1	0.11
Lake shore	Pebbles and rock	1	0.091
Lake shore	Pebbles and concrete	1	0.088
Bailey Bridge	Grass and rock	1	0.062
Bailey Bridge	Rock	1	0.088
Fish Farm	Pebbles and shale	1	0.11
Fish Farm	Pebbles and stones	1	0.094
Cae Adda	Grass and pebbles	1	0.095
Cae Adda	Pebbles and rock	1	0.084

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{125}Sb	^{137}Cs	^{238}Pu
Marine samples									
Plaice	Pipeline	2	<25	<25	72		<0.21	1.5	
Bass	Outfall	1					<0.10	6.8	
Crabs	Pipeline	2				1.5	<0.12	0.59	0.0042
Lobsters	Pipeline	2				69	<0.16	0.85	
Winkles	Cemaes Bay	2	<25	<25	39		<0.15	0.40	0.025
Seaweed	Cemaes Bay	2[E]				120	<2.0	<0.66	
Sediment	Cemaes Bay	2[E]						5.6	
Sediment	Cemlyn Bay East	1[E]						2.4	
Sediment	Cemlyn Bay West	1[E]						4.5	
Seawater	Cemaes Bay	2[E]		<4.5				<0.26	
Seawater	Cemlyn Bay East	1[E]						<0.25	
Seawater	Cemlyn Bay West	1[E]						<0.26	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Plaice	Pipeline	2			<0.07				
Bass	Outfall	1			<0.04				
Crabs	Pipeline	2	0.022		0.074	*	0.000097		
Lobsters	Pipeline	2			<0.18				170
Winkles	Cemaes Bay	2	0.15	0.81	0.21	*	0.00032		
Seaweed	Cemaes Bay	2[E]			<0.83				
Sediment	Cemaes Bay	2[E]			1.5				
Sediment	Cemlyn Bay East	1[E]			<1.3				
Sediment	Cemlyn Bay West	1[E]			<1.4				
Seawater	Cemaes Bay	2[E]			<0.37			<3.0	8.8
Seawater	Cemlyn Bay East	1[E]			<0.37			<6.0	14
Seawater	Cemlyn Bay West	1[E]			<0.36			<5.0	18

Table 4.13(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		5	<4.9	20	<0.38	<0.21		
Milk	max		<5.3	21	<0.48	<0.23		
Milk[d]		1	<5.0	11				
Milk[d]		1	<4.0	13				
Milk[e]		1	<5.0	13				
Milk[e]		1	<4.0	13				
Apples		1	<4.0	7.0	<0.20	<0.20		
Barley		1	<7.0	84	2.0	<0.30		
Beetroot		1	<4.0	9.0	<0.20	<0.30		
Blackberries		1	<4.0	27	1.5	<0.20		
Broad beans		1	<5.0	25	1.2	<0.20		
Cabbage		1	<4.0	4.0	<0.30	<0.30		
Honey		1	<6.0	89	<0.30	0.20		
Potatoes		1	<5.0	15	0.20	<0.20		
Freshwater	Public supply	1[E]	<4.0		<1.0	<0.24	<0.030	0.16

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1}, 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] *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 14 April 2008*

[e] *Additional milk sampling week commencing 21 April 2008*

[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 4.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	1	0.074
Cemaes Bay	Rock and sand	1	0.062
Cemlyn Bay East	Pebbles and sand	1	0.071
Cemlyn Bay West	Pebbles	1	0.068

5. Defence establishments

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and SEPA 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 conducted by the MoD (DSTL, 2009).

5.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston provides and maintains fundamental components of the UK's nuclear deterrent on behalf of the MoD. The site is authorised by the Environment Agency to discharge low concentrations of radioactive waste to the environment. Aqueous radioactive waste is discharged to the sewage works at Silchester and to Aldermaston Stream, location shown in Figure 3.1, and gaseous radioactive waste is discharged via stacks on the site. In 2008, a minor variation to Aldermaston's authorisation was made, allowing the transfer of certain wastes contaminated with uranium to Springfields for further treatment.

Gaseous discharges and terrestrial monitoring

Gaseous discharges remained low (Table A2.1), though there were small increases in the levels of tritium, carbon-14 and krypton-85 discharged. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the site. Activity concentrations in milk and foodstuffs (Table 5.2(a)) were generally below the limits of detection, as in 2007. The tritium concentration in one grass sample shows an increase over 2007 levels, possibly a result of the small increase in gaseous tritium discharges, although it is in line with the concentrations observed in 2006. In soil samples, concentrations of caesium-137 decreased in 2008, and levels of uranium isotopes remained similar to 2007. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Key points

- Environmental concentrations and dose rates in 2008 were broadly similar to those in 2007 at all establishments
- Minor variations were made to existing authorisations at Barrow and Derby

Aldermaston, Berkshire

- Discharges, concentrations and dose rates in 2008 were generally similar to those in 2007
- A variation to the current authorisation was made, allowing transfer of certain wastes to Springfields
- Radiation doses from all sources were less than 0.5 per cent of the dose limit

Devonport, Devon

- An unauthorised release of reactor coolant water from HMS Trafalgar into the Tamar Estuary occurred in November 2008. Samples collected soon after the incident showed no increases in relevant radionuclides and confirmed there was no significant hazard to people or the environment
- Concentrations of radionuclides in the environment were generally below the limits of detection
- Radiation doses from all sources were less than 0.5 per cent of the dose limit

Rosyth

- A variation to the gaseous and liquid discharge authorisations came into force at Rosyth. Limits for the discharge of tritium and cobalt-60 to the marine environment were reduced

Liquid waste discharges and aquatic monitoring

Alpha, beta/gamma and tritium discharges to Silchester were reduced in 2008. Discharge of tritium to Aldermaston Stream returned to its previous level from the very low level reported in 2007. There are two factors behind the longer-term decline in discharges of tritium from Aldermaston (Figure 5.1). These are the closure and decommissioning of the original tritium facility, and historical contamination of groundwater. The original tritium facility will be finally demolished during 2009 and the replacement facility uses sophisticated abatement technology that results in the discharge of significantly less

tritium into the environment. The historical contamination has been reduced in 2008 by radioactive decay and diluted by natural processes.

Samples of freshwater, fish and sediments were collected; sampling locations are shown in Figure 3.1. The results of measurements of radionuclide concentrations and dose rates are shown in Tables 5.2(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2007. Concentrations of tritium in freshwater samples were below the LoD. As in 2007, no enhancements of tritium were observed in sediments collected from road gullypots close to the site. Caesium-137 concentrations were again detected in sediment from the River Thames, although at reduced concentrations compared to 2007. Currently, routine discharges from AWE do not include significant concentrations of radiocaesium and AWE no longer discharges into the River Thames since the closure of the Pangbourne pipeline in 2005. 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 slight increase in dose rates recorded on the riverbanks at Pangbourne and Mapledurham was observed, although there is no evidence to link this to the operations or discharges from Aldermaston. Gross alpha and beta activities in freshwater samples were below the WHO screening levels for drinking water, and this pathway of exposure has been shown to be insignificant (Environment Agency, 2002a).

Doses to the public

The most recent habits survey, in 2002 (Tipple *et al.*, 2003), established that the critical group affected by discharges into the river can be represented by anglers. Accordingly, their occupancy of the river-bank has been assessed in order to estimate their exposure to external radiation. Although no consumption of freshwater fish was recorded during the survey, the assessment has conservatively included consumption of fish at a low rate of 1 kg per year. No pike were sampled in 2008 and estimates of activity concentrations have been based on earlier data. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). 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 dose from consumption of local foodstuffs and milk, affected by gaseous discharges, was also calculated. Taking into account measured concentrations of plutonium and other radionuclides in terrestrial samples, the maximum dose from consumption of local food in 2008, including contributions from the natural and fallout sources, was to the 1-year-old age group (infants). This was less than 0.005 mSv. The dose from non-food pathways arising from discharges to air was also assessed using the methods and data given in Appendix 1. The critical group dose in 2008, including both food and non-food pathways, was less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv or 0.5 per cent of the dose limit. The most exposed group in this assessment was found to be adult riverbank occupants.

5.2 Barrow, Cumbria

In April 2008, a minor variation to the discharge authorisation held by the Barrow-in-Furness submarine facility was issued. This addressed the routing of liquid effluent through a new treatment plant, and clarified minor aerial discharge routes. During 2008, authorised discharges from Barrow were below the LoD. The Food Standards Agency's monitoring is limited to grass sampling, and in 2008 tritium activity in these samples was below the LoD (Table 5.3(a)). Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 2) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2008.

5.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Limited (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 concentrations of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including the LLWR near Drigg. In February 2008, the Environment Agency issued minor variations to the existing authorisations, one of which was to allow an alternative disposal route for one of the waste streams. The limits of the gaseous and liquid discharges were not affected by the variation.

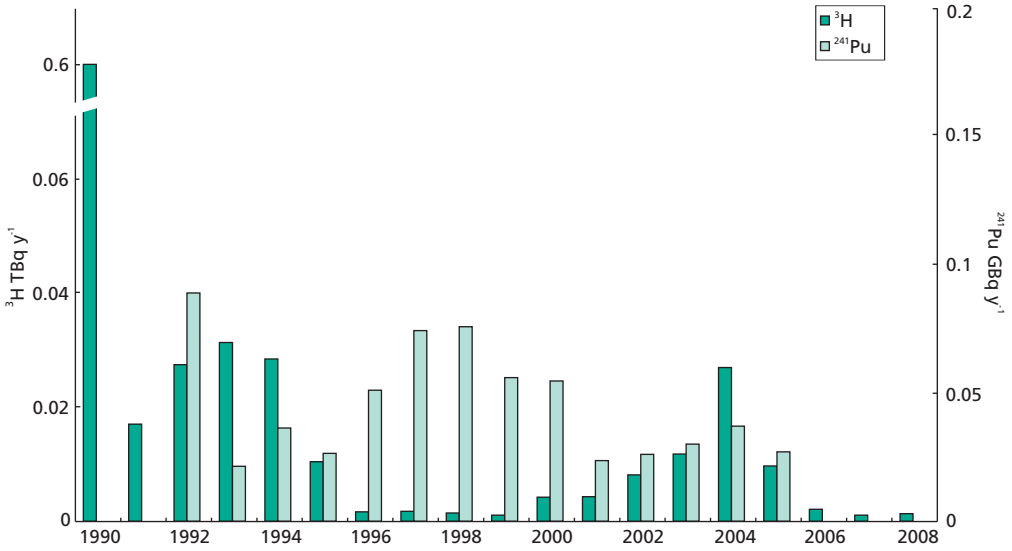
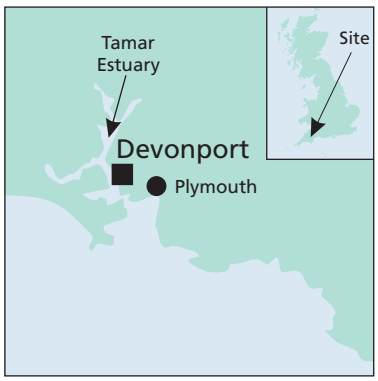


Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2008 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

Results of the routine monitoring programme at Derby are presented in Table 5.3(a). Analysis of uranium activity in grass and soil samples taken around the site in 2008 found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. Gross alpha and beta activities in water from the River Derwent were less than the WHO screening levels for drinking water, and the dose from using the river as a source of drinking water would be much less than 0.005 mSv per year (Table 5.1).

Table 5.3(a) also includes analysis results from a water sample taken from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for the controlled burial of solid low level radioactive waste. Uranium isotopes detected in the sample were at levels similar to those elsewhere in Derbyshire (Table 8.15).

5.4 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 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 radioactive waste to the Hamoaze, which is part of the Tamar Estuary, and to the local sewer, and gaseous waste to the atmosphere. The routine monitoring programme in 2008 consisted of measurements of gamma dose rate and analysis of fruit, vegetables, fish, shellfish and other marine indicator materials (Tables 5.3(a) and (b)).

In November 2008, an unauthorised release of liquid radioactive waste was made to the Tamar Estuary. This occurred after a hose transferring reactor coolant from HMS *Trafalgar* to a shoreside tank ruptured, releasing approximately 300 litres of liquid contaminated with tritium and cobalt-60. The MoD confirmed that the maximum amount of radioactivity discharged was 10 kBq of cobalt-60 and 0.7 GBq of tritium. For comparison, this was approximately 0.001 per cent and 0.1 per cent, respectively, of the annual limit on DRDL's discharges to the Tamar Estuary. Discharges from the Naval Base directly to the estuary are not authorised. There was a joint response to this incident by the Environment Agency and the Food Standards Agency. Non-routine samples taken by the Environment Agency in response to this incident found that levels of tritium and cobalt-60 in water and seaweed were below limits of detection. The Food Standards Agency also had additional samples of edible molluscs collected and analysed on top of their normal monitoring programme. The results, included in Table 5.3(a), showed tritium and cobalt-60 levels below limits of detection. The assessments from the results of both agencies' additional sampling showed that this unauthorised release posed no significant hazard to people or the environment.

Gaseous discharges and terrestrial monitoring

Low levels of particulate beta/gamma, tritium, carbon-14 and argon-41 were discharged to the atmosphere. Overall, the activity discharged was slightly lower than in 2007. Samples of fruit and vegetables were analysed for a number of radionuclides, and concentrations were below the limits of detection in all terrestrial foods.

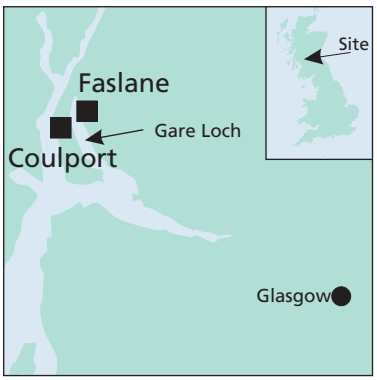
Liquid waste discharges and marine monitoring

The amount of tritium discharged to the Hamoaze decreased slightly, compared to 2007, but remained elevated above the longer term average. Cobalt-60 discharges remained typical of the low levels released since the mid-1990s. Figure 5.2 shows the discharge history of these nuclides since 1990. The main contributor to the increase in tritium discharges has been the refitting and refuelling work on Vanguard class submarines. These submarines have a higher tritium inventory in their primary circuit as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. The main reason underlying the decreases in cobalt-60 discharges was the improvement in submarine reactor design so that less cobalt-60 was produced during operation, and therefore less was released during submarine maintenance operations. Concentrations of these nuclides and others were below limits of detection for the vast majority of marine samples. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapons test fallout, were measured in fish samples. An enhanced concentration of carbon-14 was measured in a single crab sample, and the technetium-99 level in seaweed had increased compared to 2007. These isolated results are unlikely to be related to activities or discharges from Devonport. Gamma dose rates in the vicinity of Devonport were higher than in 2007, although as they are mainly based on only a single measurement it is difficult to say whether this constitutes a general increase.

Doses to the public

The most recent habits survey in 2004 (Tipple *et al.*, 2005) established that the two critical groups for marine pathways are fish and shellfish consumers and 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 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). Trends in doses in the area of the south coast (and the Severn Estuary) are shown in Figure 6.4. The dose from consumption of locally-grown fruit and vegetables, affected by gaseous discharges, was less than 0.005 mSv. The dose from non-food pathways arising from discharges to air was also assessed, using the methods and data given in Appendix 1. The dose to the critical group of prenatal children in 2008, including food and non-food pathways, was much less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv or 0.5 per cent of the dose limit. The radiological significance of this site continued to be low.

5.5 Faslane and Coulport, Argyll and Bute



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

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD. The

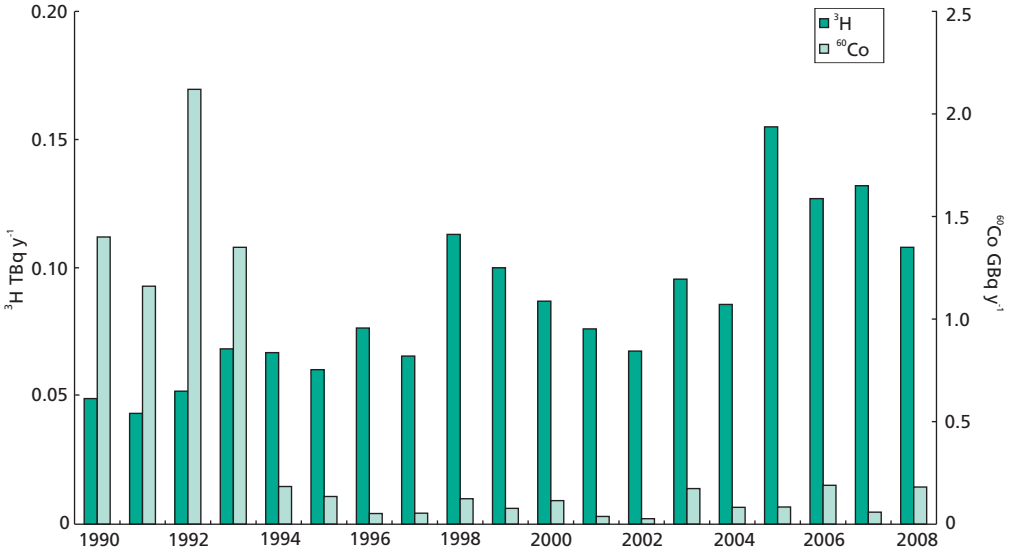


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2008

discharges released during 2008 are shown in Appendix 2. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the MoD. Disposals of solid waste from the sites continued during 2008.

The MoD began the refurbishment of the existing effluent treatment plant during 2008. The commissioning of the new plant is scheduled to take place during the summer of 2009. The discharges arising from the refurbished plant may be made under existing agreements.

During 2008, SEPA wrote to the Naval Base Commander, Clyde, regarding an incident which involved the discharge of a small volume of radioactively contaminated effluent. The discharge was not in accordance with the letter of agreement. The MoD has implemented a number of improvements with regard to radioactive waste management at Faslane as a result of this correspondence. SEPA considered there to be no discernable environmental impact as a result of the incident.

The routine monitoring programme consisted of the analysis of seawater, seaweed and sediment samples, and gamma dose rate measurements. Samples of fish and shellfish species were not available in 2008. Analysis results are given in Tables 5.3(a) and (b). These show that radionuclide concentrations were generally below the limits of detection, with caesium-137 concentrations in sediment and seaweed consistent with the distant effects of discharges from Sellafield, and with weapons testing and Chernobyl fallout. Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2006 (Sherlock *et al*., 2009). Taking into account the occupancy and consumption rate data from this survey, and using seafood concentrations based on earlier data, the dose to the critical group from external radiation and the consumption of fish and shellfish was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv or 0.5 per cent of the dose limit.

5.6 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 1992. Radionuclide concentrations were generally below detection limits (Table 5.3(a)). Where positively detected, concentrations can be attributed to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rate measurements from intertidal areas (Table 5.3(b)) showed similar levels with previous years. The external radiation dose to the critical group was less than 0.005 mSv in 2008, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

5.7 Rosyth, Fife

The site is operated by Babcock Marine, a division of Babcock International Group, who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006, and is expected to continue until 2013. To date, more than 99 per cent of the waste arising as a result of site decommissioning is being recycled.

Radioactive waste produced during decommissioning will be disposed of under the conditions of an authorisation granted to Rosyth Royal Dockyard Limited (RRDL) in November 2004. Operational wastes continue to be discharged under separate, continuing, authorisations for such wastes. RRDL has applied for authorisation to dispose of radioactive waste by transfer from RRDL to the processing facility in Sweden and an initial consignment was made in May 2009. Following volume reduction and the recovery of reusable metals, the radioactive waste will be returned to Rosyth for disposal by authorised routes.

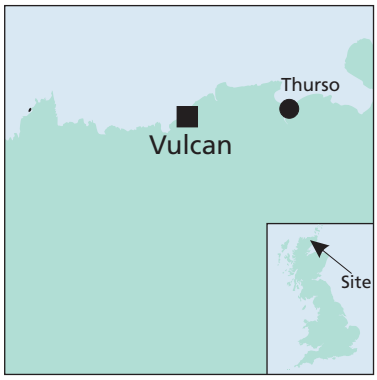
SEPA, and other stakeholders, are currently engaging with the MoD Nuclear Legacy Works Team at RRDL to identify the Best Practicable Environmental Option (BPEO) for managing radiologically contaminated Ion-exchange Resins held on the site.

In 2008, authorised gaseous discharges from Rosyth were below the LoD. Liquid wastes are discharged via pipeline to the Firth of Forth. Tritium releases during 2008 were typical of the low levels discharged since 2000, and cobalt-60 discharges continued to decline. In all cases the activity in the liquid discharged was below authorised limits.

SEPA's routine monitoring programme included analysis of crabs and whelks, as well as environmental indicator materials, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 5.3(a) and (b). The radioactivity levels detected were at similar low levels to 2007, 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. The most recent habits survey was undertaken in 2005 (Tipple *et al*., 2006b). In 2008, the doses

to the critical groups of local fishermen and beach users were assessed to be less than 0.005 mSv, which is less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv or 0.5 per cent of the dose limit.

5.8 Vulcan NRTE, Highland



The Vulcan Nuclear Reactor Test Establishment operated by the MoD (Procurement Executive) is located adjacent to the DSRL Dounreay site and the impact of its discharges is considered along with those from Dounreay in Section 3.

Table 5.1. Individual radiation exposures - defence sites, 2008

Site	Exposed population group[a]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment and water	Gaseous plume related pathways
Aldermaston	Anglers[b]	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally harvested crayfish[b]	<0.005	<0.005	-	-	-	-
	Consumers of locally grown food[e]	<0.005	-	<0.005	-	-	<0.005
	All sources[d]	<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	-	-
	Prenatal children of consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005
	All sources[d]	<0.005	-	-	-	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	All sources[d]	<0.005	-	-	-	-	-
Holy Loch	Anglers	<0.005	-	-	<0.005	-	-
Rosyth	Fishermen	<0.005	<0.005	-	-	-	-
	Beach users	<0.005	<0.005	-	<0.005	-	-
	All sources[d]	<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*
[d] *The* total dose *due to discharges and direct radiation. See Appendix 4*
[e] *Children aged 1y*

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Flounder	Beckton	1		<25	*	<0.13			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	*	<0.13	0.032	<0.00079	0.028
Sediment	Pangbourne	4[E]				7.8	12	<0.75	12
Sediment	Mapledurham	4[E]				8.6	13	<0.83	13
Sediment	Aldermaston	4[E]				<2.7	15	<1.3	13
Sediment	Spring Lane	4[E]				<1.0	8.5	<0.58	7.2
Sediment	Stream draining south	4[E]				<1.7	9.8	<0.83	10
Sediment	Reading (Kennet)	4[E]				<3.7	13	<1.1	12
Gullypot sediment	Falcon Gate	1[E]		<25		<2.0	14	<1.0	13
Gullypot sediment	Main Gate	1[E]		<25		<1.2	13	<1.0	14
Gullypot sediment	Tadley Entrance	1[E]		<25		7.1	15	<1.0	12
Gullypot sediment	Burghfield Gate	1[E]		<25		<1.6	17	<2.0	16
Freshwater	Pangbourne	4[E]		<4.5		<0.36	<0.014	<0.0050	<0.011
Freshwater	Mapledurham	4[E]		<4.3		<0.29	<0.012	<0.0045	<0.0088
Freshwater	Aldermaston	4[E]		<6.6		<0.33	0.011	<0.0045	<0.0078
Freshwater	Spring Lane	4[E]		<4.4		<0.25	<0.0060	<0.0058	<0.0060
Freshwater	Reading (Kennet)	4[E]		<4.5		<0.28	<0.012	<0.0090	<0.011
Crude liquid effluent	Silchester treatment works	4[E]		<25		<0.28	<0.0073	<0.0053	<0.0070
Final Liquid effluent	Silchester treatment works	4[E]		<25		<0.28	<0.012	<0.0042	<0.0085
Sewage sludge	Silchester treatment works	4[E]		<29		<0.48	0.34	<0.057	0.30

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Flounder	Beckton	1			<0.28				
Signal crayfish	Ufton Bridge - Theale	1	0.00014	0.00051	0.0011	*	*		
Sediment	Pangbourne	4[E]	<0.68	<1.0	2.0			220	270
Sediment	Mapledurham	4[E]	<0.55	<0.55	<1.6			170	310
Sediment	Aldermaston	4[E]	<0.58	1.3	<0.97			230	420
Sediment	Spring Lane	4[E]	<0.57	<0.48	<1.0			150	330
Sediment	Stream draining south	4[E]	<0.60	<0.79	<1.4			270	400
Sediment	Reading (Kennet)	4[E]	<0.68	<0.73	<1.6			160	420
Gullypot sediment	Falcon Gate	1[E]	<0.60	<0.50	<1.8			290	710
Gullypot sediment	Main Gate	1[E]	<0.40	<0.50	<1.4			290	750
Gullypot sediment	Tadley Entrance	1[E]	<0.50	0.43	<1.7			220	560
Gullypot sediment	Burghfield Gate	1[E]	<0.40	0.32	<1.6			180	640
Freshwater	Pangbourne	4[E]	<0.011	<0.0060	<0.0010			<0.058	0.24
Freshwater	Mapledurham	4[E]	<0.011	<0.0065	<0.012			<0.063	0.25
Freshwater	Aldermaston	4[E]	<0.013	<0.0067	<0.012			<0.035	0.18
Freshwater	Spring Lane	4[E]	<0.015	<0.0060	<0.0090			<0.052	0.16
Freshwater	Reading (Kennet)	4[E]	<0.011	<0.0065	<0.014			<0.047	0.14
Crude liquid effluent	Silchester treatment works	4[E]	<0.010	<0.011	<0.38			<0.15	0.60
Final Liquid effluent	Silchester treatment works	4[E]	<0.014	<0.012	<0.38			<0.055	0.59
Sewage sludge	Silchester treatment works	4[E]	<0.025	<0.025	<0.59			<2.5	<11

Table 5.2(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk			4	<5.2	<0.20	<0.0012	<0.00063	<0.0012
Milk		max		<6.3		<0.0015	<0.00070	<0.0014
Beetroot			1	<4.0	<0.20	0.0022	<0.00070	0.0016
Blackberries			1	<4.0	<0.20	0.0016	<0.00060	0.0021
Cabbage			1	<5.0	0.10	0.013	<0.00070	0.011
Honey			1	<7.0	<0.20	0.0087	<0.00080	0.0068
Potatoes			1	<5.0	<0.20	0.0094	0.00040	0.0063
Rabbit			1	<5.0	<0.20	0.0014	<0.0010	0.0021
Rhubarb			1	<5.0	<0.20	0.0042	0.00050	<0.0013
Wheat			1	<7.0	<0.30	<0.00080	<0.00050	<0.00070
Grass	Kestrel Meads		1[E]	83	<1.1	<0.40	<0.10	<0.20
Grass	Industrial Estate		1[E]	46	<1.3	<0.60	<0.20	<0.40
Grass	Location 3		1[E]	<25	<4.0	<0.40	<0.30	<0.30
Grass	Tadley		1[E]	<25	<3.9	0.67	<0.40	<0.80
Soil			1[#]			4.4	0.35	4.7
Soil	Kestrel Meads		1[E]	<25	2.9	15	<2.0	15
Soil	Industrial Estate		1[E]	<25	2.5	13	<0.60	10
Soil	Location 3		1[E]	<25	22	16	<0.70	18
Soil	Tadley		1[E]	<25	4.2	15	<0.80	15

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples								
Milk			4	<0.00010	<0.00010	<0.00014		
Milk		max				<0.00015		
Beetroot			1	<0.00010	<0.00020	<0.00040		
Blackberries			1	<0.00010	<0.00010	<0.00020		
Cabbage			1	0.00010	0.00040	<0.00050		
Honey			1	0.00010	<0.00020	<0.00020		
Potatoes			1	<0.00010	0.00020	0.00060		
Rabbit			1	<0.00010	<0.00020	<0.00020		
Rhubarb			1	0.00010	<0.00020	0.00020		
Wheat			1	<0.00010	0.00020	<0.00070		
Grass	Kestrel Meads		1[E]	<0.090	<0.050		<1.0	150
Grass	Industrial Estate		1[E]	<0.70	<0.30		<3.0	140
Grass	Location 3		1[E]	<0.10	<0.20		1.8	160
Grass	Tadley		1[E]	<0.20	0.34		12	250
Soil	Kestrel Meads		1[E]	<0.40	<0.50		240	640
Soil	Industrial Estate		1[E]	<0.70	<0.50		280	290
Soil	Location 3		1[E]	0.90	1.5		220	380
Soil	Tadley		1[E]	<1.1	1.3		270	450

* *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 marked with a # which are fresh 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 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2008

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	4	0.071
Mapledurham, riverbank	Mud and pebbles	1	0.066
Mapledurham, riverbank	Grass and mud	2	0.071

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2008

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{106}Ru	^{110m}Ag	^{125}Sb
Barrow												
Grass	Barrow	2[F]		<5.5								
	max			<6.0								
Derby												
Sediment	River Derwent, downstream	2						<0.95				
Sediment	River Derwent, upstream	1						<1.7				
Sediment	Station Road Bridge	2						<0.34				
Sediment	Fritchley Brook	1						<0.40				
Water	River Derwent, downstream	2						<0.30				
Water	River Derwent, upstream	1						<0.29				
Water	Station Road Bridge	2						<0.38				
Water[c]	Fritchley Brook	1		<4.0				<0.40				
Devonport												
Ballan wrasse	Plymouth Sound	2[F]				<0.15	<0.29	<0.15	<0.39	<1.5	<0.27	<0.32
Crabs	Plymouth Sound	2[F]			45	<0.06	<0.13	<0.05	<0.15	<0.56	<0.11	<0.13
Pacific oysters	Torpoint (South)	1[F]				<0.05	<0.10	<0.04	<0.13	<0.43	<0.08	<0.09
Cockles	Southdown	2[F]	<25	<25		<0.09	<0.10	<0.10	<0.21	<0.91	<0.16	<0.21
Pacific oysters	Southdown	1[F]	<25	<25		<0.07	<0.07	<0.08	<0.17	<0.76	<0.12	<0.19
Mussels	River Lynher	2[F]	<25	<25		<0.10	<0.17	<0.10	<0.25	<1.1	<0.17	<0.24
Slipper limpets	River Lynher	1[F]			23	<0.11	<0.16	<0.11	<0.27	<1.2	<0.19	<0.26
Seaweed[d]	Kinterbury	2						<1.2				
Sediment[e]	Kinterbury	1		<25				<1.3				
Sediment	Torpoint (South)	2		<25	<25			<1.4				
Sediment	Lopwell	2		<25	<25			<1.6				
Seawater	Torpoint (South)	2		<4.7	<4.5			<0.29				
Seawater	Millbrook Lake	2		<4.0	<4.5			<0.31				
Beetroot		1[F]		<5.0				<0.30		<1.8	<0.20	
Blackberries		1[F]		<5.0				<0.20		<1.2	<0.20	
Lettuce		1[F]		<5.0				<0.20		<1.2	<0.20	
Rhubarb		1[F]		<5.0				<0.20		<2.4	<0.30	
Faslane												
Fucus vesiculosus	Rhu	1				<0.10	<0.33	<0.11	<0.34	<0.95	<0.14	<0.24
Sediment	Carnban boatyard	1				<0.10	<0.13	<0.10	<0.25	<0.68	<0.11	<0.20
Seawater	Carnban boatyard	2		<1.4		<0.10	<0.10	<0.10	<0.11	<0.31	<0.10	<0.10
Holy Loch												
Sediment	Mid Loch	1				<0.10	<0.10	<0.10	<0.18	<0.44	<0.10	0.36
Rosyth												
Crabs	East of dockyard	1				<0.10	<0.12	<0.10	<0.22	<0.70	<0.10	<0.20
Whelks	East of dockyard	1				<0.10	<0.15	<0.10	<0.25	<0.83	<0.10	<0.23
Fucus vesiculosus	East of dockyard	1				<0.10	<0.10	<0.10	<0.11	<0.28	<0.10	<0.10
Sediment	East of dockyard	1				<0.10	<0.17	<0.10	<0.33	<0.83	<0.13	<0.23
Sediment	Port Edgar	1				<0.10	<0.29	<0.10	<0.38	<0.90	<0.15	<0.22
Sediment	West of dockyard	1				<0.10	<0.14	<0.10	<0.27	<0.70	<0.11	<0.20
Sediment	East Ness Pier	1				<0.10	<0.10	<0.10	<0.19	<0.52	<0.10	<0.16
Sediment	Blackness Castle	1				<0.10	<0.11	<0.10	<0.17	<0.44	<0.10	<0.13
Sediment	Charlestown Pier	1				<0.10	<0.12	<0.10	<0.24	<0.59	<0.10	<0.17
Seawater	East of dockyard	2		<1.4		<0.10	<0.10	<0.10	<0.10	<0.26	<0.10	<0.10

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Derby												
Sediment	River Derwent, downstream	2			<0.78		27	1.3	27		440	1000
Sediment	River Derwent, upstream	1					23	<2.0	22		330	600
Sediment	Station Road Bridge	2			1.2		15	<0.95	14		180	530
Sediment	Fritchley Brook	1			1.2		16	<2.0	14		410	600
Grass		4[F]					0.030	<0.0016	0.029			
Grass	max						0.065	0.0036	0.057			
Soil		4[F]					23	0.92	22			
Soil	max						28	1.0	27			
Water	River Derwent, downstream	2									<0.13	0.23
Water	River Derwent, upstream	1									<0.060	0.24
Water	Station Road Bridge	2									<0.065	0.21
Water[c]	Fritchley Brook	1			<0.35		0.025	<0.0050	0.016		<0.040	0.22
Devonport												
Ballan wrasse	Plymouth Sound	2[F]	*	<0.14	0.17	<0.20				<0.10		
Crabs	Plymouth Sound	2[F]	*	<0.06	<0.05	<0.10				<0.05		
Pacific oysters	Torpoint (South)	1[F]	*	<0.04	<0.04	<0.07				<0.04		
Cockles	Southdown	2[F]	<0.11	<0.10	<0.09	<0.14				<0.08		
Pacific oysters	Southdown	1[F]	<0.15	<0.08	<0.08	<0.19				<0.17		
Mussels	River Lynher	2[F]	*	<0.10	<0.09	<0.20				<0.15		
Slipper limpets	River Lynher	1[F]	*	<0.12	<0.10	<0.17				<0.08		
Seaweed[d]	Kinterbury	2										
Sediment[e]	Kinterbury	1								<1.1		
Beetroot		1[F]		<0.20	<0.30							
Blackberries		1[F]		<0.20	<0.20							
Lettuce		1[F]		<0.20	<0.20							
Rhubarb		1[F]		<0.30	<0.30							
Faslane												
Fucus vesiculosus	Rhu	1		<0.10	0.73	<0.23				<0.12		
Sediment	Carnban boatyard	1		<0.10	7.6	0.75				<0.30		
Seawater	Carnban boatyard	2		<0.10	<0.10	<0.10				<0.10		
Holy Loch												
Sediment	Mid Loch	1		<0.10	6.6	0.58				0.61		
Rosyth												
Crabs	East of dockyard	1		<0.10	<0.10	<0.18				<0.11		
Whelks	East of dockyard	1		<0.10	<0.10	<0.24				<0.15		
Fucus vesiculosus	East of dockyard	1		<0.10	0.12	<0.10				<0.10		
Sediment	East of dockyard	1		<0.11	4.4	0.28				<0.37		
Sediment	Port Edgar	1		<0.11	16	1.4				<0.35		
Sediment	West of dockyard	1		<0.10	1.8	0.44				<0.32		
Sediment	East Ness Pier	1		<0.10	6.8	<0.23				<0.21		
Sediment	Blackness Castle	1		<0.10	2.1	<0.18				0.31		
Sediment	Charlestown Pier	1		<0.10	0.86	<0.20				<0.23		
Seawater	East of dockyard	2		<0.10	<0.10	<0.10				<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 concentrations of ^{228}Th, ^{230}Th and ^{232}Th were 0.0080, 0.035 and <0.0050 Bq l^{-1}*

[d] *The concentration of ^{99}Tc was 4.9 Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.50 and <0.70 Bq kg^{-1}*

[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 5.3(b). Monitoring of radiation dose rates near defence establishments, 2008

Establishment	Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Devonport	Torpoint South	Mud and stones	1	0.10
Devonport	Torpoint South	Mud and rock	1	0.11
Devonport	Kinterbury Access Gate	Mud and stones	1	0.11
Devonport	Kinterbury Access Gate	Rock and stones	1	0.089
Devonport	Lopwell	Mud	2	0.093
Faslane	Gareloch Head	Mud, sand and stones	2	0.054
Faslane	Gulley Bridge Pier	Sand and stones	2	0.060
Faslane	Rhu	Gravel	2	<0.050
Faslane	Helensburgh	Sand	2	0.054
Faslane	Carnban boatyard	Gravel	2	<0.054
Holy Loch	North Sandbank	Mud and sand	1	0.063
Holy Loch	Kilmun Pier	Sand and stones	1	0.059
Holy Loch	Mid-Loch	Sand	1	0.047
Rosyth	Blackness Castle	Mud and sand	2	<0.060
Rosyth	Charlestown Pier	Sand	2	<0.049
Rosyth	East Ness Pier	Sand	2	<0.050
Rosyth	East of Dockyard	Sand	2	0.060
Rosyth	Port Edgar	Mud	2	0.064
Rosyth	West of Dockyard	Mud and rock	2	<0.055

6. Radiochemical production

GE Healthcare is a health science company operating in world-wide commercial healthcare and life science markets, with facilities at Amersham, Cardiff and Harwell. The environmental effects of the Harwell facilities are covered by general monitoring of the Harwell site (Section 3).

Gaseous and liquid discharges from each of the sites (Appendix 2) are authorised by the Environment Agency. Independent monitoring of the environment around each of the sites is conducted by the Food Standards Agency and the Environment Agency.

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- Discharges, concentrations and dose rates were similar to those in 2007
- A variation to the discharge authorisation came into effect, representing an overall reduction in discharge limits
- Radiation doses from discharges were less than 2 per cent of the dose limit, and the *total dose* from all sources, including direct radiation, was approximately 22 per cent of the dose limit

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- GE Healthcare announced its intention to cease production of radiochemicals at the Maynard Centre from 2010 and decommission and delicense the bulk of the site
- There were significant reductions in the discharge of liquid effluent leading to a continued reduction in dose from fish and shellfish consumption
- Monitoring of tritium concentrations in sludge pellets was undertaken, enabling an assessment of dose due to the transfer from conditioned soil to crops to be made
- Radiation doses from all sources were approximately 1 per cent of the dose limit

6.1 Grove Centre, Amersham, Buckinghamshire

The company's principal establishment is located in Amersham, Buckinghamshire. It consists of a wide range of plants for manufacturing radio-pharmaceutical products, using short half-life radionuclides such as fluorine-18 and technetium-99m, for use in medicine and research. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 3.1. A consumption and occupancy habits survey in the vicinity of the site was undertaken in 2004 (McTaggart *et al*., 2005).

Gaseous discharges and terrestrial monitoring

The Amersham facility discharges gaseous radioactive wastes via stacks on the site. Minor variations to the existing authorisation were made in 2008, in order that the authorisation better reflected the operations on site. This led to a reduction in the number of reporting categories. Separate limits for gaseous releases of selenium-75 and iodine-131 were removed. Discharges to the atmosphere in 2008 were very similar to those made in 2007, with radon-222 releases decreasing slightly. The activity concentrations in terrestrial samples were generally below limits of detection (Table 6.2). However, sulphur-35 was detected in some crop and grass samples, at similar concentrations to 2007, and caesium-137 was again detected in soil 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.

Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive wastes are made to sewers serving the Maple Lodge sewage works; releases subsequently enter the Grand Union Canal and the River Colne. The results of the aquatic monitoring programme are presented in Table 6.2. Activity concentrations in fish, freshwater, effluent and sludge from Maple Lodge Sewage Works were below the limits of detection. Gross alpha and beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates (see footnote, Table 6.2) above the banks of the canal were indistinguishable from background.

Doses to the public

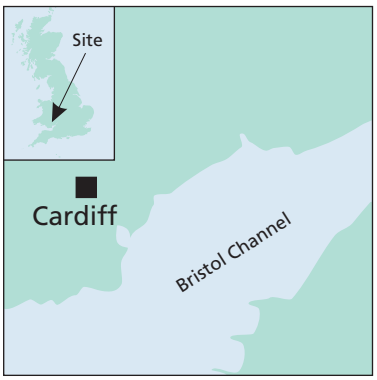
In 2008, the most exposed age group for the local terrestrial food consumption pathway was 1-year-old infants, with an estimated dose of less than 0.005 mSv. The largest contribution was from selenium-75 in milk, although as in 2007, this was assessed using concentrations at the limit of detection. The contribution from non-food pathways was also calculated, using the methods and data given in Appendix 1, in order to assess members of the public's combined exposure to plume-related pathways and locally grown foodstuffs. The dose to the most exposed age group, which was again 1-year-old infants, was 0.019 mSv, or less than 2 per cent of the dose limit to members of the public of 1 mSv (Table 6.1). The majority of this exposure can be attributed to the presence of radon-222 in the plume, and it should be noted that the current assessment methodology uses a conservative dose factor based on this nuclide being in equilibrium with its daughter products.

Exposure to aquatic pathways downstream of the release point for discharges of liquid effluents has also been considered. The most recent habits survey did not directly identify any consumers of fish, shellfish or freshwater plants. However, there was suggested evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg per year for fish has been included in the dose assessment. In 2008, no local pike sample was available, and so estimates of activity concentrations have been used from earlier data. The dose in 2008 from fish consumption and external radiation was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit of 1 mSv (Table 6.1).

The Amersham site discharges liquid waste to Maple Lodge sewage treatment works, and the prolonged proximity to raw sewage and sludge experienced by sewage treatment workers is a common exposure pathway (National Dose Assessment Working Group, 2004). In 2008, the dose received by workers was modelled using the methods described in Appendix 1. The dose from a combination of external irradiation from the raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides was less than 0.005 mSv.

The *total dose* from all sources, including direct radiation, was assessed using methods in Appendix 4 to have been 0.22 mSv or 22 per cent of the dose limit. This dose was primarily due to direct radiation.

6.2 Maynard Centre, Cardiff



GE Healthcare operate a second establishment at Forest Farm near Whitchurch, Cardiff. A proportion of the products manufactured by the company at this site incorporate the radioactive substances carbon-14 and tritium. These products are used in life science research and medical drug development. The company also uses small quantities of some short half-life radionuclides, such as sulphur-35, phosphorus-32 and iodine-125, for quality assurance analysis of non-radioactive products.

In December 2008, GE Healthcare announced its intention to cease the manufacture of radiochemicals; this is to occur in early 2010. The company will then progressively decommission and (with the permission of the HSE) delicense the major part of the site over the following two years, leaving a small licensed area for the storage of historic radioactive wastes. Discharges are expected to start to reduce from late 2009 as a result.

During 2008, the Environment Agency conducted tritium analyses on various effluents and by-products from the Cardiff East Waste Water Treatment Works (WWTW), which takes liquid waste from the Maynard Centre. The results of these analyses are included in Table 6.3(a). Sludge pellets produced from sewage effluent are sold commercially to farmers for application to soil as a fertiliser. The constraints of the Sludge (Use in Agriculture) Regulations (commonly referred to as the Safe Sludge Matrix) require that crops cannot be harvested within 10 months of the application of sludge pellets. A recent Food Standards Agency research project (Ham *et al*., 2007) investigated the transfer of tritium from treated soil to crops, under the Safe Sludge Matrix conditions, and concluded that the transfer of tritium to each of the crops considered was small. An assessment of exposure from eating crops grown on land fertilised with sludge pellets has been undertaken. Earlier monitoring and research has targeted organically bound tritium (OBT) in foodstuffs (Food Standards Agency, 2001b; Swift, 2001; Williams *et al*., 2001; Leonard *et al*., 2001 and McCubbin *et al*., 2001). A past review was undertaken of monitoring data for tritium bioaccumulation (Rowe *et al*., 2001).

A routine monitoring programme is conducted on behalf of the Welsh Assembly Government. This includes consideration of consumption of locally produced food, fish and shellfish, and external exposure over muddy, intertidal areas (Figure 6.1). Measurements of external exposure are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, seaweed, soil and grass provide additional

information. A local habits survey was completed in 2003 (McTaggart *et al*., 2004) and the assessment of exposures given below takes the results of this survey into account.

Gaseous discharges and terrestrial monitoring

The gaseous discharge from the Maynard Centre predominantly consists of tritium and carbon-14, with smaller levels of phosphorus-32/33 and iodine-125 also released. In 2008, the discharge of all nuclides was reduced, compared to 2007 levels. Enhanced tritium activities were again detected in a number of terrestrial samples (Table 6.3(a)), although a reduction from 2007 levels was observed in many of the foodstuffs previously found to have particularly high concentrations. Carbon-14 activities were also enhanced in some foodstuffs, and sulphur-35 was detected at concentrations similar to those found in the general diet survey (see Section 8). All these measurements were of low radiological significance. Phosphorus-32 and iodine-125 were below the limits of detection in terrestrial samples.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged into the Ystradyfodwg and Pontypridd public sewer (YP). This joins the Cardiff East sewer, which after passing through a 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 via surface water drains.

The Maynard Centre's liquid discharges are primarily tritium and carbon-14. In 2008 the discharge of these nuclides to the sewer was reduced by around 50 per cent from 2007 levels. Over the longer term, the discharge rate of both nuclides has decreased substantially (Figures 6.2 and 6.3). Smaller amounts of phosphorus-32/33 and iodine-125 are also released via this route.

The results of routine monitoring in 2008 are presented in Tables 6.3(a) and (b). The main effects of liquid discharges are reflected in enhanced tritium concentrations, and carbon-14 activities above background levels, in fish and shellfish samples.

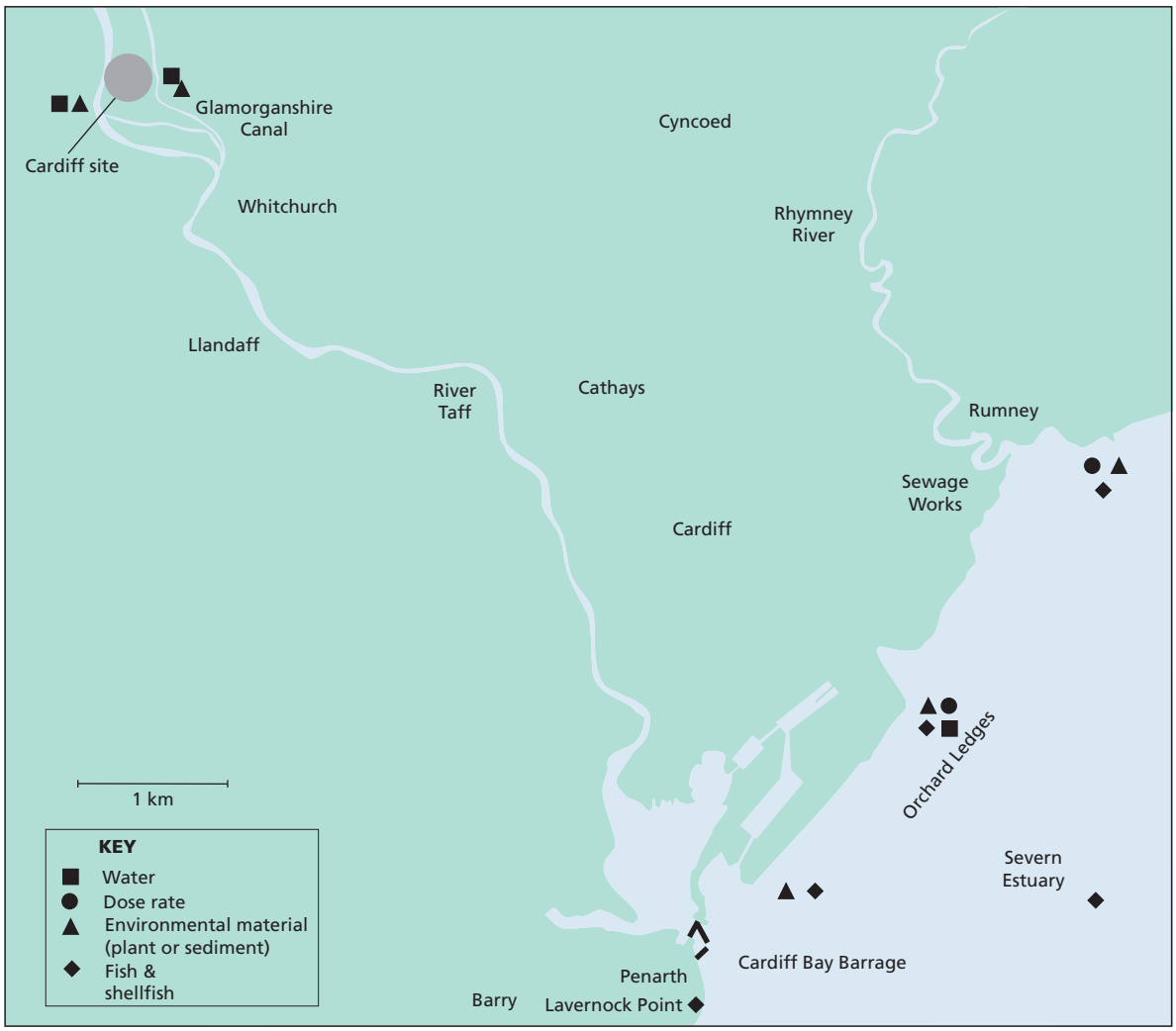


Figure 6.1. Monitoring locations at Cardiff, 2008 (not including farms)

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 food chain from small organisms to accumulate in fish. Tritium concentrations in fish samples displayed significant inter- and intra-species variability, particularly when compared to 2007 samples. The overall mean concentration was virtually unchanged (Figure 6.2), suggesting that the recent downward trend may have bottomed out despite a continued decrease in discharges. However, the individual fish observations summarised in Table 6.3(a) indicate large variations, presumably due to natural variability. For example, the tritium concentrations in the lesser spotted dogfish in 2008 ranged from 190 Bq kg^{-1} to 2600 Bq kg^{-1}, far lower and higher, respectively, than in 2007 samples, and almost seven times the range observed a year ago. The result is a doubling of the mean concentration in this species in 2008. Levels of tritium in flounder and skates/rays were more stable, and showed a downward inclination. Given the uncertainty associated with the uptake and retention mechanisms of organically bound tritium, and the small number of samples collected and analysed annually, it is difficult to confirm the causes for this apparent variability in the response to decreasing inputs of tritium from the Cardiff facility.

The concentration of tritium in molluscs showed an overall decrease (Figure 6.2). The organic fraction was only determined for one of the two mussel samples, which, given the threefold variation between concentrations in the two samples, has led to the mean organic fraction exceeding the total tritium concentration by 50 per cent (Table 6.3(a)). Tritium was also detected in marine sediment and seawater samples.

The trend in concentrations of carbon-14 in seafood and the relationship to discharges is shown in Figure 6.3. The mean concentration in both fish and molluscs showed a decrease consistent with, although not proportional to, the reduction in discharges of carbon-14 in 2008. At a species level the trend in fish is less defined, with decreases in cod and Dover sole being almost balanced by increased enhancements in other fish species.

Concentrations of other radionuclides in marine samples were low and can largely be explained by other sources such as Chernobyl, weapon test fallout and discharges from other establishments such as the Hinkley Point, Berkeley and Oldbury nuclear sites. Gamma dose rates over sediment were slightly higher than 2007 levels, although this is unlikely to have resulted from Maynard Centre activities or discharges.

Tritium and carbon-14 analyses of various samples from Cardiff East WWTW were undertaken in 2008. This additional monitoring was conducted by the Environment Agency in order to enable assessment of a potential exposure pathway, namely the transfer of tritium in sludge pellets used as fertiliser to crops

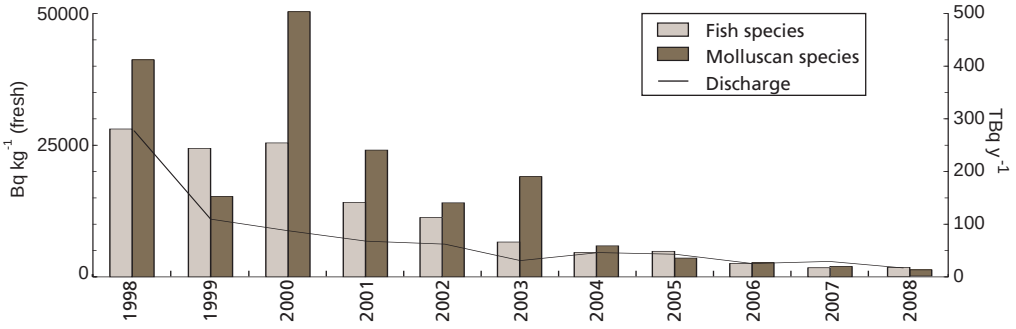


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2008 (species include all those reported in RIFE for the given year)

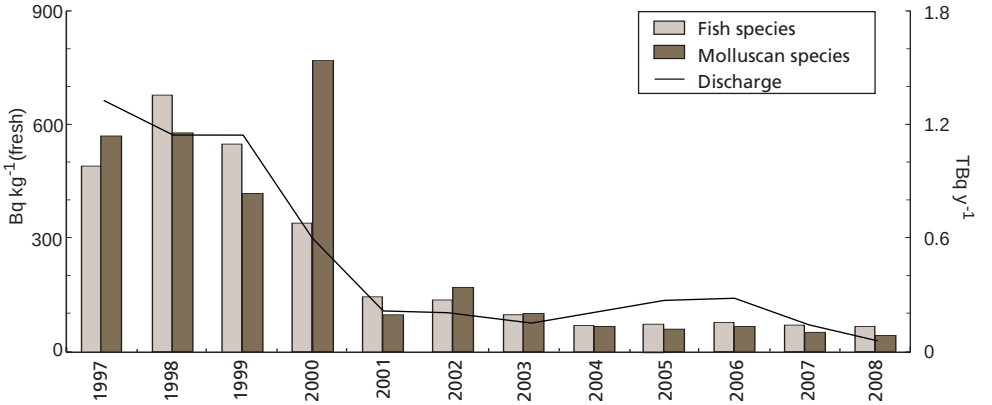


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1997-2008 (species include all those reported in RIFE for the given year)

grown in treated soil. The results (Table 6.3(a)) show enhanced concentrations of tritium and carbon-14 in sludge pellets and solids from crude effluent matter. Concentrations of tritium in liquid effluents were considerably lower.

Low levels of tritium continue to be detected in sediment from the Glamorganshire Canal; however, this is not used as a source of water for the public water supply. In 2008, tritium was also detected in water run-off from the site into the River Taff and in Glamorganshire Canal water. Concentrations in sediment from the River Taff were below the limit of detection. Both freshwater and sediment can be affected by episodic events and there are difficulties in obtaining representative samples. In each of the sample categories above, the effects were localised and were not observed further afield in the Bristol Channel (Section 8), or indeed in seafood.

Doses to the public

The maximum estimated dose from local terrestrial food consumption was to the 1-year-old age group (infants), and the dose to this group was 0.009 mSv. The largest contribution was from phosphorus-32 in milk (below the limit of detection). With the inclusion of non-food pathways, using the methods and data given in Appendix 1, the critical group dose in 2008 was 0.010 mSv, or 1 per cent of the dose limit for members of the public of 1 mSv (Table 6.1). The increase in dose, from 0.008 mSv in 2007, is due to a small increase in concentrations of carbon-14 and sulphur-35 (at the limit of detection) in milk.

In 2008, the dose from the transfer of tritium in sludge pellets to crops grown in treated soil was also assessed, using the method described in Appendix 1. Prenatal children were found to be the most exposed age group. The maximum estimated dose due to tritium transferred from sludge pellets to fruit and vegetable crops was estimated to be much less than 0.005 mSv, which is much less than 0.5 per cent of the dose limit of 1 mSv.

The dose coefficients for OBT differ from those for tritiated water (see Appendix 1) and the estimates of dose to members of the public account for this. For ingestion of seafood caught near Cardiff, an area taken to be equivalent to the Bristol Channel, a dose coefficient based on a site-specific study of the consumption of fish caught in Cardiff Bay is used. A recent experimental study by Hunt *et al.* (2009) suggests that this raised dose coefficient is conservative, but it is retained for 2008 dose assessments on the advice of the HPA. For ingestion of other food, the ICRP dose coefficient is applied for OBT.

Using an increased dose coefficient for tritium specifically derived for the OBT discharged from this site, the dose to the critical group of prenatal children of fish and shellfish consumers in 2008 was 0.012 mSv, down from 0.014 mSv in 2007. This was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 6.1). The dose to the associated adult age group in 2008 was 0.010 mSv. These dose estimates include a significant component due to external (non-Maynard Centre derived) radiation, which decreased from 0.007 mSv in 2007 to 0.006 mSv in 2008 (Table 6.1) due to a slightly decreased mean dose rate east of the pipeline. The dose from tritium and carbon-14 in fish and shellfish also decreased in 2008, compared with 2007, reflecting slightly lower overall concentrations. The prenatal age group was introduced in 2005 following the recommendations of the HPA. For anglers on the banks of the River Taff, the dose from inadvertently ingesting sediment and river water, and occupancy of the river-bank, 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, but, as in 2007, the largest contribution was estimated from the inadvertent ingestion of iodine-131 in river water. This concentration of this nuclide, which is not discharged from the Maynard Centre, was below the limit of detection.

Exposures from aquatic pathways to groups representative of the area surrounding the Severn Estuary have been kept under review (Figure 6.4). 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 6.2 and 6.3). As in recent years, the impact from Cardiff on doses for Hinkley Point and Berkeley/Oldbury was very low.

The GE Healthcare site at Cardiff discharges liquid waste to local sewers and the prolonged proximity to raw sewage and sludge experienced by sewage treatment workers is a common exposure pathway (National Dose Assessment Working Group, 2004). In 2008, the dose received by workers was modelled using the methods described in Appendix 1. The dose from a combination of external irradiation from the raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides was much less than 0.005 mSv.

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.007 mSv, or less than 1 per cent of the dose limit. The most exposed group were the prenatal children of adults who spend time over intertidal sediments. The largest contributor to this exposure is the low levels of external radiation emitted from radionuclides in the sediment, which are due to natural radioactivity or radioactive sources other than the Maynard Centre.

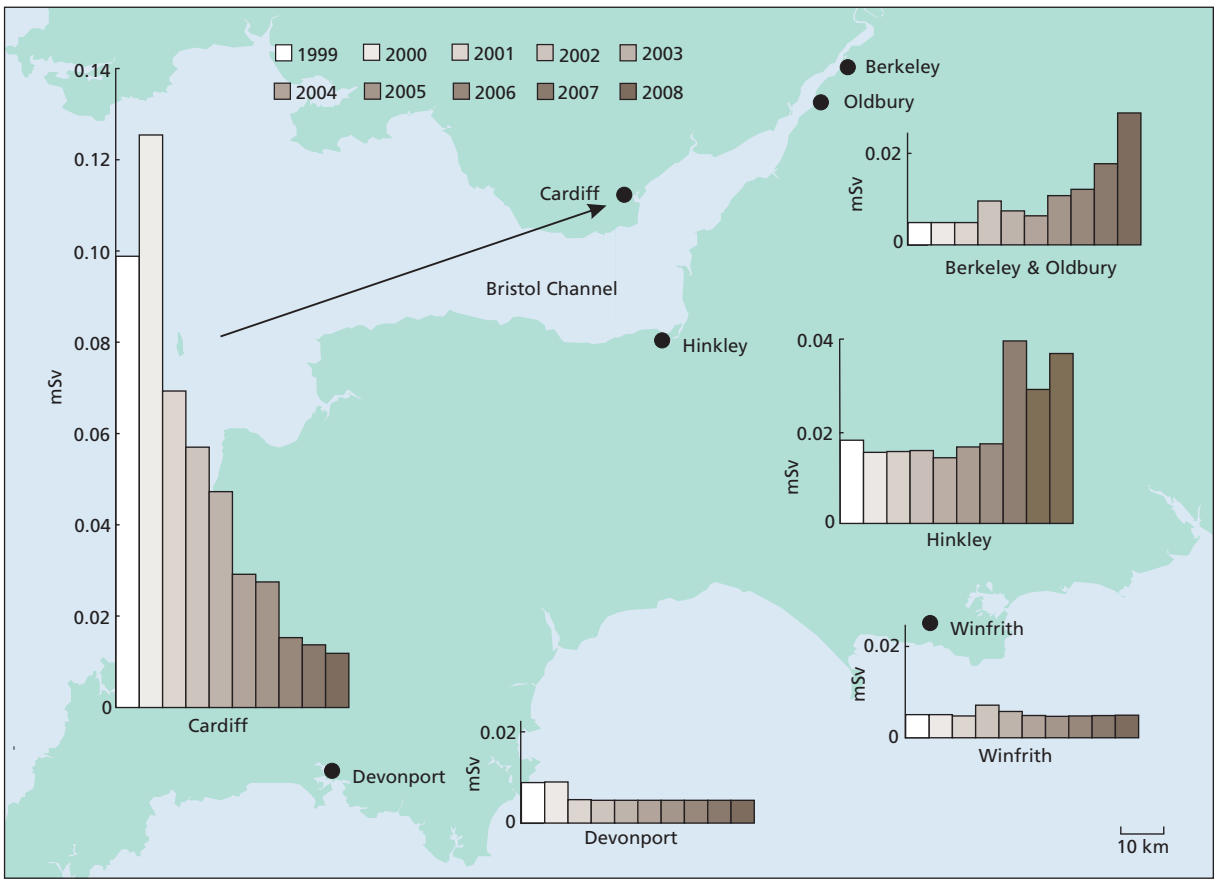


Figure 6.4. Individual radiation exposures from marine pathways for artificial radionuclides in the Severn Estuary and the south coast, 1999-2008 (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Table 6.1. Individual radiation exposures - radiochemical sites, 2008

Site	Exposed population group[a]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment and water	Gaseous plume related pathways
Amersham	Anglers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food[b]	0.019	-	<0.005	-	-	0.015
	Workers at Maple Lodge STW	<0.005	-	-	<0.005[d]	<0.005[e]	-
	All sources[c]	0.22	-	-	-	-	-
Cardiff	Prenatal children of seafood consumers	0.012	0.006	-	0.006	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Consumers of locally grown food[b]	0.010	-	0.009	-	-	<0.005
	Workers at Cardiff East WWTW	<0.005	-	-	<0.005[d]	<0.005[e]	-
	Prenatal children of consumers of crops grown in soil treated with sludge pellets	<0.005	-	<0.005	-	-	-
	All sources[c,f]	0.007	-	-	-	-	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *The* total dose *due to discharges and direct radiation. See Appendix 4*
[d] *External radiation from raw sewage and sludge*
[e] *Intakes of resuspended raw sewage and sludge*
[f] *Prenatal children*

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2008[g]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}										
			^{3}H	^{32}P	^{35}S	^{57}Co	^{65}Zn	^{125}I	^{131}I	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Freshwater samples													
Flounder	Beckton	1	<25			<0.09	<0.32		*	<0.13	<0.28		
Sediment	Outfall (Grand Union Canal)	2[E]				<3.0	<4.0	<1.5	<2.8	4.5		190	460
Sediment	Upstream of outfall (Grand Union Canal)	2[E]				<3.2	<3.5	<1.5	<2.8	7.5		<170	390
Freshwater	Maple Cross	2[E]	<4.0			<0.56	<0.62	<0.26	<0.51	<0.26		<0.060	0.38
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<4.0			<0.82	<0.83	<0.27	<0.65	<0.34		<0.070	0.19
Freshwater	River Chess	1[E]	<4.0			<1.2	<0.70	<0.38	<4.9	<0.25		<0.050	<0.20
Freshwater	River Misbourne - upstream	1[E]	<4.0			<0.14	<0.58	<0.29	<0.39	<0.25		<0.050	<0.10
Freshwater	River Misbourne - downstream	1[E]	<4.0			<1.2	<0.68	<0.39	<4.7	<0.24		<0.070	<0.10
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<25	<2.4	<0.97	<0.73	<0.88	<1.3		<0.32	<0.41	<0.14	0.64
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<51	<3.0	<1.0	<0.70	<0.84	<1.6		<0.32	<0.39	<0.65	5.6
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<25	<2.7	<0.92	<0.60	<0.72	<1.3		<0.30	<0.37	<0.11	0.75

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{3}H	^{35}S	^{57}Co	^{65}Zn	^{75}Se	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples												
Milk		2	<6.1	<0.34			<0.23	<0.023	<0.0044	<0.20		
Milk	max		<6.8	<0.35			<0.25	<0.024	<0.0045			
Apples		1	<4.0	<0.20			<0.20	<0.051		<0.20		
Beetroot		1	<4.0	<0.20			<0.30	<0.066		<0.30		
Blackberries		1	<4.0	<0.20			<0.20	<0.065		<0.20		
Carrots		1	<4.0	<0.20			<0.30	<0.056		<0.30		
Chard		1	<5.0	0.50			<0.20	<0.067		<0.20		
Runner beans		1	<5.0	<0.20			<0.20	<0.055		<0.20		
Spinach		1	<5.0	0.40			<0.20	<0.032		<0.20		
Wheat		1	<8.0	1.6			<0.20	<0.027		<0.20		
Grass	Next to site	1[E]		4.8	<6.7	<5.2		<1.2	<2.4	<1.9	<1.0	160
Grass	Orchard next to site	1[E]		9.4	<3.9	<3.0		<0.98	<1.5	<1.1	4.1	180
Grass	Water Meadows (River Chess)	1[E]		9.1	<3.1	<2.0		<1.2	<1.1	<0.75	<1.0	150
Soil	Next to site	1[E]			<1.9	<1.1		<0.53	<0.84	9.0	350	340
Soil	Orchard next to site	1[E]			<2.1	<1.3		<0.60	<0.93	12	490	770
Soil	Water Meadows (River Chess)	1[E]			<1.7	<1.0		<0.47	<0.80	8.4	310	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 <8.0 Bq l^{-1}*

[e] *The concentration of ^{3}H as tritiated water was <33 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <5.0 Bq l^{-1}*

[g] *The gamma dose rates in air at 1m over grass and grass and mud on the bank of the Grand Union Canal were 0.060 and 0.057 µGy h^{-1} respectively*

[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 6.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{125}I	^{131}I	^{134}Cs	^{137}Cs
Marine samples										
Cod	East of new pipeline	1		310		29		*	<0.04	0.55
Flounder	East of new pipeline	4	1300	1400		71		*	<0.07	0.41
Sole	East of new pipeline	2		3800		120		*	<0.06	0.27
Mullet	East of new pipeline	1		<25		38		*	<0.08	0.57
Lesser spotted dogfish	Off Orchard Ledges	2	1300	1400		57		*	<0.13	0.49
Skates/Rays	Off Orchard Ledges	2	1600	1700		91		*	<0.12	0.99
Mussels	Orchard Ledges	2	1800	1200		47		<1.6	<0.16	0.37
Limpets	Lavernock Point	1	<25	<25		41		*	<0.16	0.43
Seaweed[d]	Orchard Ledges	2[E]		<25	<8.5	<25	<0.61			<0.78
Sediment	East of new pipeline	2[E]		<30		<25	<13			19
Sediment	West of new pipeline	2[E]		52	<8.5	<25	<13			18
Seawater	Orchard Ledges	2[E]		19	<4.0	<4.5	<0.27			<0.27

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}										
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples													
Milk[g]		6	<6.7	<8.6		18	<0.43	<0.022		<0.20	<0.20		
Milk[g]	max		<12	22		21	<0.73	<0.024					
Barley		1		<7.0		100	2.1	<0.22		<0.20	<0.30		
Cabbage		1	4.0	24		11	0.70	<0.052		<0.20	<0.20		
Honey		1		<7.0		66	<0.20	<0.022		<0.20	<0.20		
Leeks		1	<6.0	<4.0		16	1.2	<0.044		<0.20	<0.20		
Onions		1	<8.0	8.0		15	0.30	<0.051		<0.20	<0.20		
Potatoes		1	14	32		24	1.0	<0.054		<0.10	<0.20		
Rape oil		1		<8.0		76	5.4	<0.066		<0.20	<0.30		
Raspberries		1	9.0	49		18	<0.20	<0.10		<0.20	<0.20		
Strawberries		1	28	63		12	<0.20	<0.036		<0.20	<0.20		
Swede		1	<6.0	6.0		11	0.30	<0.026		<0.20	<0.20		
Grass		5	35	52		35				<0.20	<0.13		
Grass	max		74	120		37					<0.20		
Silage		2	<7.0	<7.0		31							
Silage	max		<9.0	9.0		36							
Soil		3								<0.10	4.5		
Soil	max										5.4		
Sediment	Canal	2[E]		69		<29		<22			8.2		
Freshwater	Run off into River Taff	1[E]		70	<7.0	<5.0		<0.27	<0.42		<0.26	<0.040	0.16
Freshwater	Canal	2[E]		20	18	<4.5		<0.27	<0.63		<0.27	<0.055	<0.17
Freshwater	River Taff	2[E]		<20	<4.0	<4.5		<0.29	<0.63		<0.25	<0.060	0.29
Crude effluent	Cardiff East WWTW	2[E]	<20	36	30	<28							
Final effluent	Cardiff East WWTW	2[E]	<40	94	76	<25							
Sludge pellets	Cardiff East WWTW	2[E]		42000		910							
Solids from crude effluent	Cardiff East WWTW	1[E]		12000		1400							

* *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 ^{99}Tc was 9.9 Bq kg^{-1}*

[e] *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*

[f] *As tritiated water*

[g] *The concentration of ^{32}P was <0.38 (max <0.43) 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 6.3(b). Monitoring of radiation dose rates near Cardiff, 2008

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud	2	0.084
West of Pipeline	Stones	1	0.10
West of Pipeline	Pebbles and rock	1	0.12
Peterstone Wentlooge	Salt marsh	2	0.091

7. 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.

Key points

Drigg

- Disposals of solid radioactive waste at the Drigg LLWR site were similar to 2007
- Concentrations and dose rates at Drigg were similar to those in 2007
- Doses near Drigg were dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven (Table 7.1)

Other sites

- Tritium found in leachate from other landfill sites. Probably due to disposal of Gaseous Tritium Light Devices. Doses were less than 0.5 per cent of dose limit
- Enhancement in natural radionuclides at Whitehaven from phosphate processing now very difficult to detect, however the radiation dose from the enhancement was estimated to be 39 per cent of the dose limit
- Radium-226 contamination requires further investigation near Dalgety Bay, Fife
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in authorisations

7.1 Low Level Waste Repository near Drigg, Cumbria

The Low Level Waste Repository (LLWR) is the UK's national low level waste disposal facility and is located on the West Cumbrian coast, approximately 7 km south east of Sellafield. The main function of LLWR is to receive low-level solid radioactive wastes from Sellafield and other UK sites, compacted and placed in containers before being transferred to the facility. Wastes are now disposed of in engineered concrete vaults on land. The site is operated by LLW Repository Limited on behalf of the NDA. From 1 April 2008, a consortium, UK Nuclear Waste Management Ltd (UKNWM), took over as the Parent Body Organisation for LLW Repository Limited.

A report published by the Environment Agency provides new data on radionuclides in a variety of wildlife species (including small mammals and reptiles) collected in Drigg sand dunes. The wildlife are contaminated indirectly by permitted discharges from a nuclear reprocessing plant. The monitoring results indicate that there is likely to be no adverse impact on wildlife in the sand dunes (Beresford *et al*., 2008).

The disposal authorisation allows for the discharge of leachate from the site through a marine pipeline. These discharges are small compared with those discharged from the nearby Sellafield site (Appendix 2). Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme, described in Section 2. 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 2008, be distinguished from those due to Sellafield. In 2008, disposals of solid radioactive waste (Appendix 2) were generally similar to 2007.

Although the authorisation for disposal to the Drigg Stream has been revoked, reassurance monitoring of samples of water and sediment has continued. The results are given in Table 7.2. The gross alpha and beta concentrations were below the WHO screening levels for drinking water from the Drigg stream. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use could occur, for example by campers. 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 2007. 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 from the trenches and built a "curtain wall" to reduce lateral migration of leachate. The results of monitoring in the drain show that concentrations of radioactivity are now very low and have reduced significantly since the curtain wall was constructed. Both gross alpha and gross beta concentrations were below the relevant WHO screening limit. Concentrations of tritium were below the limit of detection.

The monitoring programme of terrestrial foodstuffs at the site is primarily directed at the potential migration of radionuclides from the waste burial site via groundwater. Results for 2008 are given in Table 7.2. 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 2). The radiation dose to the critical group from terrestrial pathways, including a component due to Chernobyl and weapon test fallout, was 0.013 mSv which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.47 mSv or 47 per cent of the dose limit. This is dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven, which are near to the Drigg site. If these effects were to be excluded, the *total dose* at Drigg would have been 0.048 mSv, mostly due to direct radiation.

7.2 Other landfill sites

Some organisations are authorised by SEPA 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. SEPA and the Environment Agency carry out monitoring of leachates. The distribution of landfill sites considered in 2008 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4. The programme in England and Wales reduced significantly in 2007 because the data from the previous, larger programme, collected over many years, showed that any enhancements in concentrations were predictable and gave rise to doses of very low significance. The remaining programme in England and Wales constitutes continued monitoring in relation to sites near Springfields where solid LLW has been disposed of, and at a few other landfill sites where disposals of radioactive waste are ongoing. The results, in common with previous years, show very low concentrations 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). A supplementary sample was taken at Ness landfill near Aberdeen to support an investigation of the potential for leachate from Ness landfill into an adjacent river. In this case the tritium was being used as a tracer for water movement. The sample results indicated that the landfill was unlikely to be the source of pollution in the river. Inadvertent ingestion of leachate (2.5 l per year) from the site with the highest observed concentration of tritium (Trecatti) would result in a dose of less than 0.005 mSv or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 7.1).

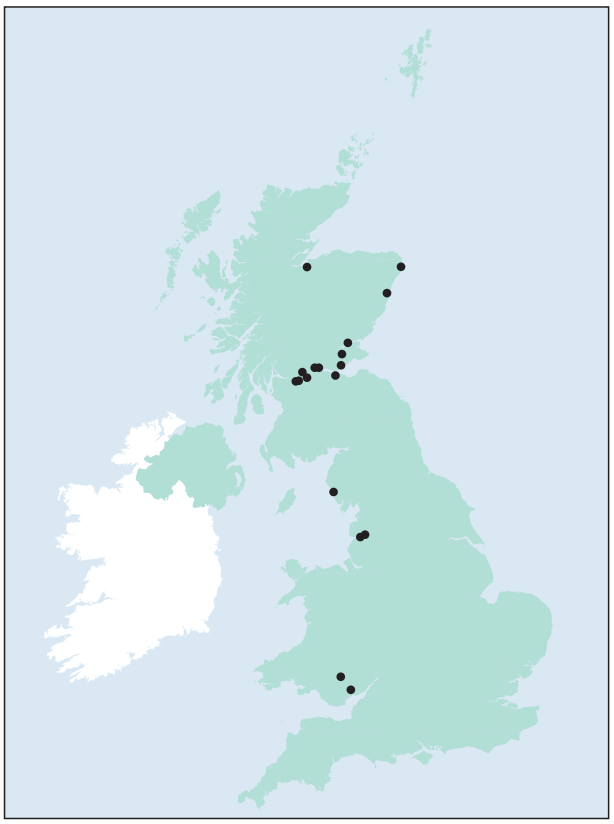


Figure 7.1. Landfill sites monitored in 2008

7.3 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 technologically enhanced naturally-occurring radioactive material (TNORM). Decommissioning of the plant was undertaken in 2002 and released small quantities of 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 2008 are shown in Table 7.5. Analytical effort has focused on lead-210 and polonium-210, which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally-occurring radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figures 7.2 and 7.3 show how concentrations of polonium-210 in winkles and crabs have decreased since 1998. Concentrations in the early 1990s were in excess of 100 Bq kg^{-1} (fresh). There were small increases in concentrations of polonium-210 and lead-210 in these samples in 2008 compared with 2007. However, the changes were small and 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. These are shown in Figures 7.2 and 7.3 and in Appendix 1 (Annex 4). There were small enhancements for some samples above the expected natural background median levels for marine species, 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.

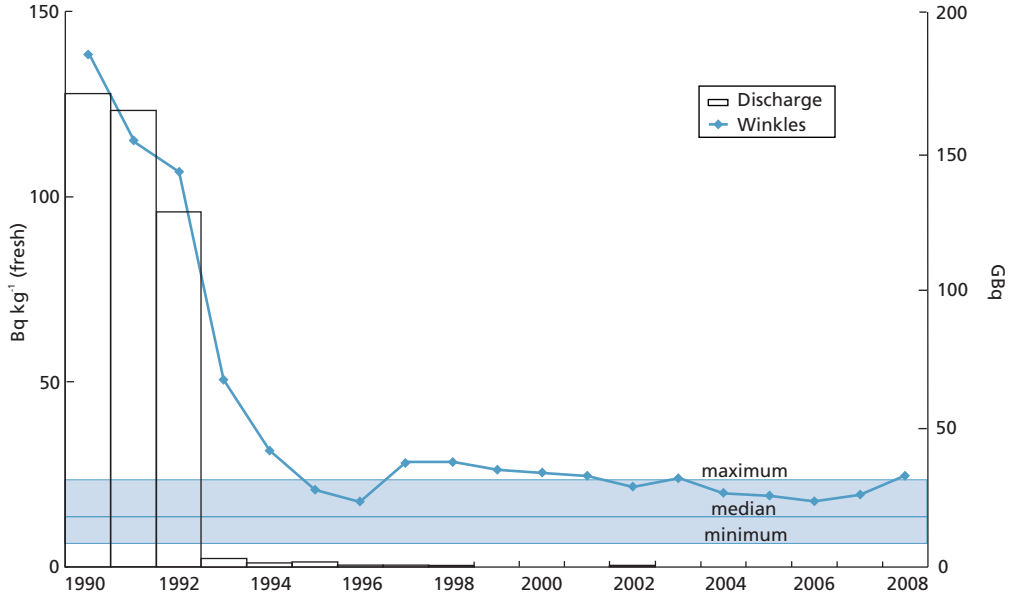


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2008

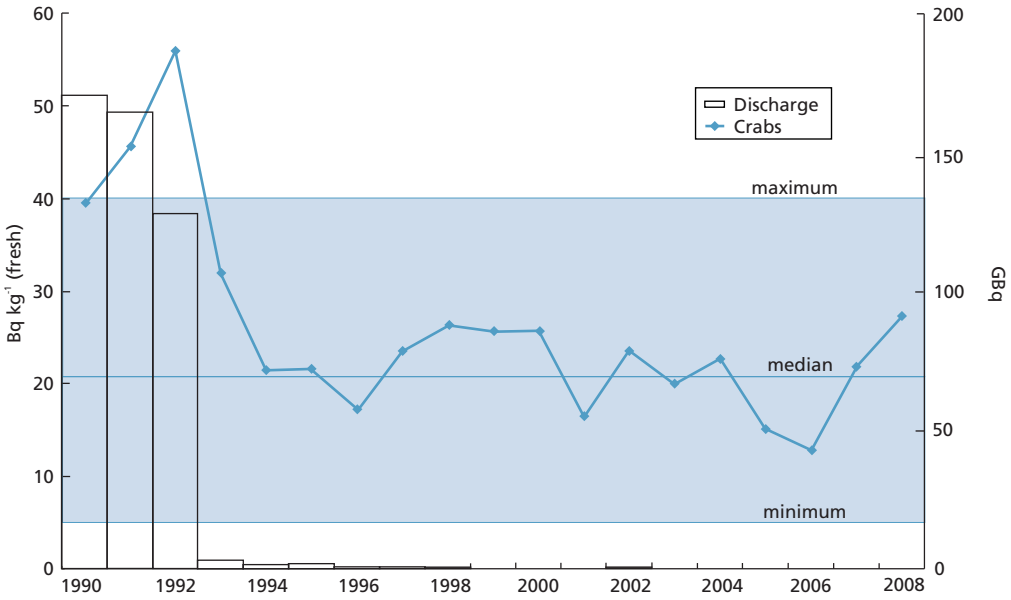


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2008

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 2). 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 concentrations of naturally-occurring radionuclides has been subtracted. Consumption rates for the critical group were reviewed and revised in 2008. The assessment is based on averaging the consumption rates over a five-year period from 2004 – 2008. The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

The critical group dose from enhanced naturally-occurring radionuclides from non-nuclear industrial activity (i.e. TNORM) was 0.39 mSv in 2008 (Table 7.1), an increase from the estimate for 2007 of 0.28 mSv. The increase is largely due to small increases in concentrations of polonium-210. A time trend plot of doses since 1998 is shown in Figure 7.4. The changes in dose reflect changes in both concentrations and consumption rates, primarily of lobsters and molluscs. 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 2. In 2008, these exposures added a further 0.23 mSv to the doses above resulting in a total dose to this group of 0.62 mSv. The estimated doses in 2008 are therefore below the dose limit for members of the public of 1 mSv.

7.4 Aberdeen

Enhancement of naturally-occurring radionuclides in the marine environment may also result from operations conducted by Scotoil in Aberdeen. The company operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations 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 SEPA 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. Following a review of the authorisation held by Scotoil, SEPA issued a variation notice requiring a range of improvements. The variation notice which required use of the discharge pipeline to cease by December 2008 was appealed by Scotoil in 2007.

Following a public inquiry in March and April 2008 to consider the appeal made by Scotoil, Scottish Ministers announced their decision, based on the Reporter's recommendations, in October 2008. The main outcome of the decision is that the discharge of solid radioactive waste into the sea must cease by October 2011.

7.5 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 Royal Naval Air Station (RNAS) Donibristle, which closed in 1959. The air station 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 Royal Dockyard conducted in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material

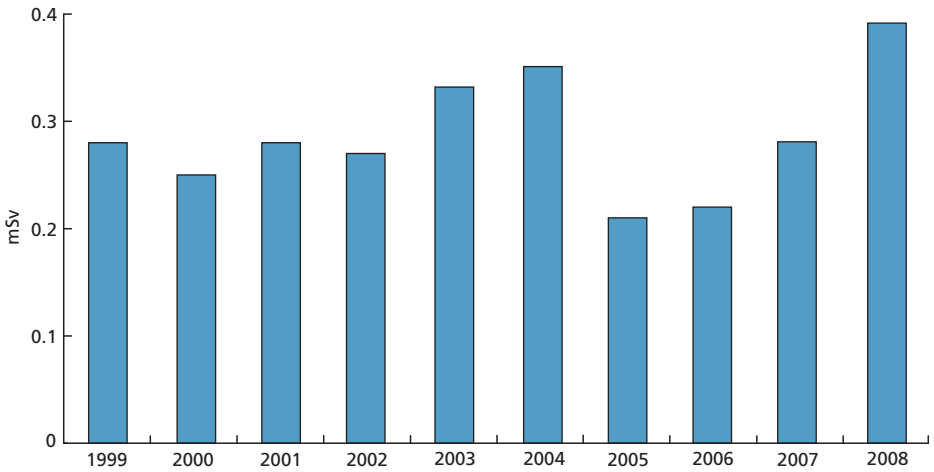


Figure 7.4. Trend in dose to seafood consumers from naturally-occurring radionuclides near Whitehaven, 1999 - 2008

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 RNAS 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 a monitoring exercise, conducted during March 2006, was used to undertake a screening risk assessment. The monitoring survey report and screening risk assessment have been published (RWE Nukem, 2006; Scottish Environment Protection Agency, 2006). 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.

More recently, further studies have been undertaken by Defence Estates (Male and Jones, 2008). Their study included sampling, measurement and assessment in parts of the beach and residential area. The results were compared to the 3 mSv per year criterion recommended for use in relation to radioactively contaminated land (Department for Environment, Food and Rural Affairs, 2006a). The results showed that contamination at two residential properties could lead to exposures in excess of 3 mSv per year.

Defence Estates has undertaken additional work at these properties to remove and safely dispose of contaminated material. In September 2008, SEPA undertook further survey work on the foreshore areas. The results of this monitoring, sampling and analytical work, which have been reported (Dale, 2009), were used to produce a dose assessment for the Dalgety Bay foreshore. The output from this process has been shared with the Dalgety Bay Forum and was used to assess the status of the land against the criteria in the Scottish Government's Statutory Guidance on the Radioactive Contaminated Land (Scotland) Regulations 2007.

SEPA concluded at this stage that while some of the dose estimates were above the criteria set out in the Guidance, there remained sufficient uncertainty, especially in the assessment of skin dose, such that a determination could not be made. In addition, it was also noted at that time that the wording of the Regulations (which have since been amended) excluded radon and its daughters from the scope of the assessment and so contributions from polonium-210 and lead-210 could not be included.

Defence Estates have set out a plan to manage the contamination on the foreshore. This plan has included improving the warning notices, regular monitoring and removal of contamination, and the deployment of a membrane aimed at helping to identify the source of the ongoing contamination. This work is underway and SEPA awaits results before deciding on the next steps.

7.6 Other non-nuclear sites

Routine discharges of small quantities of radioactive wastes to air and water are made from a wide range of other non-nuclear sites in the UK on land, and from offshore oil and gas installations.

A summary of the quantities discharged under authorisation is given in Tables 7.6 and 7.7. The data are grouped according to the main industries giving rise to such wastes in the UK and exclude information for other industries considered in other sections of this report, principally the nuclear sector. The main industries are:

- Oil and gas (on-shore)
- Oil and gas (off-shore)
- Education (Universities and Colleges)
- Hospitals
- Other (research, manufacturing and public sector)

The most recent year for which discharge data has been collated is 2007. Discharges may also occur without authorisation when the quantities are considered to be below the need for specific regulatory control. For example discharges of natural radionuclides are made from coal-fired power stations because of the presence of trace quantities of uranium and thorium and their decay products in coal.

As indicated in Section 1.2.6, general monitoring of the British Isles as reported elsewhere in this report has not detected any gross effects from non-nuclear sources. Occasionally, routine programmes directed at nuclear site operations detect the effects of discharges from the non-nuclear sector and, when this occurs, a comment is made in the relevant nuclear site text. The radiological impact of the radioactivity from the non-nuclear sector detected inadvertently in this way is very low.

Monitoring of the effects of the non-nuclear sector is not undertaken routinely because of the relatively low impact of the discharges. However, *ad hoc* programmes are carried out to confirm that impacts are low and, when these occur, they are described in this report.

In 2008, SEPA undertook a small-scale survey (as part of the annual programme) of the effects of discharges from non-nuclear operators by taking and analysing samples of mussels and other materials in the River Clyde. The results in marine samples show the expected effects of Sellafield discharges at this distance (Table 7.8). The results were similar to those in 2007. An assessment of the dose to a hypothetical group of high-rate mollusc consumers was undertaken. The dose was less than 0.005 mSv or less than 0.5 per cent of the dose limit.

SEPA also undertook a two-week sampling programme at Seafield Waste Water Treatment Works in Edinburgh to investigate the effects of discharges from non-nuclear industries to sewers. A further two-week sampling programme is being undertaken at Inverness in 2009. The results of these sampling exercises are being evaluated and will be reported when the radiological assessments are completed.

Table 7.1. Individual radiation exposures - industrial and landfill sites, 2008

Site	Exposed population group[a]	Exposure, mSv per year					
		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]	0.013	-	-	0.013	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
	All sources[d]	0.47	-	-	-	-	-
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers[b]	<0.005	-	-	-	-	<0.005
Whitehaven	Seafood consumers[c]	0.62	0.20	0.39	-	0.032	-

[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*
[d] *The* total dose *due to discharges and direct radiation. See Appendix 4. The doses from man-made and naturally occurring radionuclides were 0.18 and 0.29 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the Drigg site into the same area*

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2008

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<4.5	16	<0.19	0.071	<0.33	<0.27	<0.0050	<1.4	<0.38
Blackberries		1	<4.0	13	<0.20	0.39	<0.30	<0.20		<0.90	<0.40
Cabbage		1	<4.0	<3.0	<0.20	0.62	<0.20	<0.20	<0.049	<0.70	<0.40
Carrots		1	<5.0	5.0	<0.20	0.47	<0.40	<0.40		<2.1	<0.50
Deer muscle		1	<6.0	20	<0.10	0.034	<0.20	<0.20	0.031	<1.2	<0.20
Eggs		1	7.0	26	<0.10	<0.0060	<0.30	<0.30		<1.5	<0.70
Potatoes		1	<5.0	19	<0.20	0.072	<0.20	<0.20	<0.024	<1.1	<0.40
Rabbit		1	<5.0	14	<0.20	0.049	<0.20	<0.20	<0.020	<1.1	<0.30
Sheep muscle		1	<6.0	40	<0.20	0.025	<0.30	<0.20	<0.019	<1.9	<0.40
Sheep offal		1	<7.0	21	<0.20	0.39	<0.40	<0.30	<0.020	<1.6	<0.40
Grass		2							<0.023		
Grass	max								0.023		
Sediment[d]	Drigg Stream	4[E]			<1.1	<5.5	<1.1	<0.51		<6.2	<3.1
Freshwater	Drigg Stream	4[E]	<8.2		<0.37	<0.11					
Freshwater	Railway Drain	1[E]	<4.0		<0.53	<0.20					

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{129}I	^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.0090	<0.18	<0.19		<0.86				
Blackberries		1	<0.041			0.16	<0.80				
Cabbage		1	<0.030			0.24	<0.70				
Carrots		1	<0.028			0.18	<1.5				
Deer muscle		1	<0.048			0.92	<0.50				
Eggs		1	<0.032			0.11	<1.6				
Potatoes		1	<0.026			0.41	<0.70				
Rabbit		1	<0.031			0.73	<0.60				
Sheep muscle		1	<0.030			0.90	<0.70				
Sheep offal		1	<0.027			0.60	<0.80				
Sediment[d]	Drigg Stream	4[E]		<0.66	440		<3.4	13	16	16	13
Freshwater	Drigg Stream	4[E]		<0.32	<0.31			<0.0060	<0.014	<0.0095	<0.0060
Freshwater	Railway Drain	1[E]		<0.36	<0.39			0.012	0.0240	0.019	<0.0050

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1				<0.00010	<0.00018	<0.028	0.00028		
Blackberries		1				0.00020	0.0010	<0.077	0.0018		
Cabbage		1				0.00020	0.0021	<0.040	0.0019		
Carrots		1				<0.00030	0.00040	<0.085	0.00050		
Deer muscle		1				<0.00030	0.00030	<0.068	0.00050		
Eggs		1				<0.00020	<0.00020	<0.049	<0.00020		
Potatoes		1				<0.00010	<0.00020	<0.12	0.00070		
Rabbit		1				<0.00020	<0.00030	<0.15	<0.00030		
Sheep muscle		1				<0.00020	<0.00040	<0.062	0.00080		
Sheep offal		1				0.0015	0.010	<0.12	0.014		
Grass		2	0.025	0.0011	0.026						
Grass	max		0.039	0.0014	0.043						
Soil		1	6.2	0.40	6.1						
Sediment[d]	Drigg Stream	4[E]	63	<2.9	59	25	150	<840	180	1000	1600
Freshwater	Drigg Stream	4[E]	<0.015	<0.0093	<0.011	<0.0095	<0.0053	<1.1	<0.014	<0.11	0.65
Freshwater	Railway Drain	1[E]	<0.010	<0.0090	<0.020	<0.0060	<0.0050	<1.0	<0.030	<0.060	0.69

[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*

[d] *The mean concentration of ^{125}I was <41 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 7.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2008

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	66	<15	<0.05	<0.05
Aberdeen City	Ness Tip	1[a]	<0.95			
City of Glasgow	Summerston Tip	1	870	<15	0.07	<0.05
City of Glasgow	Cathkin	1	240	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	6.7	<15	<0.05	<0.05
Dunbartonshire	Birdstone	1	<4.0	<15	<0.05	<0.05
Dundee City	Riverside	1	7.8	<15	<0.05	<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	68	<15	<0.05	<0.06
Fife	Melville Wood	1	63	<15	<0.05	<0.05
Highland	Longman Tip	1	<4.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	430	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	360	<15	0.10	<0.05

[a] *Additional sample taken as part of special investigation*

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2008

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	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Glamorgan																		
Trecatti Landfill , Merthyr Tydfil	Raw Leachate	2	1100	720	<4.5													
Trecatti Landfill , Merthyr Tydfil	Treated leachate	2	740	490	<4.5													
Lancashire																		
Clifton Marsh	Borehole 6	2		<6.9		<6.5	<0.34			<0.28	<0.0075	0.0075	<0.0050	0.040	<0.0050	0.035	<0.20	1.6
Clifton Marsh	Borehole 19	2		<4.8		<5.2	<0.33			<0.28	0.030	0.026	<0.0070	<0.032	<0.0050	0.024	<0.21	1.7
Clifton Marsh	Borehole 40	2		<4.5		<8.6	<0.40			<0.32	<0.019	0.047	<0.0060	<0.015	<0.0050	<0.013	<0.11	1.6
Clifton Marsh	Borehole 59	1		22		<6.5	<0.31			<0.25	0.014	0.015	<0.0050	0.0060	<0.0050	<0.0050	<0.30	3.2
Ulnes Walton	Pond	1		<4.0		<6.3	<0.30			<0.25	<0.0050	<0.0050	<0.0050	0.080	<0.0050	0.072	<0.20	0.49
South Glamorgan																		
Lamby Way Tip	Borehole 1A	2		7.3	<4.5	<6.4	<0.30	<0.29	<0.48	<0.25							<0.48	0.39

[a] *As tritiated water*

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[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	15	1.1						
Winkles	Parton	4	25	3.3	0.83	1.1	0.57	1.4	0.048	<1.3
Winkles	North Harrington	1	15							
Winkles	Nethertown	4	22							
Winkles	Drigg	1			0.59	0.51	0.42			
Winkles	Tarn Bay	1	17							
Mussels	Parton	4	43	2.4						
Mussels	Nethertown	4	47	2.7						
Limpets	St Bees	2	18							
Cockles	Ravenglass	2	40							
Crabs	Parton	4	27	<0.00022	0.17	0.046	0.050	0.075	0.0027	0.076
Crabs	Sellafield coastal area	4	16	0.11						
Lobsters	Parton	4	9.5	0.16	0.032	0.011	0.0068	0.032	<0.00029	0.025
Lobsters	Sellafield coastal area	4	15	<0.00016						
Cod	Parton	2	0.66	0.10	0.029	<0.00018	<0.00070	0.0046	<0.00024	0.0037
Plaice	Whitehaven	1	1.9							
Other samples										
Winkles	South Gare (Hartlepool)	2	14	0.97						
Winkles	Kirkcudbright	1	2.4							
Mussels	Ribble Estuary	2			0.19	0.16	0.066			
Cockles	Southern North Sea	1			0.45	0.21	0.34			
Cockles	Flookburgh	2	15							
Crabs	Kirkcudbright	1	3.6							
Lobsters	Kirkcudbright	1	0.98							
Shrimps	Ribble Estuary	2			0.0092	0.0030	0.0016			
Wild fowl	Ribble Estuary	1			0.0032	0.0074	0.0026			
Seaweed	Isle of Man	1						2.4	<0.33	2.1
Sediment	Kirkcudbright	1						11	0.47	9.7
Sediment	Rascarrel Bay	1						28	1.4	26

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

Table 7.6. Discharges of gaseous radioactive wastes from non-nuclear establishments in the United Kingdom, 2007[a]

	Discharges during 2007, GBq						
	Education (Universities and Colleges)			Hospitals		Other (Research, manufacturing and public sector)	
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	England and Wales	Northern Ireland
^{3}H	0.12			24	0.012	2285	
^{14}C	5.5 10^{-3}	2.2 10^{-3}		249	2.0 10^{-3}	870	0.21
^{18}F				1060		353	
^{35}S	0.15			0.58		0.36	
^{41}Ar	0.3						
^{85}Kr						317	
^{99m}Tc				2.1			
^{125}I	2.6 10^{-5}	1.7 10^{-5}	0.01	0.76		0.11	
^{131}I				0.91	0.012	0.024	
^{137}Cs				0.021			
^{222}Rn						2	
Plutonium Alpha						2.6 10^{-7}	
Uranium Alpha						1.2 10^{-9}	
^{241}Am						3.2 10^{-7}	
Other Alpha particulate						168	
Other Beta/Gamma			0.03		33		
Other Beta/Gamma Particulate				758		2169	

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting*

Table 7.7. Discharges of liquid radioactive waste from non-nuclear establishments in the United Kingdom, 2007[a]

	Discharges during 2007, TBq										
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)			Oil and gas (onshore)	Oil and gas (offshore)
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Scotland	Northern Ireland	Scotland	United Kingdom
^{3}H	0.02	$1.4\ 10^{-4}$		0.24	$4.1\ 10^{-4}$		0.72	$7.5\ 10^{-4}$	$1.8\ 10^{-5}$		
^{14}C	$4.9\ 10^{-3}$	$6.7\ 10^{-4}$	$1.4\ 10^{-4}$	$1.9\ 10^{-3}$		$1.4\ 10^{-4}$	0.66	$1.3\ 10^{-3}$	0.034		
^{18}F	0.01			2	0.16		0.74				
^{22}Na	$9.1\ 10^{-6}$			$3.1\ 10^{-5}$			$7.2\ 10^{-7}$				
^{32}P	0.02	$3.5\ 10^{-5}$	$5.7\ 10^{-3}$	0.011	$2.5\ 10^{-5}$	$6.5\ 10^{-4}$	0.04	$4.4\ 10^{-4}$			
^{33}P	10^{-3}	$1.1\ 10^{-6}$	$6\ 10^{-4}$	$2.5\ 10^{-4}$			$7.2\ 10^{-3}$	0.27			
^{35}S	0.041	$7.7\ 10^{-4}$	$4.5\ 10^{-3}$	$7.9\ 10^{-3}$		$2.8\ 10^{-5}$	0.019	$4.4\ 10^{-4}$			
^{51}Cr	0.01		$4.9\ 10^{-5}$	0.057	$3.5\ 10^{-4}$	$2.5\ 10^{-3}$	$2.1\ 10^{-3}$				
^{57}Co	$1.8\ 10^{-7}$			$7.2\ 10^{-5}$	10^{-7}		$4\ 10^{-9}$				
^{58}Co				$1.2\ 10^{-5}$			$4.6\ 10^{-11}$				
^{60}Co	$3.5\ 10^{-6}$						$3.8\ 10^{-5}$				
^{67}Ga				0.026	$1.2\ 10^{-4}$						
^{75}Se	$2.6\ 10^{-5}$			$6.1\ 10^{-4}$							
^{89}Sr	$1.6\ 10^{-10}$			0.018		$2.8\ 10^{-3}$					
^{90}Sr	$3.2\ 10^{-7}$						$1.8\ 10^{-8}$				
^{90}Y	$2.6\ 10^{-5}$			0.42							
^{99}Tc	10^{-4}						$3.7\ 10^{-5}$				
^{99m}Tc	0.62		0.012	51	1.7	0.31	0.41				
^{111}In	$2.5\ 10^{-3}$			0.25	$7.2\ 10^{-3}$	0.034	$3.2\ 10^{-4}$				
^{123}I	0.014			0.77	0.031	$2.4\ 10^{-3}$	10^{-3}				
^{125}Sb							$1.8\ 10^{-5}$				
^{125}I	$7.8\ 10^{-3}$	$6.6\ 10^{-6}$	$1.4\ 10^{-4}$	$4.1\ 10^{-3}$	$4.4\ 10^{-5}$	$9.2\ 10^{-4}$	0.054		$8.3\ 10^{-5}$		
^{129}I	$9.3\ 10^{-10}$						$2\ 10^{-8}$				
^{131}I	0.23			9.7	0.013	0.38	$1.4\ 10^{-5}$	$2.5\ 10^{-3}$			
^{134}Cs	$9\ 10^{-7}$						$2.7\ 10^{-9}$				
^{137}Cs	$2.8\ 10^{-5}$						$3.8\ 10^{-5}$				
^{144}Ce							$5\ 10^{-12}$				
^{153}Sm				0.084	$1.2\ 10^{-3}$						
^{210}Pb											0.027
^{201}Tl				0.12							
^{226}Ra											0.24
^{228}Ra											0.2
^{232}Th							10^{-3}				
Plutonium Alpha	$1.2\ 10^{-8}$						$1.8\ 10^{-8}$				
Uranium Alpha	$2.6\ 10^{-6}$						$6.9\ 10^{-4}$				
^{237}Np	$7.2\ 10^{-6}$						$2.9\ 10^{-8}$				
^{241}Am	$8.2\ 10^{-8}$						$1.1\ 10^{-7}$				
^{241}Pu							$1.1\ 10^{-7}$				
Total Alpha	$1.2\ 10^{-5}$			$2.3\ 10^{-4}$			0.029	$2\ 10^{-6}$		$4.2\ 10^{-3}$	
Total Beta/Gamma (Excl Tritium)	0.97		0.022	53		0.56	0.51	$4.9\ 10^{-3}$		$2.9\ 10^{-3}$	
Other Alpha particulate	$2.6\ 10^{-6}$			$2.3\ 10^{-4}$			$4.5\ 10^{-4}$				
Other Beta/Gamma[b]	$1.1\ 10^{-3}$		$1.1\ 10^{-4}$	0.12		$5.6\ 10^{-4}$	$2.3\ 10^{-4}$	$2\ 10^{-6}$	$7.2\ 10^{-8}$		
Other Beta/ Gamma particulate				$3.9\ 10^{-3}$			$1.5\ 10^{-3}$				

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting*

[b] *Excluding specific radionuclides*

Table 7.8. Monitoring in the River Clyde, 2008[a]

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{32}P	^{90}Sr	^{99}Tc	^{125}Sb
Between Finlaystone and Woodhall	Mussels	1		29	<1.1		11	<0.26
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1			<1.2		180	<0.12
14 km downstream of Dalmuir	Sediment	1		<15	<1.0			0.87
Downstream of Dalmuir	Freshwater	4			<0.29			<0.11
River Clyde	Freshwater	4	<1.0			<0.0050		
Daldowie	Sludge pellets	4			<25			<0.86

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}				
			^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Between Finlaystone and Woodhall	Mussels	1	0.48	<0.23	<0.15		
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1	0.87	<0.11	<0.10		
14 km downstream of Dalmuir	Sediment	1	42	1.8	1.7		
Downstream of Dalmuir	Freshwater	4	<0.10	<0.10	<0.10		
River Clyde	Freshwater	4	<0.10			<0.034	0.62
Daldowie	Sludge pellets	4	5.0	<0.74	<0.54		

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

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

8. Chernobyl and regional monitoring

8.1 Chernobyl

Key points

- Contamination of sheep and fish with caesium-137 from Chernobyl continues. Over 95 per cent of restrictions have been lifted since 1986, but restrictions are still in place on the movement, sale and slaughter of sheep
- Monitoring of Channel Islands continued to check possible effects from French nuclear facilities. Doses were less than 0.5 per cent of the limit
- Monitoring in Northern Ireland and the Isle of Man showed low concentration of man-made radionuclides from UK industry. Doses were less than 2 per cent of the dose limit
- Natural radionuclides dominated the doses due to consumption of general diet. Samples from the UK food supply, air, rain and drinking water were analysed
- Surveys of seas around the UK supported international assessments for the OSPAR Treaty and showed the extent of tritium and caesium-137 contamination

The Chernobyl accident occurred in April 1986, in the former USSR (now Ukraine). After the accident, radiocaesium was detected in sheep grazing certain upland areas in the UK, which were subjected to heavy rainfall in the days following the accident. Restrictions were put in place on the movement, sale and slaughter of sheep from the affected 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 monitoring live animals, known as the Mark and Release Scheme, ensures that food safety is protected, whilst allowing established sheep farming practices to continue. A farmer wishing to move sheep out of a restricted area must have them tested using an external monitor held against the sheep. Any sheep which is assessed to have levels of contamination exceeding the limit of 1,000 Bq kg^{-1} is marked on the back of the head with coloured paint. Painted sheep may be moved off restricted areas, but cannot be sold to slaughter nor returned to the restricted areas for a minimum of three months, which allows time for the radiocaesium to pass out of the body. Results of the Mark and Release monitoring programme for 2008 are given in Table 8.1.

In the summer of 2008, whole flock monitoring surveys of sheep on selected farms in the post-Chernobyl restricted areas of England, Scotland and Wales were conducted with the aim of removing restrictions where controls are no longer necessary. The results of the 2008 surveys did not cause any farms to have their controls lifted.

There remain a total of 373 farms or part farms (9 in England, 5 in Scotland and 359 in Wales) subject to restrictions. There are approximately 190,000 sheep within these restricted areas. This represents a reduction of over 95 per cent since 1986, when approximately 9,700 farms and 4,225,000 sheep were under restriction across the UK. All remaining restrictions in Northern Ireland were lifted in 2000.

Sampling locations for freshwater fish affected by Chernobyl are now limited to Cumbria in England which has areas of relatively high deposition of fallout from the accident. Samples from areas of low deposition in England were also obtained for comparison. Table 8.2 presents concentrations of caesium-134 and caesium-137 in fish. Other artificial radionuclides from the Chernobyl accident are no longer detectable. The highest concentration was 110 Bq kg^{-1} in perch, with overall levels generally similar to those in recent years and substantially less than the 1,000 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 per year, 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, i.e. higher than expected, (Leonard *et al*., 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have a much lower radiocaesium concentration. In 2008, estimated doses were less than 0.1 mSv.

8.2 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, a natural trough in the western English Channel. Fish and shellfish are monitored in relation to the internal irradiation pathway; sediment is analysed with relevance to external exposures. Seawater and seaweeds are sampled as environmental

indicator materials and, in the latter case, because of their use as fertilisers.

The results for 2008 are given in Table 8.3. Radionuclides that 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 2008, which is less than 0.5 per cent 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 included in Tables 8.10 and 8.11, respectively, and form part of the programmes considered in Sections 8.6 and 8.7, respectively.

8.3 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 2 because of their significance in relation to Sellafield, but are also included here for completeness (Table 8.4).

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, 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. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2008.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2008 was 0.009 mSv (0.012 mSv in 2007), which is less than 1 per cent of the dose limit for members of the public of 1 mSv.

The effects of liquid discharges from Sellafield into the Irish Sea are discussed fully in Section 2. The dose to the critical group of Manx fish and shellfish consumers was 0.007 mSv in 2008 (similar to 2007) which is less than 1 per cent of the dose limit.

8.4 Northern Ireland

The Northern Ireland Environment Agency 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 8.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 8.5(a) and (b).

In 2008, the main effects of Sellafield were evident as concentrations of technetium-99, caesium-137 and transuranics in marine samples. Observed concentrations and dose rates were less than those found nearer to Sellafield and were generally similar to those in 2007. An increase of technetium-99 in seaweed was found at Ardglass, but the contribution that this nuclide makes to the radiation dose is very small. The radiation dose rates over intertidal areas were similar to those in previous years.

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 monitoring results from the marine environment in 2008 was 0.017 mSv, which is less than 2 per cent of the dose limit for members of the public.

Monitoring results for the terrestrial environment of Northern Ireland are given in following parts of Section 8.

8.5 General diet

As part of the Government's general responsibility for food safety, levels of radioactivity are determined in diets of the regions. Most samples are derived from the Food Standards Agency's Total Diet Study (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 (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 radioactivity. The system of sampling mixed diet, rather than individual foodstuffs from specific locations, provides more

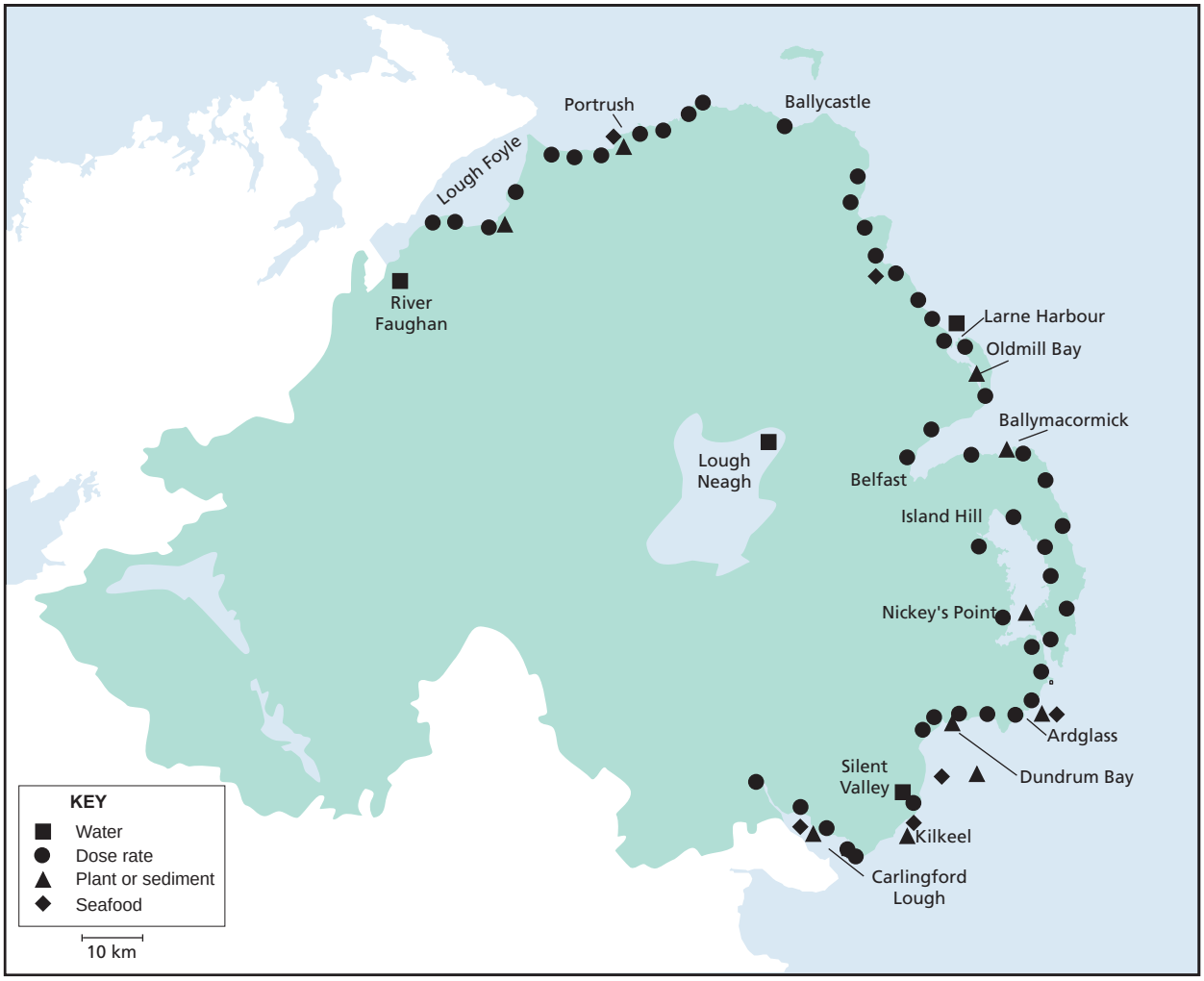


Figure 8.1. Monitoring locations in Northern Ireland, 2008

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 2008. The results are provided in Tables 8.6 and 8.7. These data and those on other dietary components in Sections 8.6 and 8.7 form the basis of the UK submission to the EU under Articles 35 and 36 of the Euratom Treaty.

There was little or no evidence for the effects of radioactive waste disposal into the environment reaching the general diet and all of the results for man-made radionuclides were low. Many were close to the limits of detection for the various analytical methods used. Whilst there was some variability from region to region, in general it was no more than is usual for the programme, and there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 8.6 and 8.7 have been assessed for intakes by adults and summarised in Table 8.8. 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 0.001 mSv.

The mean dose due to consumption of naturally-occurring radionuclides (excluding potassium-40*) was 0.039 mSv, a decrease from the value for 2007 of 0.056 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. Man-made radionuclides only contributed about 3 per cent of the mean dose.

The maximum exposures from diet in each region are also provided in Table 8.8. The highest exposure in the UK was estimated to be 0.062 mSv based on sampling at Cumbernauld in Dunbartonshire, with over 75 per cent of the dose being derived from lead-210 and polonium-210. In 2007, the highest exposure in the UK was 0.20 mSv.

* *The potassium content of the body is under strict homeostatic control. It remains constant in the body. The dose does not vary with the levels in the environment and is often treated separately from doses due to other naturally occurring radionuclides.*

The concentrations found in a survey of radioactivity in canteen meals collected across the UK (Table 8.9) were generally similar to the mean concentrations found in UK diet.

8.6 Milk

The programme of milk sampling across dairies in the UK continued in 2008. 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 2008 were similar to those for previous years. These results are summarised in Table 8.10. Tritium results were below their limits of detection. Mean and maximum values for carbon-14 from all dairies were generally similar and at expected background levels. The mean concentration of strontium-90 was about 0.03 Bq l^{-1}. In the past, the concentrations of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. However, the concentrations are now very low and it is less easy to distinguish this trend. The highest concentrations of caesium-137 were found in Northern Ireland.

The assessed doses from consumption of 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 whereas man-made radionuclides contribute less than 10 per cent.

8.7 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2008 (Table 8.11). Tritium activity was below the LoD in most samples. The activities of carbon-14 detected in crop samples were mainly close to those expected from consideration of background sources. Naturally-occurring radionuclides tended to vary from region to region. However, within the variability observed, the concentrations of all radionuclides in crops were similar to those observed in 2007.

In 2008, screening instruments for radioactivity were triggered at Felixstowe and Dover Docks by the presence of caesium-137 in consignments of food being imported into the UK. Six samples were analysed and the results are given in Table 8.12. The activity concentrations ranged from < 3.0 – 550 Bq kg^{-1}. No action on food restrictions was necessary.

8.8 Airborne particulate, rain, freshwater, groundwater and sediments

Monitoring of radioactivity in air and rain took place at several locations as part of a UK-wide monitoring programme of background sampling under the Euratom Treaty. The results are given in Table 8.13. The routine 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 the limits of detection. These levels in air, typical of recent years, remain less than 0.01 per cent 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 2007. 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 2008 (Figure 8.2). 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 8.14, 8.15 and 8.16, show that concentrations of tritium are all substantially 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 levels for drinking water of 0.5 and 1.0 Bq l^{-1}, respectively.

The mean annual dose from consumption of drinking water in the UK was assessed as 0.028 mSv in 2008 (Table 8.17). 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 0.031 mSv due to radionuclides in a source of drinking water from the Silent Valley in County Down.

During 2008, SEPA took a series of groundwater samples from across Scotland with the aim of determining natural variability. Samples were taken in summer and winter to assess seasonal effects which may be caused by changes in ground water flow. The mean results are displayed in Table 8.18. Analysis of the data demonstrates that variability within the samples, seasonally and geographically, was low.

SEPA also began in 2008 a programme of sampling and analysis of marine and freshwater sediments to determine natural variability in the east of Scotland. The results are shown in Table 8.19.

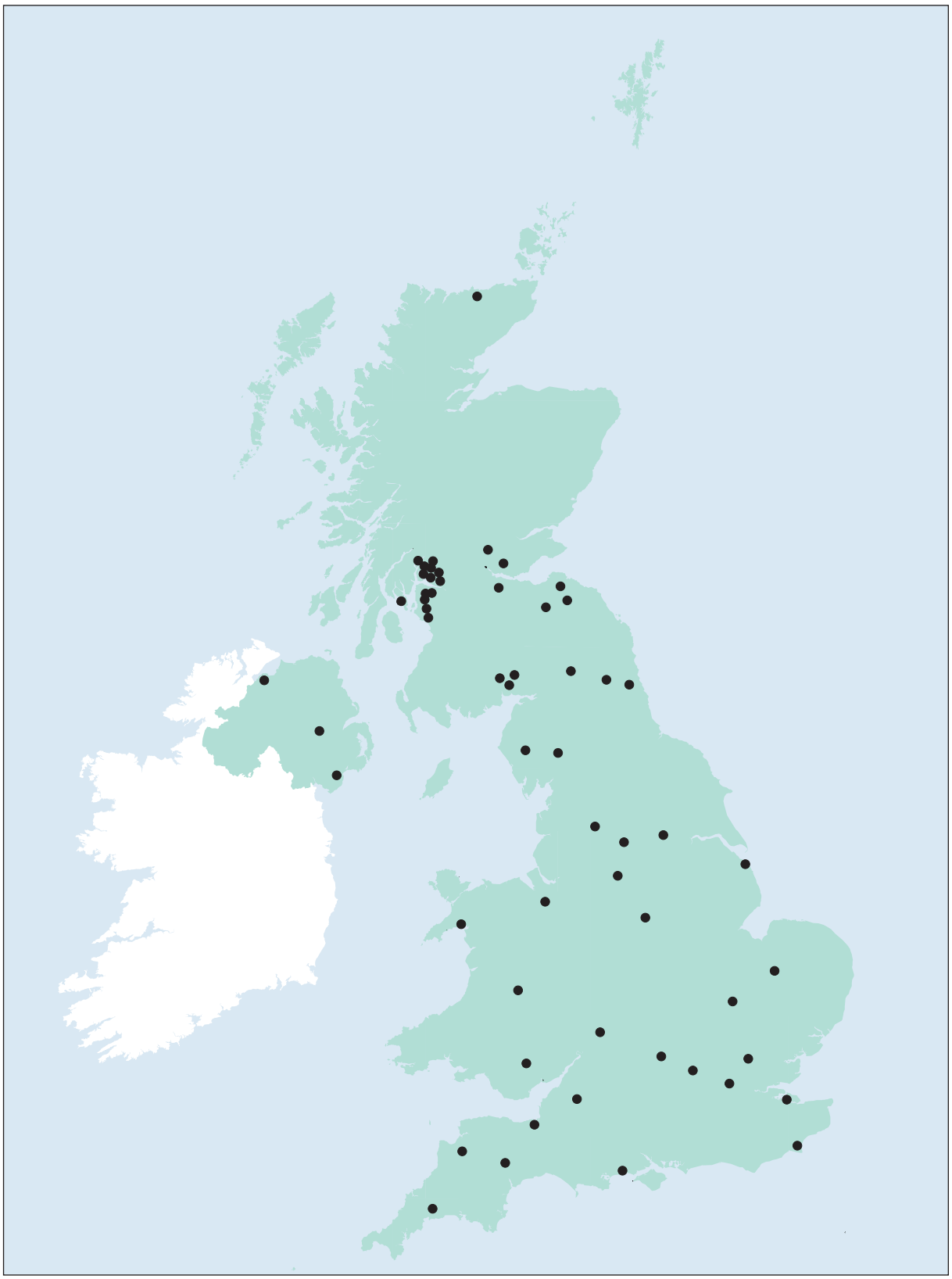


Figure 8.2. Drinking water sampling locations, 2008

During 2008, SEPA responded to a release of a large volume of sediment during maintenance works at Logan Reservoir in South Lanarkshire. The release of sediment raised concerns about historic deposits of radioactivity arising from the Chernobyl incident in 1986. Sediment samples were collected to check that the pollution did not represent a significant radiological risk. Results obtained for caesium-137 at three locations are low and typical of those to be expected from fallout due to Chernobyl and did not therefore require intervention. These are displayed in Table 8.19.

8.9 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, 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). In 2006 OSPAR adopted the Periodic Evaluation of the Progress in Implementing the OSPAR Radioactive Substances Strategy (concerning progressive and substantial reductions in discharges of radioactive substances, as compared with the agreed baseline) (OSPAR, 2007). The programme of radiological surveillance work provides the source data and therefore the means to monitor and make an assessment of progress in line with the UK's commitments towards OSPAR's 1998 Strategy for Radioactive Substances target for 2020. The surveys also 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 for Environment, Food and Rural Affairs, 2005a).

The research vessel programme on radionuclide distribution currently comprises annual surveys of the Bristol Channel/western English Channel and biennial surveys of the Irish Sea and the North Sea. The results of the 2008 cruises are presented in Figures 8.3 – 8.7. Shoreline sampling is also conducted around the UK, and the data are given in Table 8.20. 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 2008 caesium-137 data for the North Sea (Figure 8.3) show very low activities (<0.01 Bq l^{-1}) throughout the majority of the survey area, and that are only slightly above the global fallout levels in North Atlantic surface waters (~0.0012 Bq l^{-1} in 2002, Bailly du Bois pers. comm.). The overall distribution in the North Sea is characteristic of that observed in the last 5 years. Typically high activities were observed at two stations close to the Norwegian Coast, due to the input of Chernobyl-derived caesium-137 from the Baltic, via the Skaggerak. The 2008 survey also indicates a few anomalous results of slightly elevated caesium-137 in the southern North Sea. These are likely to be outliers, or the outcome of complex water circulation from an unknown source (possibly Chernobyl-derived).

In the previous three decades the impact of discharges from the reprocessing plants at Sellafield and La Hague has been readily apparent, carried by the prevailing residual currents from the Irish Sea and the Channel, respectively (Povinec *et al*., 2003). The activity of caesium-137 in the North Sea has tended to follow the temporal trends of the discharges, albeit with a time lag. The maximum discharge of caesium-137 occurred at Sellafield in 1975, and caesium-137 activities of up to 0.5 Bq l^{-1} were measured in the North Sea in the late 1970s. Due to significantly decreasing discharges after 1978, remobilisation of caesium-137 from contaminated sediments in the Irish Sea is now the dominant source of water contamination for most of the North Sea (McCubbin *et al*., 2002).

Caesium-137 concentrations in the Irish Sea 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. The 2007 seawater survey recorded concentrations of up to 0.2 Bq l^{-1} in the eastern Irish Sea, and levels elsewhere were generally below 0.05 Bq l^{-1}.

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, concentrations in seawater have shown 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 8.8 for shoreline seawater at St Bees (~ 10 km to the north of Sellafield). Longer time series showing the peaks in concentrations in the 1970s are shown in Figures 8.9 (Irish Sea) and 8.10 (North Sea).

Concentrations of caesium-137 in the western English Channel (average activity 0.002 Bq l^{-1}) were, within experimental error, similar to the background level resulting from global fallout (Figure 8.4).

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 North Sea (Figure 8.5) were generally lower than those observed in the Irish Sea in 2007 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2008) due to the influence

of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 8.6) and decreasing. Concentrations in the western English Channel were very low (Figure 8.7).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed from 1994 to their most recent peak in 2003. The results of research cruises to study this radionuclide have been published by Leonard *et al.*, (1997a,b, 2004) and McCubbin *et al.*, (2002, 2008). 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).

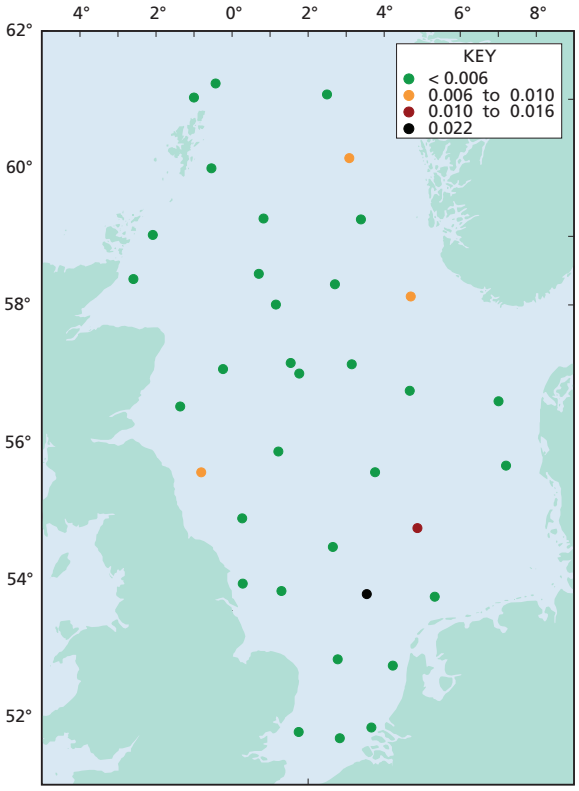


Figure 8.3. Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the North Sea, August-September 2008

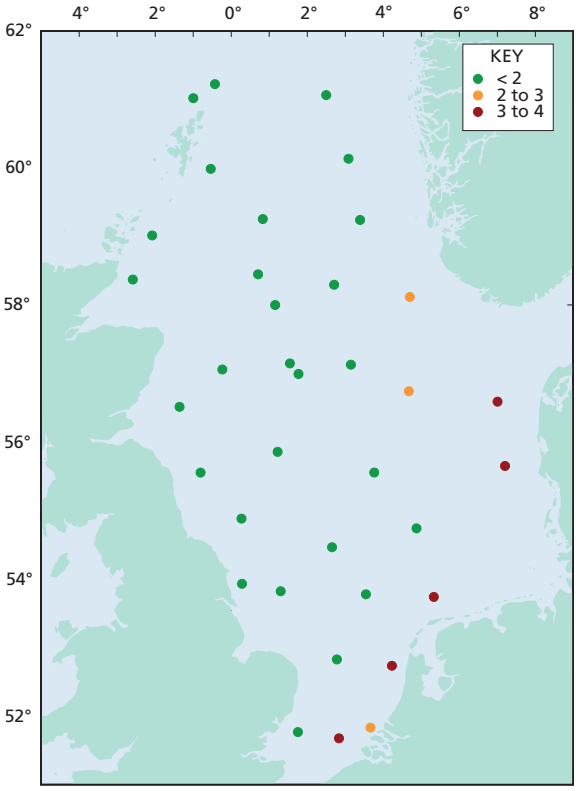


Figure 8.5. Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, August-September 2008

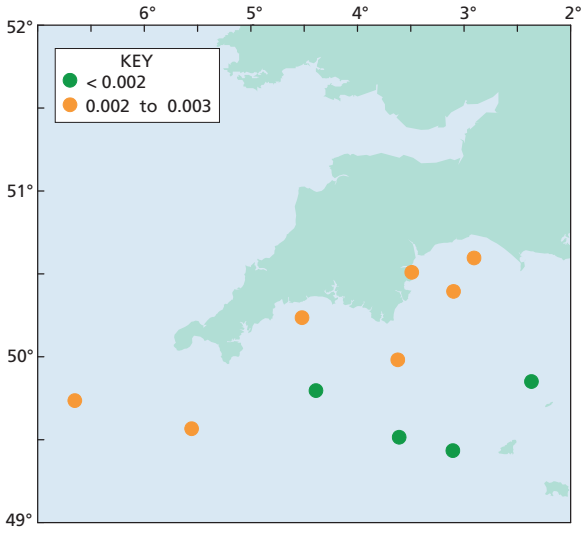


Figure 8.4. Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the western English Channel, March 2008

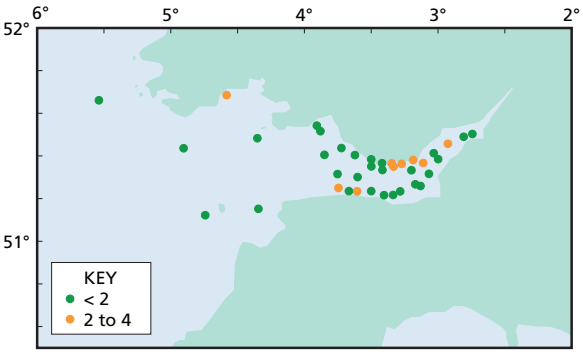


Figure 8.6. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September–October 2008

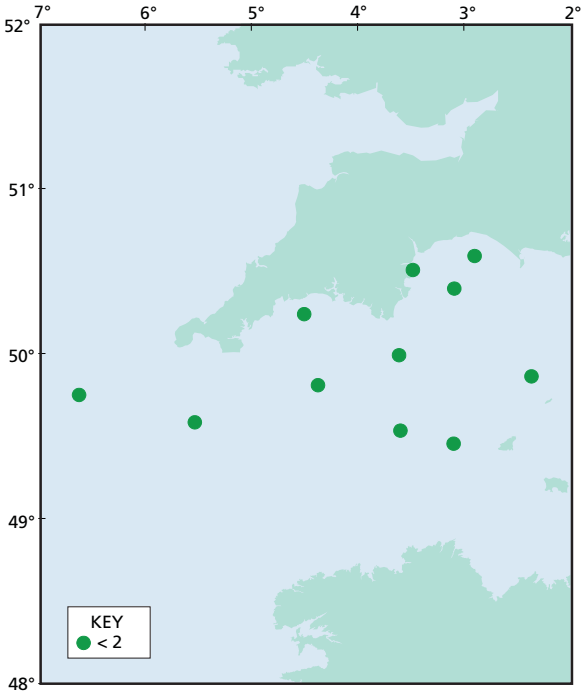


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water from the western English Channel, March 2008

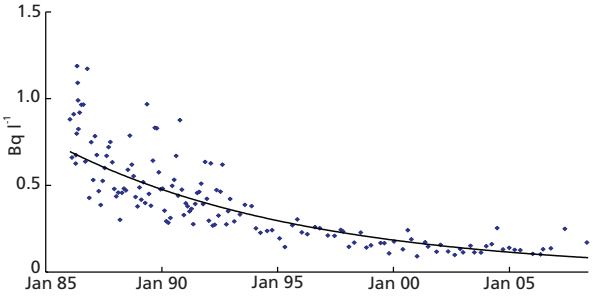


Figure 8.8. Temporal variation of dissolved caesium-137 in shoreline seawater close to Sellafield (at St Bees), 1986-2008

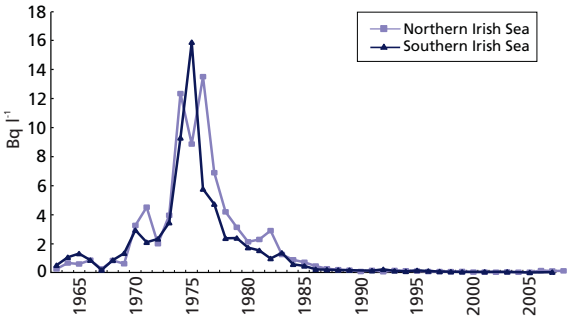


Figure 8.9. Concentrations of caesium-137 in the Irish Sea, 1963-2008

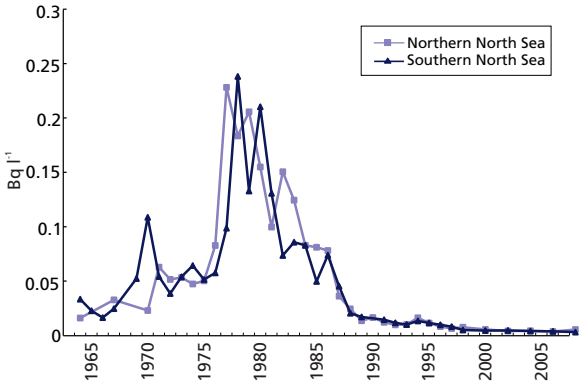


Figure 8.10. Concentrations of caesium-137 in the North Sea, 1964-2008

Table 8.1. Monitoring of sheep in England, Wales and Scotland, 2008

	England	Wales	Scotland	United Kingdom
Number of sheep monitored	6902	85427	1957	94286
Number of sheep above action level	0	200	0	200
Percentage of sheep above action level	0	0.23	0	0.21
Number of farms under restriction	9	359	5	373
Approximate number of sheep	7000	180000	3000	190000
Approximate land area (ha)	12000	53000	7000	72000

Table 8.2. Concentrations of radiocaesium in the freshwater environment, 2008

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Rainbow trout	1	<0.09	0.28
Cogra Moss	Rainbow trout	2	<0.10	0.21
Narborough[a]	Rainbow trout	1	<0.05	<0.05
Low Wath	Rainbow trout	1	<0.09	0.29
Devoke Water	Brown trout	1	<0.23	33
Devoke Water	Perch	1	<0.58	110
Gilcrux	Rainbow trout	1	<0.05	0.11

[a] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}$Pu and ^{241}Am were 60, 0.00014, 0.00082 and 0.0015 Bq kg^{-1} respectively*

Table 8.3. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2008

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{137}Cs
Mackerel	Guernsey	1				<0.10			<1.1		0.12
Mackerel	Jersey	1				<0.07			<0.85		0.17
Pollack	Jersey	2				<0.06			<0.65		0.20
Bass	Guernsey	1				<0.08			<0.85		0.33
Bass	Jersey	1				<0.05			<0.51		0.20
Edible crabs	Guernsey	1				<0.09			<1.0		<0.08
Edible crabs	Jersey	1				<0.08			<0.81		0.08
Edible crabs	Alderney	2	<25	<25	68	<0.13		<0.55	<0.86		<0.07
Spiny spider crab	Jersey	1				0.19			<0.75		<0.06
Spiny spider crab	Alderney	1				0.42			<0.56		<0.05
Lobsters	Guernsey	1				<0.08			<0.86		<0.07
Lobsters	Jersey	1				<0.03		0.73	<0.36		0.05
Lobsters	Alderney	1				<0.04			<0.38		0.07
Oysters	Jersey La Rocque	1				<0.03			<0.27		<0.02
Limpets	Guernsey	1				<0.18			<2.2		<0.14
Limpets	Jersey La Rozel	1				0.08			<0.32		<0.03
Toothed winkle	Alderney	1	<25	<25	44	0.28	0.12		<0.53		0.08
Scallops	Guernsey	1				<0.16			<1.6		<0.14
Scallops	Jersey	2				0.12			<0.57		<0.08
Ormers	Guernsey	1				<0.08			<0.90		<0.07
Porphyra	Guernsey Fermain Bay	2				<0.17			<1.9		<0.14
Porphyra	Jersey Plemont Bay	2				<0.07			<0.70		<0.06
Fucus vesiculosus	Jersey La Rozel	3				<0.11	<0.10	6.7	<0.86		<0.08
Ascophyllum nodosum	Jersey La Rozel	1				<0.10			<0.86		<0.09
Fucus vesiculosus	Alderney Quenard Point	2								0.89	
Fucus serratus	Guernsey Fermain Bay	2				<0.16	<0.050	3.1	<1.8		<0.14
Fucus serratus	Alderney Quenard Point	4				<0.16	<0.090	2.6	<0.57		<0.05
Laminaria digitata	Jersey Verclut	4				<0.07			<0.73		<0.06
Laminaria digitata	Alderney Quenard Point	4				<0.07			<0.66		<0.07
Sand	Guernsey St. Sampson's Harbour	1				0.39			<2.7		0.59
Mud	Jersey St Helier	1				5.9			<3.5		2.6
Sand	Alderney Lt. Crabbe Harbour	1				0.85			<2.6		1.2
Seawater	Guernsey	4									0.002
Seawater	Jersey	1									0.001
Seawater	Alderney East	4		3.8							0.001

Table 8.3. continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Mackerel	Guernsey	1	<0.45	<0.17	0.00014	0.00016	0.00015	*	*	160
Mackerel	Jersey	1	<0.53	<0.21	0.000032	0.00013	0.00024	*	0.000021	
Pollack	Jersey	2	<0.32	<0.13			<0.13			180
Bass	Guernsey	1	<0.47	<0.20	0.000048	0.000048	0.00016	*	*	150
Bass	Jersey	1	<0.30	<0.13			<0.12			140
Edible crabs	Guernsey	1	<0.56	<0.21	0.0010	0.00029	0.0023	*	0.00032	94
Edible crabs	Jersey	1	<0.50	<0.20	0.00056	0.0022	0.0061	*	0.00043	130
Edible crabs	Alderney	2	<0.44	<0.19	0.00048	0.0010	0.0033	<0.000032	0.00052	130
Spiny spider crab	Jersey	1	<0.43	<0.17			<0.20			81
Spiny spider crab	Alderney	1	<0.25	<0.09	0.0018	0.0058	0.0081	0.000052	0.00050	97
Lobsters	Guernsey	1	<0.48	<0.19			<0.22			130
Lobsters	Jersey	1	<0.23	<0.10	0.00026	0.0011	0.0047	*	0.00047	91
Lobsters	Alderney	1	<0.25	<0.10	0.00034	0.00082	0.010	0.00012	0.0015	96
Oysters	Jersey La Rocque	1	<0.17	<0.07	0.00073	0.0025	0.0021	*	0.00020	63
Limpets	Guernsey	1	<0.77	<0.24			<0.12			90
Limpets	Jersey La Rozel	1	<0.16	<0.06	0.0045	0.015	0.0270	0.00038	0.0020	99
Toothed winkle	Alderney	1	<0.36	<0.14	0.012	0.037	0.054	0.00046	0.0063	90
Scallops	Guernsey	1	<0.57	<0.22	0.00061	0.0027	0.0014	*	0.00013	130
Scallops	Jersey	2	<0.31	<0.13	0.011	0.048	0.046	0.00019	0.0044	140
Ormers	Guernsey	1	<0.51	<0.21			<0.23			110
Porphyra	Guernsey Fermain Bay	2	<0.67	<0.23	0.0026	0.011	0.012	*	0.00091	180
Porphyra	Jersey Plemont Bay	2	<0.34	<0.14			<0.12			140
Fucus vesiculosus	Jersey La Rozel	3	<0.44	<0.19	0.0078	0.023	0.0065	*	0.00071	250
Ascophyllum nodosum	Jersey La Rozel	1	<0.47	<0.22			<0.26			210
Fucus serratus	Guernsey Fermain Bay	2	<0.74	<0.24	0.0043	0.019	0.0071	0.000070	0.00066	190
Fucus serratus	Alderney Quenard Point	4	<0.34	<0.16	0.0048	0.015	0.0045	<0.000021	0.00058	290
Laminaria digitata	Jersey Verclut	4	<0.36	<0.15			<0.14			240
Laminaria digitata	Alderney Quenard Point	4	<0.31	<0.13			<0.12			370
Sand	Guernsey St. Sampson's Harbour	1	<1.5	<0.50	0.037	0.14	0.17	*	0.016	600
Mud	Jersey St Helier	1	<1.7	1.3	0.57	1.4	3.1	0.028	0.30	720
Sand	Alderney Lt. Crabbe Harbour	1	<1.4	0.89			0.59			930

* *Not detected by the method used*

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

Table 8.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2008[a]

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Cod	4	<0.05	<0.28	<0.52		<0.52	<0.13	<0.05	1.8
Herring	4	<0.05	<0.18	<0.25		<0.42	<0.11	<0.05	1.5
Lobsters	4	<0.06	<0.27	<0.44	50	<0.56	<0.13	<0.06	0.42
Scallops	4	<0.07	<0.32	<0.66		<0.57	<0.14	<0.06	0.61
Seaweed[c]	4[E]	<1.2	<1.6	<0.87	410	<7.1	<2.9	<0.89	<1.3
Sediment	1[E]	<0.35	<0.62	<0.32		<2.5	<0.73	<0.27	13

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Aquatic samples									
Cod	4	<0.28	0.00016	0.00096	0.0015	*	*		
Herring	4	<0.24	0.0023	0.014	0.026	*	0.000059		
Lobsters	4	<0.29			<0.14				160
Scallops	4	<0.32	0.043	0.24	0.14	*	0.00027		
Seaweed[c]	4[E]	<3.1			<1.2				
Sediment	1[E]	<1.6			2.3			290	500

Material or selection[d]	No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Terrestrial samples								
Milk	2	<5.1	<14	<0.49	<0.18	0.031	<0.0040	<1.2
Milk max		<5.8	<15	<0.55		0.033		<1.4
Cabbage	1	<4.0	11	1.0	<0.20	0.13	<0.020	<1.0
Potatoes	1	<5.0	19	0.50	<0.30	0.067	<0.018	<2.0
Strawberries	1	<5.0	4.0	0.30	<0.20	0.11		<0.90

Material or selection[d]	No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{125}Sb	^{129}I	Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples								
Milk	2	<0.38	<0.012	0.081	0.00010	0.00020	<0.056	<0.00020
Milk max		<0.40		0.083				
Cabbage	1	<0.20	<0.027	0.069	<0.00030	<0.00030	<0.073	0.00040
Potatoes	1	<0.40	<0.027	0.044	<0.00020	<0.00010	<0.038	0.00030
Strawberries	1	<0.30		0.037				

* *Not detected by the method used*

[a] *The gamma dose rate in air at 1m over pebbles and sand at Ramsey[E] was 0.092 μGy h^{-1}*

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

[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 2.4, <0.33 and 2.1 Bq kg^{-1} respectively*

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

[e] *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 8.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2008[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Cod	Kilkeel	4	57	<0.08		<0.19	<0.09	2.2
Plaice	Kilkeel	4		<0.07		<0.16	<0.07	1.9
Haddock	Kilkeel	4		<0.12		<0.28	<0.13	0.98
Hake	Kilkeel	3		<0.08		<0.19	<0.08	0.78
Herring	Ardglass	2		<0.25		<0.63	<0.27	0.60
Spurdog	North coast	4		<0.10		<0.22	<0.10	1.7
Spurdog	Kilkeel	1		<0.15		<0.37	<0.16	5.6
Crabs	Kilkeel	4		<0.10		<0.23	<0.10	0.29
Lobsters	Ballycastle	2		<0.05	130	<0.12	<0.05	0.71
Lobsters	Kilkeel	4		<0.09	29	<0.20	<0.09	0.31
Nephrops	Kilkeel	4		<0.12	12	<0.28	<0.13	0.80
Winkles	Minerstown	4		<0.11		<0.25	<0.11	<0.25
Mussels	Carlingford Lough	2		<0.18	20	<0.41	<0.20	0.96
Scallops	Co. Down	2		<0.11		<0.25	<0.11	0.38
Ascophyllum nodosum	Ardglass	1		<0.06		0.21	<0.06	0.41
Fucus spp.	Carlingford Lough	4		<0.14	120	<0.28	<0.15	0.49
Fucus spp.	Portrush	4		<0.10		<0.22	<0.10	<0.15
Fucus vesiculosus	Ardglass	3		<0.18	770	<0.46	<0.19	0.72
Rhodymenia spp.	Strangford Lough	4		<0.13	7.1	<0.28	<0.14	0.51
Mud	Carlingford Lough	2		<0.64		<2.0	<0.88	45
Mud	Dundrum Bay	1		<0.57		<1.4	<0.76	4.2
Mud	Oldmill Bay	2		<0.82		<2.8	<1.3	57
Mud	Strangford Lough-Nicky's point	2		<0.66		<2.1	<0.91	37
Mud	Ballymacormick	2		<0.40		<1.3	<0.55	15
Mud and sand	Carrichue	2		<0.35		<0.95	<0.41	1.5
Mud and sand	Dundrum Bay	1		<0.44		<1.2	<0.57	5.4
Sand	Portrush	2		<0.29		<0.88	<0.38	0.72
Seawater	North of Larne	11			0.0053		*	0.02

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cod	Kilkeel	4			<0.18		
Plaice	Kilkeel	4			<0.06		
Haddock	Kilkeel	4			<0.28		
Hake	Kilkeel	3			<0.22		
Herring	Ardglass	2			<0.48		
Spurdog	North coast	4			<0.11		
Spurdog	Kilkeel	1			<0.13		
Crabs	Kilkeel	4			<0.23		
Lobsters	Ballycastle	2			0.55		
Lobsters	Kilkeel	4			<0.14		
Nephrops	Kilkeel	4	0.0017	0.0095	0.024	*	*
Winkles	Minerstown	4	0.020	0.11	0.11	*	0.00011
Mussels	Carlingford Lough	2			0.31		
Scallops	Co. Down	2			<0.29		
Ascophyllum nodosum	Ardglass	1			0.14		
Fucus spp.	Carlingford Lough	4			<0.11		
Fucus spp.	Portrush	4			<0.29		
Fucus vesiculosus	Ardglass	3			<0.46		
Rhodymenia spp.	Strangford Lough	4	0.047	0.25	0.33	*	0.00061
Mud	Carlingford Lough	2	1.9	12	13	0.013	0.016
Mud	Dundrum Bay	1			<4.3		
Mud	Oldmill Bay	2			<16		
Mud	Strangford Lough-Nicky's point	2			9.0		
Mud	Ballymacormick	2			12		
Mud and sand	Carrichue	2	0.041	0.25	0.37	*	*
Mud and sand	Dundrum Bay	1			<2.3		
Sand	Portrush	2			<1.4		

* *Not detected by the method used*

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

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

Table 8.5(b). Monitoring of radiation dose rates in Northern Ireland, 2008

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lishally	Mud	1	0.066
Eglington	Shingle	1	0.058
Carrichue	Mud	1	0.069
Bellerena	Mud	1	0.061
Benone	Sand	1	0.061
Castlerock	Sand	1	0.063
Portstewart	Sand	1	0.066
Portrush, Blue Pool	Sand	1	0.064
Portrush, White Rocks	Sand	1	0.060
Portballintrae	Sand	1	0.058
Giant's Causeway	Sand	1	0.068
Ballycastle	Sand	1	0.060
Cushendun	Sand	1	0.063
Cushendall	Sand and stones	1	0.069
Red Bay	Sand	1	0.072
Carnlough	Sand	1	0.058
Glenarm	Sand	1	0.056
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.057
Drains Bay	Sand	1	0.055
Larne	Sand	1	0.061
Whitehead	Sand	1	0.068
Carrickfergus	Sand	1	0.058
Jordanstown	Sand	1	0.065
Helen's Bay	Sand	1	0.058
Groomsport	Sand	1	0.071
Millisle	Sand	1	0.067
Ballywalter	Sand	1	0.067
Ballyhalbert	Sand	1	0.064
Cloghy	Sand	1	0.076
Portaferry	Shingle and stones	1	0.097
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.092
Ards Maltings	Mud	1	0.085
Island Hill	Mud	1	0.072
Nicky's Point	Mud	1	0.071
Strangford	Shingle and stones	1	0.093
Kilclief	Sand	1	0.079
Ardglass	Mud	1	0.089
Killough	Mud	1	0.086
Rocky Beach	Sand	1	0.074
Tyrella	Sand	1	0.080
Dundrum	Sand	1	0.092
Newcastle	Sand	1	0.092
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.090
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.082
Rostrevor	Sand	1	0.10
Narrow Water	Mud	1	0.097

Table 8.6. Concentrations of radionuclides in regional diet (TDS survey), 2008[a]

Country	Town	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
England	Harpurhey	1	<2.1	30	<0.35	70	0.057	0.02	0.047	0.064
England	Workington	1	<2.1	40	<0.33	65	0.039	<0.06	0.069	0.029
England	Sheffield	1	<2.0	40	<0.18	73	<0.058	0.30	<0.020	0.037
England	Grantham	1	<2.0	40	<0.36	79	0.036	0.07	<0.010	0.038
England	Hertford	1	<2.0	40	<0.26	73	0.035	0.04	0.020	0.039
England	Maidenhead	1	33[b]	40	<0.20	69	0.033	<0.06	<0.030	0.050
England	Earls Court	1	<2.1	30	<0.22	63	<0.071	0.03	0.018	0.062
England	Shaftesbury	1	<2.0	30	<0.22	70	0.050	0.04	0.017	0.029
Wales	Cardiff	1	<2.0	30	<0.38	69	0.052	0.05	0.024	0.057
England	Northfield	1	<2.0	30	<0.28	67	0.030	<0.06	0.026	0.037
Northern Ireland	Bangor	1	<2.1	40	<0.43	62	<0.042	0.03	0.045	0.050
Mean			<2.0	35	<0.29	69	<0.046	<0.07	<0.030	0.045

Country	Town	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{236}Ra	^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
England	Harpurhey	1	0.028	0.00084	0.015	0.00060	0.013	<0.00017	0.00017	<0.000087
England	Workington	1	0.029	0.00047	0.017	0.00070	0.017	<0.00019	0.00028	0.00068
England	Sheffield	1	0.021	0.0039	0.014	<0.00050	0.012	<0.00017	0.00061	0.0011
England	Grantham	1	0.042	0.00057	0.015	0.0013	0.0087	<0.00012	0.00077	0.0011
England	Hertford	1	0.025	0.0015	0.011	0.00060	0.010	<0.00010	0.0021	0.0019
England	Maidenhead	1	0.043	0.0029	0.021	0.0011	0.020	<0.000092	0.00030	<0.00040
England	Earls Court	1	0.025	0.00097	0.025	0.0010	0.021	<0.00019	<0.00038	<0.00050
England	Shaftesbury	1	0.031	<0.00058	0.0085	0.00080	0.0054	<0.00015	<0.00040	<0.00050
Wales	Cardiff	1	0.029	0.00031	0.016	0.00040	0.012	<0.00018	<0.00043	<0.00040
England	Northfield	1	0.037	0.0012	0.021	0.0017	0.017	<0.00019	0.00017	<0.00060
Northern Ireland	Bangor	1	0.028	0.00061	0.011	0.00050	0.010	<0.00011	0.00016	<0.00060
Mean			0.031	<0.0013	0.016	<0.00084	0.013	<0.00015	<0.00052	<0.00072

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

[b] *This result is believed to be anomalous but the dose implications are small. This result has not been included in the mean*

Table 8.7. Concentrations of radionuclides in regional diet in Scotland, 2008[a]

Area	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra
Aberdeen (Aberdeenshire)	1	<20	37	<1.0	<0.050	<0.40	<0.090	0.039	0.051
Cumbernauld (Dunbartonshire)	1	<20	52	<1.0	<0.050	<0.40	<0.12	0.038	0.036

Area	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
		^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239+240}$Pu	^{241}Am
Aberdeen (Aberdeenshire)	1	0.011	0.0011	0.011	<0.00020	<0.00020	<0.0016
Cumbernauld (Dunbartonshire)	1	0.020	0.0010	0.019	<0.00020	<0.00020	<0.00080

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

Table 8.8. Estimates of radiation exposure from radionuclides in diet, 2008[a]

Region	Mean[b] exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides[c]	Naturally occurring radionuclides[d]	All radionuclides	Location	All radionuclides
England	0.001	0.035	0.036	Harpurhey	0.048
Wales	0.001	0.038	0.039	Cardiff	0.039
Northern Ireland	0.001	0.042	0.043	Bangor	0.043
Scotland	0.003	0.054	0.057	Cumbernauld	0.062
UK	0.001	0.039	0.040	Cumbernauld	0.062

[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 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*

Table 8.9. Concentrations of radionuclides in canteen meals, 2008[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	4	32	90	0.048	<0.06
Northern Ireland	4	24	95	0.058	<0.07
Scotland	12	30		<0.053	<0.04
Wales	4	26	90	<0.040	<0.04

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

Table 8.10. Concentrations of radionuclides in milk remote from nuclear sites, 2008

Location	Selection[a]	No. of farms/dairies[b]	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{14}C	^{90}Sr	Total Cs
Co. Antrim		1	<5.0	18	0.020	0.18
Co. Armagh		1	<4.5	16	0.021	0.099
Cambridgeshire		1	<3.5	13	0.017	0.072
Cheshire		1	<5.0	18	0.017	0.13
Clwyd		1	<4.5	17	0.021	0.074
Cornwall		1	<4.7	16	0.028	0.083
Dorset		1	<5.0	17	0.017	0.085
Co. Down		1	<5.0	16	0.025	0.12
Essex		1	<5.0	11	0.019	0.063
Co. Fermanagh		1	<5.5	19	0.021	0.13
Gloucestershire		1	<5.0	11	0.022	0.070
Guernsey		1	<3.1	13	0.020	0.073
Gwent		1	<3.0	13	0.036	0.079
Gwynedd		1	<5.0	16	0.030	0.095
Hampshire		1	<5.0	15	0.019	0.086
Humberside		1	<5.0	15	0.019	0.090
Kent		1	<5.0	18	0.019	0.10
Kirkcudbrightshire		1	<5.0	<15	<0.10	<0.05[c]
Lanarkshire		1			0.014	0.03[c]
Lancashire		1	<5.0	19	0.021	0.094
Leicestershire		1	<4.5	21	0.019	0.076
Lincolnshie		1	<5.0	16	0.014	0.062
Middlesex		1	<5.0	19	0.020	<0.080
Midlothian		1	<5.0	<15	<0.10	<0.05[c]
Nairnshire		1	<5.0	<15	<0.10	<0.05[c]
Norfolk		1	<5.0	15	0.015	0.069
North Yorkshire		1	<4.5	18	0.021	0.077
Renfrewshire		1	<5.0	<15	<0.10	<0.06[c]
Tyneside		1	<5.0	13	0.021	0.087
Co. Tyrone		2	<3.1	15	0.022	0.13
	max			17		
Mean Values						
Channel Islands			<3.1	13	0.020	0.073
England			<4.5	15	0.019	<0.082
Northern Ireland			<3.8	16	0.022	0.13
Wales			<3.4	14	0.029	0.082
Scotland			<5.0	<15	<0.069	<0.05[c]
United Kingdom			<4.2	<15	<0.025	<0.087

[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 8.11. Concentrations of radionuclides in animals and crops remote from nuclear sites, 2008[a]

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{3}H	^{14}C	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra
Channel Islands									
Guernsey	Blackberries	1	<4.0	22	0.076	<0.024	0.096	0.030	0.023
	Lettuce	1	<5.0	<3.0	0.063	0.071	0.089	0.034	0.026
Jersey	Potatoes	1	<5.0	20	0.044	0.044			
	Strawberries	1	<5.0	9.0	0.033	0.064			
Cheshire									
Wilmslow	Carrots	1	<5.0	7.0	0.085	0.066	0.12	0.028	0.085
	Lettuce	1	<5.0	<3.0	0.017	0.032	0.078	0.023	<0.0040
Clwyd									
Colwyn Bay	Raspberries	1	<5.0	15	0.14	0.039	0.17	0.021	0.018
	Spinach	1	<5.0	<3.0	1.1	0.11	0.71	0.26	0.041
Devon									
Torrington	Lettuce	1	<5.0	4.0	0.24	0.12	0.40	0.19	0.0070
	Turnips	1	<5.0	10	0.23	0.042	0.038	0.012	0.030
East Lothian									
North Berwick	Lettuce	4			<0.10	<0.05[b]			
Dumfriesshire									
Dumfries	Lettuce	4			<0.10	<0.05[b]			
Gloucestershire									
Tewkesbury	Cabbage	1	<5.0	14	0.21	0.059	0.073	0.027	0.040
	Strawberries	1	<5.0	12	0.041	0.099	0.059	0.023	0.020
Herefordshire									
Ross-on-Wye	Cabbage	1	<4.0	4.0	0.072	0.033	<0.043	0.010	0.004
	Potatoes	1	<5.0	20	0.038	0.062	<0.042	0.0027	0.019
Kent									
Sittingbourne	Cabbage	1	<5.0	7.0	0.064	0.051	0.062	0.018	0.014
	Strawberries	1	<5.0	9.0	0.073	0.078	<0.038	0.017	0.034
Leicestershire									
Loughborough	Cabbage	1	<5.0	7.0	0.13	0.030	0.12	0.016	0.034
	Strawberries	1	<5.0	7.0	0.029	0.034	0.10	0.016	0.019
Lincolnshire									
Louth	Cabbage	1	<5.0	8.0	0.12	0.059	<0.042	0.010	0.017
	Potatoes	1	<5.0	13	0.042	0.067	0.094	0.0057	0.0080
North Yorkshire									
Harrogate	Blackberries	1	<5.0	16	0.061	<0.012	0.16	0.12	0.023
	Lettuce	1	<5.0	<3.0	0.13	<0.028	0.25	0.061	0.043
Northumbria									
Corbridge	Chard	1	<4.0	6.0	0.35	0.15	0.59	0.19	0.13
	Raspberries	1	<5.0	14	0.049	0.015	0.040	0.017	0.025
Pembrokeshire									
Fishguard	Cabbage	1	<5.0	3.0	0.23	0.077	<0.052	0.016	<0.0030
	Potatoes	1	<5.0	22	0.038	0.26	0.080	0.0073	0.0090
Renfrewshire									
Paisley	Lettuce	4			<0.10	<0.05[b]			
Ross-shire									
Dingwall	Lettuce	4			<0.10	<0.06[b]			
Somerset									
Yeovil	Cabbage	1	<5.0	7.0	0.058	0.068	<0.030	0.0091	0.051
	Potatoes	1	<5.0	19	0.021	0.048	0.039	0.0093	0.017
Staffordshire									
Stafford	Lettuce	1	<5.0	6.0	0.16	0.040	0.30	0.10	0.032
	Strawberries	1	<5.0	11	0.047	0.024	<0.041	0.012	0.027
Suffolk									
Newmarket	Lettuce	1	<5.0	<3.0	0.16	0.073	0.15	0.094	0.021
	Potatoes	1	<6.0	16	0.038	0.047	<0.036	<0.0016	0.013
Surrey									
Weybridge	Beef Kidney	1	<8.0	20	0.092	0.46			
	Beef Liver	1	<7.0	26	<0.0090	0.88			
	Beef Muscle	1	<6.0	15	<0.0070	0.79			
	Sheep Kidney/Liver	1	<8.0	17	0.053	0.84			
	Sheep Muscle	1	<6.0	40	<0.0070	0.53			
West Sussex									
Worthing	Cabbage	1	<5.0	15	0.19	0.030	0.059	0.019	0.020
	Potatoes	1	<5.0	19	0.035	<0.027	<0.047	0.0045	0.0080
Wiltshire									
Marlborough	Chard	1	<5.0	6.0	0.11	0.11	0.45	0.21	0.047
	Strawberries	1	<5.0	15	0.065	<0.026	<0.033	0.019	0.010
Yorkshire (East Riding)									
Great Driffield	Lettuce	1	<4.0	<3.0	0.15	0.072	0.46	0.12	0.012
	Potatoes	1	<5.0	13	0.038	0.076	0.045	0.0053	0.021
Mean Values[c]									
Channel Islands			<4.8	<14	0.054	<0.051	0.093	0.032	0.025
England			<5.2	<12	<0.092	<0.15	<0.13	<0.046	<0.028
Wales			<5.0	<11	0.38	0.12	<0.25	0.076	<0.018
Scotland					<0.10	<0.05[b]			
Great Britain			<5.2	<12	<0.12	<0.12	<0.15	<0.050	<0.027

Table 8.11. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Channel Islands									
Guernsey	Blackberries	1	<0.0012	0.0024	<0.00070	<0.0010	0.00020	<0.00020	0.00070
	Lettuce	1	0.0051				<0.00010	<0.00020	<0.00020
Jersey	Potatoes	1					<0.00010	<0.00010	0.00020
	Strawberries	1					<0.00010	<0.00010	<0.00020
Cheshire									
Wilmslow	Carrots	1	0.0022	0.0045	<0.00070	0.0024			
	Lettuce	1	<0.0010						
Clwyd									
Colwyn Bay	Raspberries	1	<0.00060						
	Spinach	1	0.019						
Devon									
Torrington	Lettuce	1	0.0056						
	Turnips	1	0.0019	0.0030	<0.00060	0.0043			
Gloucestershire									
Tewkesbury	Cabbage	1	<0.0020						
	Strawberries	1	<0.00090	0.0018	<0.00070	0.0018			
Herefordshire									
Ross-on-Wye	Cabbage	1	0.0010						
	Potatoes	1	0.0011						
Kent									
Sittingbourne	Cabbage	1	0.00070						
	Strawberries	1	0.0099						
Leicestershire									
Loughborough	Cabbage	1	<0.0010						
	Strawberries	1	0.0010						
Lincolnshire									
Louth	Cabbage	1	<0.0018						
	Potatoes	1	0.0071	0.0074	<0.00090	0.0060			
North Yorkshire									
Harrogate	Blackberries	1	0.0013	0.0018	<0.00060	0.0029			
	Lettuce	1	0.014						
Northumbria									
Corbridge	Chard	1	<0.0024	0.0027	<0.00060	0.0024			
	Raspberries	1	<0.0010						
Pembrokeshire									
Fishguard	Cabbage	1	0.00090	0.010	0.00050	0.0093			
	Potatoes	1	0.0023						
Somerset									
Yeovil	Cabbage	1	0.0014						
	Potatoes	1	0.0055	0.0044	0.00040	0.0049			
Staffordshire									
Stafford	Lettuce	1	0.0084						
	Strawberries	1	0.0012						
Suffolk									
Newmarket	Lettuce	1	0.0028	0.013	<0.00080	0.010			
	Potatoes	1	0.0019						
Surrey									
Weybridge	Beef Kidney	1		0.0026	<0.0012	0.0023	<0.00020	<0.00030	<0.00040
	Beef Liver	1					<0.00010	<0.00020	<0.00020
	Beef Muscle	1					<0.00010	0.00020	<0.00020
	Sheep Kidney/Liver	1					<0.00010	<0.00020	<0.00020
	Sheep Muscle	1					<0.00010	<0.00010	<0.00030
West Sussex									
Worthing	Cabbage	1	<0.0010						
	Potatoes	1	0.0029	0.0034	<0.00040	0.0037			
Wiltshire									
Marlborough	Chard	1	<0.0012						
	Strawberries	1	0.00080						
Yorkshire (East Riding)									
Great Driffield	Lettuce	1	0.0019						
	Potatoes	1	0.0021						
Mean Values[c]									
Channel Islands			<0.0032	0.0024	<0.00070	<0.0010	<0.00013	<0.00015	<0.00033
England			<0.0029	0.0045	<0.00069	0.0041	<0.00012	<0.00020	<0.00026
Wales			<0.0058	0.010	0.00050	0.0093			
Scotland									
Great Britain			<0.0032	0.0050	<0.00067	0.0046	<0.00012	<0.00020	<0.00026

[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] *Great Britain mean excludes Channel Islands. Mean values include crops and animals*

Table 8.12. Concentrations of caesium-137 in imported foods monitored at ports, 2008

Port	Country of origin	Foodstuff	No. of sampling observations	Mean radioactivity concentration, Bq kg^{-1} (fresh)[a] ^{137}Cs	Dilution factor
Dover					
	Ukraine	Blueberries	1	330	Nil
	Morocco	Strawberries	1	<4.0	Nil
	Serbia	Blackberries	1	<3.0	Nil
	Poland	Bilberries	1	44	Nil
Felixstowe					
	Holland	Blueberry juice concentrate	2	550	0.05

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

Table 8.13. Concentrations of radionuclides in rainwater and air 2008

Location	Sample	Number of sampling observations	Mean radioactivity concentration[a] ^{3}H	^{7}Be	^{40}K	^{90}Sr[b]	^{137}Cs	^{210}Pb	^{214}Pb	^{234}Th	$^{239}Pu+$ ^{240}Pu[c]	^{241}Am[c]	Gross alpha[d]	Gross beta[d]
Ceredigion														
Aberporth	Rainwater	4	<0.60	<1.1	*		<0.042	*	*	*	$<3.2\ 10^{-5}$	$3.9\ 10^{-5}$		
	Air	4		0.0020	$8.6\ 10^{-5}$		$<6.4\ 10^{-7}$	0.00014	$1.1\ 10^{-6}$	*	$4.1\ 10^{-10}$	$<1.1\ 10^{-8}$		
Co. Down														
Conlig	Rainwater	4		1.6	*		<0.039	*	*	*				
	Air	4		0.0020	$7.5\ 10^{-5}$		$<5.5\ 10^{-7}$	0.00013	*	*				
Dumfries and Galloway														
Eskdalemuir	Rainwater	4	<0.60	1.5	*		<0.013	*	*	0.15				
	Air	4		0.0015	$7.1\ 10^{-5}$		$<5.1\ 10^{-7}$	$9.1\ 10^{-5}$	*	*				
Glasgow														
Glasgow	Air	12		0.0025			<0.010							<0.0020
North Yorkshire														
Dishforth	Rainwater	4		1.9	*		<0.041	*	*	*				
	Air	4		0.0015	$8.8\ 10^{-5}$		$<6.2\ 10^{-7}$	0.00010	*	*				
Oxfordshire														
Chilton	Rainwater	4		<0.88	*	<0.00064	<0.038	*	*	*			<0.020	0.14
	Air	4		0.0020	$7.8\ 10^{-5}$		$<6.1\ 10^{-7}$	0.00014	*	*				
Shetland														
Lerwick	Rainwater	4		2.2	*		<0.040	*	*	*				
	Air	4		0.0019	$9.8\ 10^{-5}$		$<7.6\ 10^{-7}$	0.00011	*	*				
Suffolk														
Orfordness	Rainwater	4	<0.60	<1.9	*		<0.087	*	*	*				
	Air	4		0.0021	$8.0\ 10^{-5}$		$<6.3\ 10^{-7}$	0.00015	*	*				

* *Not detected by the method used*

[a] *Bq l^{-1} for rainwater and Bq kg^{-1} for air. 1kg air occupies $1m^3$ at standard temperature and pressure*

[b] *Bulked from 4 quarterly samples*

[c] *Separate annual sample for rain, annual bulked sample for air*

[d] *Bulked from 12 monthly samples*

Table 8.14. Concentrations of radionuclides in sources of drinking water in Scotland, 2008

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Angus	Loch Lee	4	<1.0	<0.0050	<0.01	<0.078	<0.081
Argyll and Bute	Auchengaich	1	<1.0		<0.01	<0.010	0.049
Argyll and Bute	Helensburgh Reservoir	1	<1.1		<0.01	<0.010	0.016
Argyll and Bute	Loch Ascog	1	<1.1		<0.01	<0.010	0.13
Argyll and Bute	Loch Eck	1	1.6		<0.01	<0.010	0.031
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.0		<0.01	<0.010	0.033
Argyll and Bute	Loch Finlas	1	<1.0		<0.01	<0.010	0.017
Clackmannanshire	Gartmorn	1	<1.0		<0.01	<0.010	0.11
Dumfries and Galloway	Black Esk	1	<1.1		<0.01	<0.010	0.041
Dumfries and Galloway	Purdomstone	1	2.5		<0.01	<0.010	0.092
Dumfries and Galloway	Winterhope	1	<4.0		<0.01	<0.010	0.049
East Lothian	Hopes Reservoir	1	<1.0		<0.01	<0.013	0.025
East Lothian	Thorters Reservoir	1	<1.0		<0.01	<0.011	0.036
East Lothian	Whiteadder	1	<1.0		<0.01	<0.010	0.035
Fife	Holl Reservoir	1	<1.0		<0.01	<0.010	0.040
Highland	Loch Baligill	1	<1.1		0.02	<0.010	0.063
Highland	Loch Calder	1	<1.1		<0.01	<0.011	0.063
Highland	Loch Glass	4	<1.0	<0.0050	<0.01	<0.055	<0.066
Highland	Loch Shurrerey	1	<1.1		<0.01	<0.010	0.045
North Ayrshire	Camphill	1	<1.0		<0.01	<0.010	0.035
North Ayrshire	Knockendon Reservoir	1	<1.1		<0.01	<0.010	0.040
North Ayrshire	Munnoch Reservoir	1	<1.1		<0.01	<0.010	0.053
North Ayrshire	Outerwards	1	<1.0		<0.01	0.012	0.037
Perth and Kinross	Castlehill	1	<1.0		<0.01	<0.010	0.029
Scottish Borders	Knowesdean	4	<1.0	<0.0050	<0.01	<0.033	<0.048
Stirling	Loch Katrine	12	<1.0	0.0035	<0.002	<0.024	<0.042
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0		<0.01	<0.010	0.024
West Lothian	Morton No 2	1	<1.0		<0.01	<0.010	0.031

Table 8.15. Concentrations of radionuclides in sources of drinking water in England and Wales, 2008

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{40}K	^{90}Sr	^{125}I
England						
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.044	<0.0010	
Cambridgeshire	Grafham Water	4	<4.0	0.28	0.0025	
Cheshire	River Dee, Chester	4	<4.0	0.075	0.0036	<0.0020
Cornwall	River Fowey	4	<4.0	0.086	0.0021	<0.0020
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.080	0.0030	
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.059	0.0051	
County Durham	River Tees, Darlington	4	<4.0	0.043	0.0048	<0.0030
Cumbria	Haweswater Reservoir	4	<4.0	<0.029	0.0034	
Cumbria	Ennerdale Lake	4	<4.0	<0.031	0.0026	
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.045	0.0022	
Derbyshire	Matlock, Groundwater[a]	3	<4.0	0.048	<0.0010	
Devon	River Exe, Exeter	4	<4.0	0.080	0.0027	<0.0020
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.15	0.0025	<0.0020
Greater London	River Lee, Chingford	4	<4.0	0.29	<0.0013	<0.0019
Hampshire	River Avon, Christchurch	4	<4.0	0.070	0.0013	<0.0020
Humberside	Littlecoates, Groundwater	4	<4.0	0.12	<0.0012	
Kent	Denge, Shallow Groundwater	4	<4.0	0.13	0.0036	
Kent	Chatham, Deep Groundwater	4	<4.0	0.048	0.0017	
Lancashire	Corn Close, Groundwater	4	<4.0	0.10	<0.0013	
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.11	0.0022	<0.0020
Northumberland	Kielder Reservoir	4	<4.0	0.066	0.0038	
Oxfordshire	River Thames, Oxford	4	<4.0	0.15	0.0027	<0.0020
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.073	0.0017	
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.13	0.0032	
Surrey	River Thames, Walton	4	<4.0	0.17	0.0016	<0.0020
Surrey	River Thames, Chertsey	4	<4.0	0.18	0.0015	<0.0020
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<4.0	0.077	0.0031	
Yorkshire	Chellow Heights, Bradford	2	<4.0	0.18	<0.0010	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England						
Buckinghamshire	Bourne End, Groundwater	4	<0.0012	0.021	0.057	<0.052
Cambridgeshire	Grafham Water	4	<0.0010	0.024	0.39	0.25
Cheshire	River Dee, Chester	4	<0.0013	0.016	0.12	0.077
Cornwall	River Fowey	4	<0.0011	0.067	0.23	0.15
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.0010	<0.020	0.090	0.057
County Durham	Honey Hill Water Treatment Works, Consett	4	0.0028	0.042	0.099	0.063
County Durham	River Tees, Darlington	4	<0.0010	0.019	0.078	0.049
Cumbria	Haweswater Reservoir	4	<0.0011	<0.020	<0.048	<0.050
Cumbria	Ennerdale Lake	4	<0.0011	<0.020	<0.050	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<0.0010	0.020	0.063	<0.052
Derbyshire	Matlock, Groundwater	3	<0.0010	0.090	0.12	0.074
Devon	River Exe, Exeter	4	<0.0010	0.040	0.13	0.082
Gloucestershire	River Severn, Tewkesbury	4	<0.0010	0.046	0.24	0.15
Greater London	River Lee, Chingford	4	<0.0010	0.021	0.38	0.24
Hampshire	River Avon, Christchurch	4	<0.0010	0.019	0.10	0.064
Humberside	Littlecoates, Groundwater	4	<0.0011	0.020	0.15	0.092
Kent	Denge, Shallow Groundwater	4	<0.0010	<0.0020	0.20	0.13
Kent	Chatham, Deep Groundwater	4	<0.0010	<0.019	0.072	0.053
Lancashire	Corn Close, Groundwater	4	<0.0010	<0.020	0.12	0.077
Norfolk	River Drove, Stoke Ferry	4	<0.0010	0.028	0.15	0.096
Northumberland	Kielder Reservoir	4	<0.0013	0.023	0.081	0.060
Oxfordshire	River Thames, Oxford	4	<0.0010	0.026	0.20	0.13
Somerset	Ashford Reservoir, Bridgwater	4	<0.0010	0.018	0.087	0.058
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.0010	0.020	0.19	0.12
Surrey	River Thames, Walton	4	<0.0010	0.020	0.21	0.13
Surrey	River Thames, Chertsey	4	<0.0010	0.021	0.25	0.16
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<0.0014	0.047	0.15	0.094
Yorkshire	Chellow Heights, Bradford	2	<0.0013	<0.020	0.051	<0.050

Table 8.15. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}		
			^{3}H	^{40}K	^{90}Sr
Wales					
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.013	0.0038
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	0.045	0.0025
Powys	Elan Valley Reservoir	4	<4.0	0.026	0.0043

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.0010	<0.020	0.063	<0.054
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.0010	<0.022	<0.048	<0.050
Powys	Elan Valley Reservoir	4	<0.0010	<0.020	<0.050	<0.050

1 *Using ^{137}Cs standard*
2 *Using ^{40}K standard*
a *The concentrations of ^{210}Po, ^{226}Ra, ^{234}U, ^{235}U and ^{238}U were <0.010, 0.011, 0.041, <0.010 and 0.021 Bq l^{-1} respectively*

Table 8.16. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2008

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	Gross alpha	Gross beta
Co. Londonderry	R Faughan	4	<1.0	<0.0016	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.027	0.062
Co. Antrim	Lough Neagh	4	<1.0	<0.0018	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.044
Co. Down	Silent Valley	4	<1.0	<0.0016	<0.05	<0.012	<0.010	<0.010	<0.010	<0.010	<0.020	0.083

Table 8.17. Estimates of radiation exposure from radionuclides in drinking water, 2008[a]

Region	Mean exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides[b,c]	Naturally occurring radionuclides[b,d]	All radionuclides	Location	All radionuclides
England	<0.001	0.028	0.028	Matlock, Groundwater, Derbyshire	0.028
Wales[e]	<0.001			Elan Valley Reservoir, Powys	<0.001[e]
Northern Ireland	<0.001	0.028	0.028	Silent Valley, Co. Down	0.031
Scotland[e]	<0.001			Loch Lee, Angus; Loch Glass, Highland; Knowesdean, Scottish Borders	<0.001[e]
UK	<0.001	0.028	0.028	Silent Valley, Co. Down	0.031

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 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*

Table 8.18. Analysis of groundwater in Scotland, 2008

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Aberdeenshire	Braemar, Borehole	2	<1.1	<0.01	<0.010	0.040
Aberdeenshire	Nr Peterhead, Shallow well	2	<1.0	<0.01	0.015	0.11
Aberdeenshire	Turriff, Borehole	2	<1.0	<0.01	<0.018	0.063
Dumfriesshire	Nr Annan, Borehole	2	2.4	<0.01	0.033	0.062
Dumfriesshire	Dumfries, Deep borehole	2	1.1	<0.01	<0.013	0.064
Fife	Deep borehole	2	<1.0	<0.01	<0.010	0.095
Invernesshire	Tomich, Borehole	2	<1.2	<0.01	<0.010	0.052
Kirkcudbrightshire	Nr Castle Douglas, Shallow borehole	2	<1.0	<0.01	<0.010	0.042
Midlothian	Nr Selkirk, Shallow borehole	2	<1.0	<0.01	<0.010	0.047
Orkney	Shapinsay, Borehole	1	1.1	<0.01	<0.010	0.059
Perthshire	Shallow borehole	2	<1.0	<0.01	<0.010	<0.022

Table 8.19. Concentrations of radionuclides in sediments in Scotland, 2008

Area Location	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}													
		^{3}H	^{14}C	^{90}Sr	^{99}Tc	^{137}Cs	^{155}Eu	^{210}Pb	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+$ ^{240}Pu	Gross alpha	Gross beta
Marine samples															
Kincardineshire															
Stonehaven Bay position 1	1	<1.5	<15	<0.12	<0.95	1.1	0.33	5.0	4.2	<0.21	4.1	0.21	0.34	100	1300
Stonehaven Bay position 2	1	<1.0	<15	<0.13	<1.4	0.99	<0.22	6.3	3.6	0.16	3.7	<0.068	0.39	160	1300
Stonehaven Bay position 3	1	<1.6	<15	<0.11	<0.90	1.2	0.36	7.1	3.5	0.15	3.9	<0.047	0.34	73	1400
Angus															
Montrose position 1	1	<1.6	<15	<0.10	<0.59	0.61	0.29	3.9	2.7	0.097	3.0	0.081	0.15	110	1300
Montrose position 2	1	<1.5	<15	<0.11	<1.1	0.51	0.60	3.7	3.1	0.12	3.1	<0.060	0.13	79	1200
Montrose position 3	1	<1.6	<15	<0.11	<0.66	0.78	<0.32	4.1	3.0	0.16	3.2	<0.032	0.26	<38	1100
Fife															
St Andrews position 1	1	<1.0	<15	<0.51	1.1	0.97	<0.16	4.2	2.3	<0.074	2.3	0.13	0.44	62	440
St Andrews position 2	1	<1.0	<15	<0.29	1.2	0.96	<0.24	4.6	2.5	0.13	2.4	<0.12	<0.45	80	560
St Andrews position 3	1	<1.0	<15	<0.25	0.84	0.87	<0.20	3.9	2.1	0.10	2.1	0.13	0.34	68	580
East Lothian															
Gullane Sands position 1	1	<1.0	<15	<0.28	0.88	0.49	0.32	2.8	2.7	<0.20	2.3	<0.030	0.15	47	350
Gullane Sands position 2	1	<1.0	<15	<0.31	1.3	0.49	<0.20	3.2	2.1	0.076	1.9	<0.036	0.11	68	390
Gullane Sands position 3	1	<1.0	<15	<0.34	0.56	0.49	<0.38	3.3	2.7	<0.12	2.5	0.053	0.098	67	410
Berwickshire															
Eyemouth position 1	1	<1.0	<15	<0.27	1.4	1.9	0.38	7.1	4.4	0.13	3.8	0.24	0.48	120	790
Eyemouth position 2	1	<1.0	<15	<0.30	1.6	1.8	0.32	5.5	4.2	<0.16	3.6	0.15	0.51	61	690
Eyemouth position 3	1	<1.0	<15	<0.23	1.1	2.0	0.64	6.4	3.9	0.16	3.6	0.14	0.37	190	710
Freshwater samples															
Shetland															
Olnafirth	1	<4.0				6.5								84	540
Aberdeenshire															
Aberdeen	1	<4.0				1.6								87	1500
South Lanarkshire															
Logan Water position 1[a]	1					58									
Logan Water position 2[b]	1					50									
Logan Water position 3[c]	1					31									

[a] *The concentrations of ^{212}Pb, ^{212}Bi, ^{214}Pb and ^{214}Bi were 13, 15, 10 and 7.5 Bq kg^{-1} respectively*
[b] *The concentrations of ^{212}Pb, ^{212}Bi, ^{214}Pb and ^{214}Bi were 11, 11, 10 and 9.3 Bq kg^{-1} respectively*
[c] *The concentrations of ^{212}Pb, ^{212}Bi, ^{214}Pb and ^{214}Bi were 6.3, 7.1, 5.4 and 4.6 Bq kg^{-1} respectively*

Table 8.20. Concentrations of radionuclides in seawater, 2008

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag
Dounreay (Sandside Bay)	4	<1.0		<0.10			<0.36	<0.10
Dounreay (Brims Ness)	4	<1.0		<0.10			<0.25	<0.10
Rosyth	2	<1.4		<0.10			<0.26	<0.10
Torness	2	130		<0.10			<0.23	<0.10
Hartlepool (North Gare)	2	<4.0		<0.30			<2.1	<0.31
Sizewell	2	<7.2		<0.31			<2.0	<0.30
Bradwell	2			<0.31			<2.2	<0.32
Dungeness south	2	<4.5		<0.30			<2.1	<0.30
Winfrith (Lulworth Cove)	1			<0.42			<2.6	<0.45
Alderney	4[F]	3.8						
Devonport (Millbrook Lake)	2	<4.0	<4.5	<0.31				
Devonport (Tor Point South)	2	<4.7	<4.5	<0.29				
Hinkley	2			<0.40	<0.040		<2.7	<0.38
Berkeley and Oldbury	2			<0.31			<2.1	<0.30
Cardiff (Orchard Ledges)[a]	2	19	<4.5	<0.30				
Holyhead	4[c]	<1.8						
Wylfa (Cemaes Bay)	2	<4.5		<0.30			<2.1	<0.31
Wylfa (Cemlyn Bay East)	1			<0.31			<2.1	<0.24
Wylfa (Cemlyn Bay West)	1			<0.30			<2.1	<0.38
Heysham (inlet)	2	21		<0.34			<2.3	<0.34
Seascale (Particulate)	2			<0.07	<0.030		<0.54	<0.08
Seascale (Filtrate)	2			<0.42	<0.060	<0.20	<2.7	<0.44
St. Bees	4	<9.3				<0.80		
St. Bees (Particulate)	2			<0.05	<0.030		<0.38	<0.05
St. Bees (Filtrate)	2	<7.0		<0.13	<0.045	<0.30	<0.90	<0.13
Seafield	4	<2.3		<0.10			<0.38	<0.10
Southerness[b]	4	3.9		<0.10			<0.34	<0.10
Auchencairn	4	3.4		<0.10			<0.33	<0.10
Knock Bay	4	<1.5		<0.10			<0.53	<0.10
Knock Bay	4[c]	<1.8						
Hunterston	2	3.8						
North of Larne	11[N]					0.0053		
Faslane (Carnban)	2	<1.4		<0.10			<0.31	<0.10

Table 8.20. continued

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}					
		^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	4	<0.10	<0.10	<0.23	<0.10		
Dounreay (Brims Ness)	4	<0.10	<0.10	<0.16	<0.10		
Rosyth	2	<0.10	<0.10	<0.16	<0.10		
Torness	2	<0.10	<0.10	<0.15	<0.10		
Hartlepool (North Gare)	2	<0.25	<0.25	<1.1	<0.37	<3.5	15
Sizewell	2	<0.26	<0.27	<1.1	<0.37	<3.5	14
Bradwell	2	<0.28	<0.27	<1.1	<0.37	<4.5	18
Dungeness south	2	<0.25	<0.25	<1.1	<0.36	<5.5	16
Winfrith (Lulworth Cove)	1	<0.34	<0.32	<1.1	<0.38	<3.0	14
Alderney	4[F]	*	0.001				
Jersey	1[F]	*	0.001				
Guernsey	4[F]	*	0.002				
Hinkley	2	<0.33	<0.33	<1.3	<0.42	<2.0	9.5
Berkeley and Oldbury	2	<0.25	<0.25	<1.1	<0.36	<1.2	4.0
Cardiff (Orchard Ledges)[a]	2		<0.27				
Holyhead	4[c]	*	0.02				
Wylfa (Cemaes Bay)	2	<0.26	<0.26	<1.1	<0.37	<3.0	8.8
Wylfa (Cemlyn Bay East)	1	<0.23	<0.25	<1.1	<0.37	<6.0	14
Wylfa (Cemlyn Bay West)	1	<0.30	<0.26	<1.2	<0.36	<5.0	18
Llandudno	1[c]	*	0.03				
Prestatyn	1[c]	*	0.03				
New Brighton	1[c]	*	0.03				
Ainsdale	1[c]	*	0.05				
Rossall	1[c]	*	0.08				
Heysham (inlet)	2	<0.27	<0.30	<1.2	<0.38	<3.5	11
Half Moon Bay	1[c]	*	0.11				
Silecroft	1[c]	*	0.09				
Seascale (Particulate)	2	<0.06	<0.06	<0.22	<0.09	0.38	0.15
Seascale (Filtrate)	2	<0.35	<0.34	<1.3	<0.42	<3.5	13
St. Bees	4	<0.16	<0.17				
St. Bees (Particulate)	2	<0.04	<0.04	<0.18	<0.17	<0.30	<1.6
St. Bees (Filtrate)	2	<0.10	<0.11	<0.49	<0.16	<0.90	4.5
Whitehaven	1[c]	*	0.07				
Maryport	1[c]	*	0.09				
Silloth	1[c]	*	0.10				
Seafield	4	<0.10	<0.11	<0.24	<0.10		
Southerness[b]	4	<0.10	<0.11	<0.21	0.0049		
Auchencairn	4	<0.10	<0.10	<0.20	<0.10		
Ross Bay	1[c]	*	0.06				
Isle of Whithorn	1[c]	*	0.04				
Drummore	1[c]	*	0.05				
Knock Bay	4	<0.10	<0.10	<0.32	<0.10		
Knock Bay	4[c]	*	0.03				
North of Larne	11[N]	*	0.02				
Faslane (Carnban)	2	<0.10	<0.10	<0.18	<0.10		

* *Not detected by the method used*

[a] *The concentration of ^{3}H as tritiated water was <4.0 Bq l^{-1}, and the concentration of ^{125}I was <0.27 Bq l^{-1}*

[b] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00058 and 0.0031 Bq l^{-1} respectively*

[c] *Measurements labelled "c" are made by Cefas on behalf of Defra*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency and the Channel Island States*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

9. References

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APPENDIX 1. CD Supplement

This Appendix contains information on the methods of sampling, measurement, presentation and assessment. It is provided on the CD accompanying the printed report.

If the CD is missing, or you experience problems with accessing the contents of the CD, please contact one of the organisations given at the start of the report, via the E-Mail address.

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2008

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], TBq	Discharges during 2008	
			TBq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Sellafield Ltd)[1]				
Other authorised outlets	Alpha	BPM	$6\ 10^{-7}$	NA
	Beta	BPM	$1.17\ 10^{-6}$	NA
Incinerator	Total Alpha	$2\ 10^{-4}$	Nil	Nil
	Total Beta	$2.5\ 10^{-4}$	Nil	Nil
Capenhurst				
(Urenco UK)	Uranium	$2.5\ 10^{-6}$	$2.73\ 10^{-7}$	11
Sellafield[d,2]	Alpha	$8.8\ 10^{-4}$	$1.09\ 10^{-4}$	12
	Beta	0.042	0.00145	3.5
	Tritium	1100	141	13
	Carbon-14	3.3	0.686	21
	Krypton-85	$4.4\ 10^{5}$	$2.57\ 10^{4}$	5.8
	Strontium-90	$7.1\ 10^{-4}$	$3.76\ 10^{-5}$	5.3
	Ruthenium-106	0.028	0.00139	5.0
	Antimony-125[6]	0.0069	0.0036	52
	Iodine-129	0.07	0.00574	8.2
	Iodine-131	0.055	$6.26\ 10^{-4}$	1.1
	Caesium-137	0.0058	$1.31\ 10^{-4}$	2.3
	Plutonium alpha	$1.9\ 10^{-4}$	$2.27\ 10^{-5}$	12
	Plutonium-241	0.003	$2.62\ 10^{-4}$	8.7
	Americium-241 and curium-242	$1.2\ 10^{-4}$	$1.71\ 10^{-5}$	14
Springfields	Uranium	0.0053	$5.6\ 10^{-4}$	11
Springfields	Tritium	10^{-4}	$8.7\ 10^{-7}$	<1
(National Nuclear Laboratory)[c]	Carbon-14	10^{-5}	$5.1\ 10^{-8}$	<1
	Other alpha radionuclides	10^{-6}	Nil	Nil
	Other beta radionuclides	10^{-5}	$1.5\ 10^{-9}$	<1
Research establishments				
Dounreay				
(Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$1.21\ 10^{-5}$	1.2
	Beta[f,g]	0.045	$2.01\ 10^{-4}$	<1
	Tritium	2	0.195	9.8
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$4.78\ 10^{-5}$	1.1
	Ruthenium-106	0.0039	$7.73\ 10^{-6}$	<1
	Iodine-129	0.0011	$1.05\ 10^{-4}$	9.5
	Iodine-131	$1.5\ 10^{-4}$	$6.8\ 10^{-5}$	45
	Caesium-134	$8.4\ 10^{-4}$	$1.02\ 10^{-6}$	<1
	Caesium-137	0.007	$1.42\ 10^{-5}$	<1
	Cerium-144	0.007	$6.31\ 10^{-6}$	<1
	Plutonium-241	0.0033	$3.52\ 10^{-6}$	<1
	Curium-242	$2.7\ 10^{-4}$	$2.32\ 10^{-8}$	<1
	Curium-244[h]	$5.4\ 10^{-5}$	$3.52\ 10^{-9}$	<1
Dounreay				
(Fast Reactor)	Alpha	10^{-5}	$9.29\ 10^{-9}$	<1
	Beta	0.0015	$3.52\ 10^{-8}$	<1
	Tritium	4.5	0.0015	<1
	Krypton-85	$4\ 10^{-4}$	$5.24\ 10^{-6}$	1.3
Dounreay				
(Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$3.02\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$2.76\ 10^{-7}$	<1
	Tritium	10.5	0.062	<1
	Krypton-85	4	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq	% of annual limit[b]
Dounreay				
(PFR minor sources)	Alpha[i]	$6\ 10^{-8}$	$5.28\ 10^{-10}$	<1
	Beta[f]	$5\ 10^{-7}$	$2.01\ 10^{-9}$	<1
	Tritium	0.2	$2.89\ 10^{-4}$	<1
Dounreay				
(East minor sources)	Alpha[i]	$1.37\ 10^{-5}$	$6.29\ 10^{-8}$	<1
	Beta[f]	$3.71\ 10^{-4}$	$3.66\ 10^{-7}$	<1
	Krypton-85[j]	1	Nil	Nil
Dounreay				
(West minor sources)	Alpha[i]	$3\ 10^{-7}$	$2.41\ 10^{-9}$	<1
	Beta[f,g]	$7.5\ 10^{-5}$	$1.28\ 10^{-8}$	<1
	Tritium	0.01	$2.36\ 10^{-4}$	2.4
Harwell				
(AEA Technology)	Alpha	$7\ 10^{-7}$	Nil	Nil
	Beta	$3\ 10^{-5}$	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
Harwell				
Research Sites Restoration Ltd	Alpha	$8\ 10^{-7}$	$5\ 10^{-8}$	6.2
(UKAEA)	Beta	$2\ 10^{-5}$	$7.2\ 10^{-7}$	3.6
	Tritium	15	0.32	2.1
	Krypton-85	2	Nil	Nil
	Radon-220	100	7.9	7.9
	Radon-222	3	0.32	11
	Iodines	0.01	Nil	Nil
	Other radionuclides	0.1	Nil	Nil
Harwell[5]				
(GE Healthcare B10.23)				
	Alpha	$5\ 10^{-8}$	Nil	Nil
	Beta/gamma	$1.5\ 10^{-5}$	Nil	Nil
Harwell				
(GE Healthcare B443.26)				
	Alpha	10^{-7}	$3\ 10^{-9}$	3.0
	Beta/gamma	$3\ 10^{-5}$	$1.95\ 10^{-7}$	<1
	Radon-222	1	0.0108	1.1
	Tritium	2	0.251	13
	Krypton-85	0.06	Nil	Nil
Winfrith				
(WMT Ltd)	Alpha	10^{-7}	Nil	Nil
	Tritium	19.5	4.75	24
	Carbon -14	0.03	$6.07\ 10^{-6}$	<1
	Other	10^{-7}	Nil	Nil
Winfrith[4]				
Research Sites Restoration Ltd	Alpha	$2\ 10^{-6}$	$6\ 10^{-11}$	<1
(UKAEA)	Tritium	50	0.048	<1
	Carbon-14	0.006	$9.28\ 10^{-4}$	16
	Other	$5\ 10^{-6}$	$1.2\ 10^{-8}$	<1
Minor sites				
Imperial College Reactor Centre				
Ascot	Tritium	$3\ 10^{-4}$	$2.61\ 10^{-5}$	8.7
	Argon-41	1.7	0.0348	2.0
Scottish Universities Environmental Research Centre				
East Kilbride	Beta	$5\ 10^{-7}$	Nil	Nil
	Tritium	0.05	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq	% of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	$2\ 10^{-5}$	$2.73\ 10^{-7}$	1.4
	Tritium	0.02	0.00469	23
	Carbon-14	0.005	$2.82\ 10^{-4}$	5.6
Bradwell	Beta	$6\ 10^{-4}$	$1.91\ 10^{-7}$	<1
	Tritium	1.5	0.00691	<1
	Carbon-14	0.6	0.00116	<1
Chapelcross	Tritium	5000	68.4	1.4
	Sulphur-35	0.05	$3.9\ 10^{-5}$	<1
	Argon-41	4500	Nil	Nil
Dungeness				
A Station	Beta[q]	$5.5\ 10^{-4}$	$5.21\ 10^{-5}$	9.4
	Tritium	2.6	0.0347	1.3
	Carbon-14	5	0.00111	<1
	Sulphur-35	0.15	$2.58\ 10^{-4}$	<1
	Argon-41	1700	Nil	Nil
Dungeness[3]				
B Station	Tritium	12	8.1	68
	Carbon-14	3.7	0.73	20
	Sulphur-35	0.3	0.0509	17
	Argon-41	75	12.8	17
	Cobalt-60[q,v]	10^{-4}	$3.14\ 10^{-7}$	<1
	Iodine-131	0.0015	$1.52\ 10^{-5}$	1.0
Hartlepool[3]	Tritium	10	0.114	1.1
	Carbon-14	4.5	0.0152	<1
	Sulphur-35	0.23	0.0025	1.1
	Argon-41	150	0.00104	<1
	Cobalt-60[q,v]	10^{-4}	$4.0\ 10^{-6}$	4.0
	Iodine-131	0.0015	$8.9\ 10^{-5}$	5.9
Heysham[3]				
Station 1	Tritium	10	0.47	4.7
	Carbon-14	4.5	0.033	<1
	Sulphur-35	0.2	0.014	7.0
	Argon-41	150	Nil	Nil
	Cobalt-60[q,v]	10^{-4}	$5.9\ 10^{-6}$	5.9
	Iodine-131	0.0015	$8\ 10^{-5}$	5.3
Heysham[3]				
Station 2	Tritium	10	1.2	12
	Carbon-14	3.7	1.7	46
	Sulphur-35	0.23	0.013	5.7
	Argon-41	75	6.6	8.8
	Cobalt-60[q,v]	10^{-4}	$7.3\ 10^{-6}$	7.3
	Iodine-131	0.0015	$5.8\ 10^{-5}$	3.9
Hinkley Point				
A Station	Beta	$1.5\ 10^{-4}$	$4.99\ 10^{-7}$	<1
	Tritium	1.5	0.113	7.5
	Carbon-14	0.6	$7.31\ 10^{-4}$	<1
Hinkley Point[3]				
B Station	Tritium	12	1.48	12
	Carbon-14	3.7	1.11	30
	Sulphur-35	0.35	0.12	34
	Argon-41	100	8.85	8.9
	Cobalt-60[q,v]	10^{-4}	$8.03\ 10^{-6}$	<1
	Iodine-131	0.0015	$7.03\ 10^{-6}$	<1
Hunterston				
A Station	Beta[q]	$6\ 10^{-5}$	$4.26\ 10^{-7}$	<1
	Tritium	0.02	0.0013	6.5
	Carbon-14	0.002	$1.28\ 10^{-4}$	6.4

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq	% of annual limit[b]
Hunterston[s]				
B Station	Particulate beta	$5\ 10^{-4}$	$7.08\ 10^{-5}$	14
	Tritium	15	2.78	19
	Carbon-14	4.5	1.31	29
	Sulphur-35	0.5	0.0436	8.7
	Argon-41	150	12.4	8.3
	Iodine-131[w]	0.002	$4\ 10^{-4}$	20
Oldbury	Beta	10^{-4}	$2.94\ 10^{-5}$	29
	Tritium	9	1.59	18
	Carbon-14	4	0.93	23
	Sulphur-35	0.45	0.0546	12.0
	Argon-41	500	19.3	3.9
Sizewell				
A Station	Beta	$8.5\ 10^{-4}$	10^{-6}	<1
	Tritium	3.5	0.659	19
	Carbon-14	2	0.0464	2.3
	Sulphur-35	0.35	0.00202	<1
	Argon-41	3000	Nil	Nil
Sizewell[3]				
B Station	Noble gases	30	2.87	9.6
	Particulate Beta	10^{-4}	$7\ 10^{-6}$	7.0
	Tritium	3	0.598	20
	Carbon-14	0.5	0.333	67
	Iodine-131[v]	$5\ 10^{-4}$	$3.6\ 10^{-5}$	7.2
Torness[s]	Particulate beta	$4\ 10^{-4}$	$3.41\ 10^{-6}$	<1
	Tritium	11	1.60	15
	Carbon-14	4.5	0.841	19
	Sulphur-35	0.3	0.00595	2.0
	Argon-41	75	4.27	5.7
	Iodine-131	0.002	$2.08\ 10^{-6}$	<1
Trawsfynydd	Beta	$5\ 10^{-5}$	$5\ 10^{-7}$	1.0
	Tritium	0.75	0.0959	13
	Carbon-14	0.01	0.00213	21
Wylfa	Beta	$7\ 10^{-4}$	$3.39\ 10^{-5}$	4.8
	Tritium	18	2.63	15
	Carbon-14	2.3	1.49	65
	Sulphur-35	0.45	0.154	34
	Argon-41	100	22	22
Defence establishments				
Aldermaston[m,t]	Alpha	$1.65\ 10^{-7}$	$4.8\ 10^{-8}$	29
	Particulate Beta	$6\ 10^{-7}$	$8.2\ 10^{-8}$	14
	Tritium	39	0.67	1.7
	Carbon-14	$6\ 10^{-6}$	$3.5\ 10^{-7}$	5.8
	Argon-41	0.001	Nil	Nil
	Krypton-85	0.075	0.028	37
	Volatile beta	$4.4\ 10^{-6}$	10^{-8}	<1
Barrow[l]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.048	Nil	Nil
Burghfield[a,m]	Tritium	0.01	$1.5\ 10^{-8}$	<1
	Alpha	$6\ 10^{-9}$	$6.7\ 10^{-10}$	11
Coulport	Tritium	0.05	0.00334	6.7
Derby[n,r]	Uranium	$4\ 10^{-6}$	$8.51\ 10^{-7}$	21
	Alpha[q]	$2.4\ 10^{-8}$	$2.1\ 10^{-10}$	<1
	Beta[q]	$1.8\ 10^{-6}$	$4.23\ 10^{-8}$	2.4

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq	% of annual limit[b]
Devonport[o]	Beta/gamma[q]	$3\ 10^{-7}$	$1.57\ 10^{-8}$	5.2
	Tritium	0.004	$4.46\ 10^{-4}$	11
	Carbon-14	0.043	$2.49\ 10^{-4}$	<1
	Argon-41	0.015	10^{-5}	<1
Dounreay (Vulcan)	Alpha[q]	10^{-6}	$4.68\ 10^{-8}$	4.7
	Beta[q]	10^{-4}	$1.2\ 10^{-6}$	1.2
	Noble gases	0.027	$1.2\ 10^{-4}$	<1
	Iodine-131	$3.7\ 10^{-4}$	$2.6\ 10^{-5}$	7.0
Rosyth[p]	Beta (particulate)	10^{-7}	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
	Carbon-14	$5\ 10^{-4}$	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$2.25\ 10^{-6}$	$2.17\ 10^{-7}$	9.6
	Beta>0.4 MeV	0.02	Nil	Nil
	Radionuclides T1/2<2hr	0.75	0.0536	7.2
	Tritium	2	$1.08\ 10^{-6}$	<1
	Sulphur-35	0.035	0.00666	19
	Selenium-75	0.001	Nil	Nil
	Iodine-125	0.02	$8.78\ 10^{-4}$	4.4
	Iodine-131	0.001	Nil	Nil
	Radon-222	10	4.24	42
	Other noble gases	50	Nil	Nil
	Other	0.01	$2.02\ 10^{-4}$	2.0
Cardiff (GE Healthcare)	Soluble tritium	156	48.8	31
	Insoluble tritium	600	242	40
	Carbon-14	2.38	1.26	53
	Phosphorus-32/33	$5\ 10^{-6}$	$6.1\ 10^{-7}$	12
	Iodine-125	$1.8\ 10^{-4}$	$1.38\ 10^{-5}$	7.7
	Other radionuclides	0.001	Nil	Nil

* *As reported to SEPA and the Environment Agency*

[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 where values are <1%*

[c] *Formerly Nexia Solutions*

[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 excludes 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 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*

[s] *Discharge authorisation revised with effect from 1 June 2007*

[t] *Discharge authorisation revised with effect from 1 March 2007*

[v] *Not reported prior to 1 April 2007*

[w] *Not reported prior to 1 June 2007*

[x] *In some cases 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*

[1] *Discharge authorisation revised with effect from 1 September 2007, with further variation 1 September 2008*

[2] *Windscale authorisation transferred from UKAEA to Sellafield Ltd (into one authorisation) with effect from 1 April 2008*

[3] *Discharge authorisation revised with effect from 1 April 2007*

[4] *Discharge authorisation revised with effect from 1 January 2008*

[5] *Discharge authorisation revoked (B10.23) with effect from 1 February 2009*

[6] *Discharge authorisation revised with effect from 1 April 2008*

NA Not applicable under authorisation

BPM Best practicable means

Table A2.2. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2008

Establishment	Radioactivity	Discharge limit (annual equivalent)[n], TBq	Discharges during 2008	
			TBq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Uranium	$7.5\ 10^{-4}$	$1.43\ 10^{-4}$	19
	Uranium daughters	0.00136	$1.02\ 10^{-5}$	<1
	Non-uranic alpha	$2.2\ 10^{-4}$	$1.63\ 10^{-5}$	7.4
	Technetium-99	0.001	$1.73\ 10^{-5}$	1.7
Sellafield[c,9] (sea pipelines)	Alpha	1	0.127	13
	Beta	220	14.3	6.5
	Tritium	2 104	778	3.9
	Carbon-14	21	7.19	34
	Cobalt-60	3.6	0.0721	2.0
	Strontium-90	48	1.7	3.5
	Zirconium-95 + Niobium-95	3.8	0.125	3.3
	Technetium-99	10	2.37	24
	Ruthenium-106	63	1.39	2.2
	Iodine-129	2.0	0.199	10
	Caesium-134	1.6	0.115	7.2
	Caesium-137	34	5.11	15
	Cerium-144	4.0	0.354	8.9
	Neptunium-237	1.0	0.043	4.3
	Plutonium alpha	0.7	0.108	15
	Plutonium-241	25	2.44	9.8
	Americium-241	0.3	0.0297	9.9
	Curium-243+244	0.069	0.00292	4.2
	Uranium[e]	2000	276	14
Sellafield (factory sewer)	Alpha	$3\ 10^{-4}$	$7.85\ 10^{-5}$	26
	Beta	0.0061	$5.47\ 10^{-4}$	9.0
	Tritium	0.068	0.0155	23
Springfields[10]	Alpha	0.1	0.022	22
	Beta	20	4.58	23
	Technetium-99	0.6	0.0677	11
	Thorium-230	0.02	0.0018	9.0
	Thorium-232	0.015	$2.3\ 10^{-4}$	1.5
	Neptunium-237	0.04	0.002	5.0
	Other transuranic radionuclides	0.02	0.002	10
	Uranium	0.04	0.013	33
Research establishments				
Dounreay	Alpha[4]	0.02	$1.4\ 10^{-5}$	<1
PFR liquid metal disposal plant	Beta[1]	0.11	$7.04\ 10^{-4}$	<1
	Tritium	1.4	0.0051	<1
	Sodium-22	1.8	0.021	1.2
	Caesium-137	0.066	$4.6\ 10^{-5}$	<1
Dounreay	Alpha[4]	0.09	$1.46\ 10^{-4}$	<1
Other facilities	Beta[2]	0.62	0.00129	<1
	Tritium	5.5	0.091	1.7
	Strontium-90	0.77	0.0314	4.1
	Caesium-137	1	0.008	<1
Harwell (pipeline)				
	Alpha	$5\ 10^{-5}$	$3.53\ 10^{-6}$	7.1
	Beta	0.0033	$1.14\ 10^{-4}$	3.4
	Tritium	0.3	0.00429	1.4
	Cobalt-60	$1.2\ 10^{-4}$	$1.5\ 10^{-6}$	1.3
	Caesium-137	$5.4\ 10^{-4}$	$2.24\ 10^{-5}$	4.2
Harwell (Lydebank Brook)	Alpha	10^{-4}	$1.57\ 10^{-5}$	16
	Beta	$6\ 10^{-4}$	$2.28\ 10^{-4}$	38
	Tritium	0.08	0.00745	9.3

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq[a]	% of annual limit[b]
Winfrith (inner pipeline)	Alpha	0.02	$4.03\ 10^{-4}$	2.0
	Tritium	220	9.86	4.5
	Caesium-137	2	0.117	5.8
	Other radionuclides	1	0.0321	3.2
Winfrith (outer pipeline)	Alpha	0.002	$9.97\ 10^{-6}$	<1
	Tritium	0.15	0.00172	1.1
	Other radionuclides	0.001	$2.42\ 10^{-5}$	2.4
Winfrith (River Frome)	Tritium	0.75	Nil	Nil
Minor sites				
Imperial College Reactor Centre	Tritium	$4\ 10^{-5}$	Nil	Nil
Ascot	Other radioactivity	10^{-4}	Nil	Nil
Scottish Universities Environmental Research Centre East Kilbride	Total activity	0.00169	Nil	Nil
Nuclear power stations				
Berkeley	Tritium[11]	1	$4.89\ 10^{-5}$	<1
	Caesium-137	0.2	$3.75\ 10^{-4}$	<1
	Other radionuclides[11]	0.2	0.00125	<1
Bradwell	Tritium	7	0.02	<1
	Caesium-137	0.7	0.0545	7.8
	Other radionuclides	0.7	0.0543	7.8
Chapelcross	Alpha	0.1	$2.51\ 10^{-5}$	<1
	Beta[1]	25	0.00102	<1
	Tritium	5.5	$2.49\ 10^{-4}$	<1
Dungeness A Station	Tritium	8	0.0951	1.2
	Caesium-137	1.1	0.0236	2.1
	Other radionuclides	0.8	0.00816	1.0
Dungeness[d] B Station	Tritium	650	173	27
	Sulphur-35	2	0.25	13
	Cobalt-60	0.01	$7.18\ 10^{-4}$	7.2
	Caesium-137[7]	0.1	0.0024	2.4
	Other radionuclides[8]	0.08	0.0015	1.9
Hartlepool[d]	Tritium	650	3.97	<1
	Sulphur-35	3	0.006	<1
	Cobalt-60	0.01	$5.35\ 10^{-5}$	<1
	Caesium-137[7]	0.1	0.00199	2.0
	Other radionuclides[8]	0.08	0.00151	1.9
Heysham[d] Station 1	Tritium	650	2.2	<1
	Sulphur-35	2	0.001	<1
	Cobalt-60	0.01	$1.88\ 10^{-4}$	1.9
	Caesium-137[7]	0.1	0.00108	1.1
	Other radionuclides[8]	0.08	0.00542	6.8
Heysham[d] Station 2	Tritium	650	288	44
	Sulphur-35	2	0.0681	3.4
	Cobalt-60	0.01	$3.7\ 10^{-5}$	<1
	Caesium-137[7]	0.1	$7.1\ 10^{-4}$	<1
	Other radionuclides	0.08	0.0106	13
Hinkley Point A Station	Tritium	1.8	0.294	16
	Caesium-137	1	0.11	11
	Other radionuclides	0.7	0.37	53

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq[a]	% of annual limit[b]
Hinkley Point[d]				
B Station	Tritium	650	77.9	12
	Sulphur-35	2	0.15	7.4
	Cobalt-60	0.01	$2.28\ 10^{-4}$	2.3
	Caesium-137[7]	0.1	0.00419	4.2
	Other radionuclides[8]	0.08	0.00354	4.4
Hunterston				
A Station	Alpha	0.04	$1.35\ 10^{-4}$	<1
	Beta	0.6	0.0386	6.4
	Tritium	0.7	$6.1\ 10^{-4}$	<1
	Plutonium-241	1	$8.2\ 10^{-5}$	<1
Hunterston[l]				
B Station	Alpha	0.001	$9.81\ 10^{-5}$	9.8
	All other non-alpha	0.15	0.00882	5.9
	Tritium	700	66.2	9.5
	Sulphur-35	6	0.137	2.3
	Cobalt-60	0.01	$3.3\ 10^{-4}$	3.3
Oldbury	Tritium	1	0.184	18
	Caesium-137	0.7	0.309	44
	Other radionuclides	0.7	0.127	18
Sizewell				
A Station	Tritium	11	0.145	1.3
	Caesium-137	1	0.177	18
	Other radionuclides	0.7	0.111	16
Sizewell[d]				
B Station	Tritium	80	51.6	65
	Caesium-137[7]	0.02	0.005	25
	Other radionuclides[8]	0.13	0.015	12
Torness[l]	Alpha	$5\ 10^{-4}$	$1.8\ 10^{-5}$	3.6
	All other non-alpha	0.15	0.00471	3.1
	Tritium	700	358	51
	Sulphur-35	3	0.0188	<1
	Cobalt-60	0.01	$3.16\ 10^{-4}$	3.2
Trawsfynydd	Tritium	0.5	0.0026	<1
	Strontium-90	0.05	$1.72\ 10^{-4}$	<1
	Caesium-137	0.03	$8.0\ 10^{-4}$	2.7
	Other radionuclides[5]	0.17	0.00118	<1
Wylfa	Tritium	15	3.0	20
	Other radionuclides	0.11	0.012	1.1
Defence establishments				
Aldermaston (Silchester)[m]	Alpha	0.01	$2.7\ 10^{-6}$	<1
	Beta/gamma	0.02	$1.3\ 10^{-5}$	<1
	Tritium	0.025	$4.75\ 10^{-4}$	1.9
Aldermaston (to Stream)	Tritium	0.010	$8.61\ 10^{-4}$	8.6
Barrow[h]	Tritium	0.012	Nil	Nil
	Other gamma emitting radionuclides	$3.5\ 10^{-6}$	Nil	Nil
Derby[i]	Alpha[j]	0.002	$1.03\ 10^{-4}$	5.2
	Alpha[k]	$3\ 10^{-7}$	$2.6\ 10^{-8}$	8.7
	Beta[k]	$3\ 10^{-4}$	$4.8\ 10^{-7}$	<1
Devonport[g] (sewer)	Tritium	0.002	$1.01\ 10^{-4}$	5.1
	Cobalt-60	$3.5\ 10^{-4}$	$1.11\ 10^{-5}$	3.2
	Other radionuclides	$6.5\ 10^{-4}$	$2.42\ 10^{-4}$	37

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq[a]	% of annual limit[b]
Devonport[g] (estuary)	Tritium	0.7	0.108	15
	Carbon-14	0.0017	$3.06\ 10^{-4}$	18
	Cobalt-60	$8\ 10^{-4}$	$1.81\ 10^{-4}$	23
	Other radionuclides	$3\ 10^{-4}$	$6.03\ 10^{-5}$	20
Faslane	Alpha	$2\ 10^{-4}$	$3.58\ 10^{-7}$	<1
	Beta[3,6]	$5\ 10^{-4}$	$1.85\ 10^{-5}$	3.7
	Tritium	1	0.072	7.2
	Cobalt-60	$5\ 10^{-4}$	$5.11\ 10^{-6}$	1.0
Rosyth[f]	Tritium	0.003	0.00173	58
	Cobalt-60	$3\ 10^{-4}$	$3.99\ 10^{-5}$	13
	Other radionuclides	$3\ 10^{-4}$	$1.33\ 10^{-5}$	4.4
Radiochemical production				
Amersham (GE Healthcare)[3]	Alpha	$3\ 10^{-4}$	$9.66\ 10^{-6}$	3.2
	Tritium	0.141	$3.93\ 10^{-4}$	<1
	Iodine-125	0.004	$1.47\ 10^{-5}$	<1
	Caesium-137	0.005	$1.01\ 10^{-5}$	<1
	Other radionuclides	0.215	$6.54\ 10^{-4}$	<1
Cardiff (GE Healthcare)	Tritium	130	14.4	11
	Carbon-14	0.91	0.0648	7.1
	Phosphorus-32/33	$8.5\ 10^{-5}$	$3.7\ 10^{-8}$	<1
	Iodine-125	$3\ 10^{-4}$	$7.4\ 10^{-7}$	<1
	Others	$1.2\ 10^{-4}$	Nil	Nil
Industrial and landfill sites				
Drigg (sea pipeline)	Alpha	BPM	$7.09\ 10^{-8}$	NA
	Beta	BPM	$8.59\ 10^{-7}$	NA
	Tritium	BPM	$1.18\ 10^{-4}$	NA

[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] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[d] *Discharge authorisation revised with effect from 1 April 2007*
[e] *The limit and discharge data are expressed in kg*
[f] *Discharges were made by Rosyth Royal Dockyard Ltd. Discharge authorisation revised with effect from 1 April 2008*
[g] *Discharges were made by Devonport Royal Dockyard Ltd*
[h] *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*
[i] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[j] *Discharge limit is for Nuclear Fuel Production Plant*
[k] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[l] *Discharge authorisation revised with effect from 1 June 2007*
[m] *Discharge authorisation revised with effect from 1 March 2007*
[n] *In some cases 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*
[1] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[2] *All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together*
[3] *Excluding cobalt-60*
[4] *All alpha emitting radionuclides taken together*
[5] *Including strontium*
[6] *Excluding tritium*
[7] *Not reported prior to 1 April 2007*
[8] *Includes caesium-137 prior to 1 April 2007*
[9] *Windscale authorisation transferred from UKAEA to Sellafield (into one combined authorisation) with effect from 1 April 2008 with no overall change in limits*
[10] *Discharge authorisation revised with effect from 1 January 2008*
[11] *Discharge authorisation varied with effect from September 2006*
NA Not applicable under new authorisation
BPM Best practicable means

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2008

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2008	
			TBq	% of limit[a]
Drigg[b]	Tritium	10	0.352	3.5
	Carbon-14	0.05	0.0312	62
	Cobalt-60	2	0.291	15
	Iodine-129	0.05	$1.15\ 10^{-4}$	<1
	Radium-226 plus			
	thorium-232	0.03	0.00342	11
	Uranium	0.3	0.0135	4.5
	Other alpha[d]	0.3	0.146	49
	Others[d,e]	15	1.75	12
Dounreay[c]	Alpha		Nil	Nil
	Beta/gamma		Nil	Nil

[a] *Data quoted to 2 significant figures except where values are less than 1%*
[b] *Under current planning permission at the LLWR near to Drigg, certain wastes are temporarily stored, as opposed to being disopsed, pending disposal/storage elsewhere or permission for disposal in-situ*
[c] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits*
[d] *With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232*
[e] *Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table*

Table A2.4. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2008

Site	Month	Summary of incident	Consequences and action taken
Devonport	November	An unauthorised release of liquid radioactive waste was made to the Tamar Estuary. This occurred after a hose transferring reactor coolant from HMS Trafalgar to a shoreside tank ruptured, releasing approximately 300 litres of liquid contaminated with tritium and cobalt-60. The MoD confirmed that the maximum amount of radioactivity discharged was 10 kBq of cobalt-60 and 0.7 GBq of tritium.	A special sampling programme undertaken by the Environment Agency in response to this incident found that levels of tritium and cobalt-60 in water and seaweed were below limits of detection, and the Agency was satisfied that there was no significant hazard to people or the environment. Additional samples of edible molluscs were also collected and analysed on behalf of the Food Standards Agency. The results, included in Table 5.3(a), showed tritium and cobalt-60 levels below limits of detection.
GE Healthcare Maynard Centre	August	A tritium storage vessel unexpectedly leaked while being heated in a laboratory enclosure. The tritium gas released from the vessel was collected by the laboratory ventilation system and discharged to atmosphere via the main discharge stack. The release did not breach the site's authorised daily discharge limit for tritium.	The release had negligible environmental impact and the dose to the critical group for gaseous discharges would be less than 1/4000 of the annual public dose limit (i.e. <0.25 μSv). The subsequent investigation identified that the source of the leak was a defect in the tritium storage vessel. The tritium storage vessel is the property of the Canadian supplier. The vessel has been returned to Canada for further investigations. No action was taken against GE Healthcare
Sellafield	January - December	Contamination of local beaches by radioactive particles, the finds from the monitoring programme for 2008 being 302 (including stones) over 370 Ha.	A formal programme of work for the assessment of contamination by radioactive particles encountered on beaches was put in place early in the year, which over 2008 covered 370 hectares of beach area, revealing 302 finds (117 of which are particles of less than 2mm diameter) All of these finds have been removed from the beaches. Most finds are detected on Sellafield beach area where, compared to 2007, find rates (no of finds per hectare surveyed) are lower. A sampling strategy has been agreed covering a further 250 Ha of beach for 2009/10, which will increase monitoring in areas and periods of higher occupancy, and extend the monitored area further south to Silecroft. Detailed analysis of a number of the finds carried out over 2008 continues to support the advice that we have received from HPA, that no special precautions for protecting the public, or for restricting access to beach areas, are required based on our current understanding. We are continuing to work with the operator on an ongoing review of practices in plant specific areas to prevent or minimise the potential for radioactive particles to be released, and a number of improvements have already been made to strengthen arrangements for excluding high activity solids from liquid effluent management discharges from site.
Sellafield	March	Spillage of low level liquid effluent from a holding tank.	Leakage from a bund at the Segregated Effluent Treatment Plant (SETP) led to less than a cubic metre of low active effluent destined for sea discharge, with less than 10 kBq alpha estimated activity, being released predominately into surface drainage. A warning letter was issued, and improvements requested to the bunding and working arrangements related to management of liquid effluent flow into the tanks. Because of the minor quantity released there were minimal impacts on sea discharges.
Sellafield	April - June	Breach of antimony-125 (Sb-125) quarterly notification level for discharges to air, (known to be associated with elevated levels of Sb-125 in higher burn up Magnox fuels). Sb-125 discharges and their investigation have previously been reported on in RIFE12 and 13 (2006 and 2007).	Elevated Sb-125 discharges from the fuel handling plant are associated with decanning an increasing proportion of higher burn-up Magnox fuels. Further increases are expected as the fuel Sellafield reprocesses will increasingly come from Wylfa, which typically generates the highest burn-up Magnox fuel. We are considering a formal request from Sellafield Ltd to increase the Sb-125 plant and site discharge limit as part of the RSA Authorisation review for 2008-09, to accommodate expected trends associated with continuing reprocessing of an increasing proportion of higher burn up Magnox fuels. The proposed variation in limit is not expected to have any significant impact on radiation doses to the public.

APPENDIX 3. Abbreviations and glossary

AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques or Best Available Technology
BNFL	British Nuclear Fuels plc
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
BSS	Basic Safety Standards
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CoRWM	Committee on Radioactive Waste Management
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DH	Department of Health
DPAG	Dounreay Particles Advisory Group
DRDL	Devonport Royal Dockyard Limited
DSRL	Dounreay Site Restoration Limited
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EDF	Electricite de France
EHS	Environment and Heritage Service
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FSA	Food Standards Agency
GDL	Generalised Derived Limit
GE	General Electric
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency
HSE	Health & Safety Executive
HSL	Harwell Scientifics Limited
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
ISO	International Standards Organisation
LGC	Laboratory of the Government Chemist
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low level Waste
LLWR	Low level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries & Food
MoD	Ministry of Defence
MRL	Minimum reporting level
MRWS	Managing Radioactive Waste Safely
Na/K	Sodium / Potassium
ND	Not detected
NDA	Nuclear Decommissioning Authority
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NMP	Nuclear Management Partners Limited
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval Reactor Test Establishment
NSL	Nexia Solutions Ltd
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
PBO	Parent Body Organisation
PWR	Pressurised Water Reactor
REP	RSR Environmental Principle
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Limited
RRMPOL	Rolls Royce Marine Power Operations Limited
RNAS	Royal Naval Air Station
RSA 93	Radioactive Substances Act 1993
RSR	Radioactive Substances Regulation
RSRL	Research Sites Restoration Limited
RSS	Radioactive Substances Strategy
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Limited
SIXEP	Site Exchange Effluent Plant
SL	Scientifics Limited
SRP	Society for Radiological Protection
STW	Sewage Treatment Works
SWIMMER	Sustainable Water Integrated Management and Ecosystem Research
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally-Occurring Radioactive Material
TPP	Tetraphenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UKAEA	United Kingdom Atomic Energy Authority
UKNWM	UK Nuclear Waste Management Limited
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UOC	Uranium Ore Concentrate
UUK	URENCO UK Limited
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WWTW	Waste Water Treatment Works
YP	Ystradyfodwg and Pontypridd

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^{-1}.
Authorised Premises	This is a premises that has been authorised by the environment agencies to discharge to the environment.
Becquerel	One radioactive transformation per second.
Bioaccumulation	Excretion may occur, however the rate of excretion is less than the rate of intake + accumulation
Biota	Flora and fauna
Committed effective dose	The sum of the committed equivalent doses for all organs and tissues in 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). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.
Critical group	Those (or the 'representative individual') 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 per year 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	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 food chain. 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.
Millisievert	The millisievert is a 1/1000 of a sievert. A sievert is one of the International System of Units used for the measurement of dose equivalent.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting Factor	Factor used to weight the tissue or organ absorbed dose to take account 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 transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative individual	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
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. Factors 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

APPENDIX 4. Assessment of the *total dose* integrated across pathways

A4.1 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 conducted around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gather 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, Berkeley and Oldbury, Bradwell, Capenhurst, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Faslane, Hartlepool, Harwell, Heysham, Hinkley Point, Hunterston, Rosyth, Sellafield, Sizewell, Springfields, Torness, Trawsfynydd, Winfrith and Wylfa. In addition, a total dose assessment has been made at Drigg in 2008. The habits data used are an amalgamation of the most recent terrestrial habits survey for Drigg and aquatic data from the 2008 integrated Sellafield survey. Further sites will be added in future RIFE reports as new integrated surveys are undertaken.

A4.2 Objectives

The environment agencies are required to ensure that doses to the public do not exceed 1 mSv per year 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.

A4.3 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, from data collected by the operators, who are responsible for regulating dose from direct radiation to the public (see Table A4.1) (Mackie, 2009).

A flow diagram of the method is given as Figure A4.1.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2008 data are given in files on the CD accompanying this report. Care should be taken in using these data in other circumstance because the profile 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). Using a similar approach as the routine assessments (see Appendix 1) the dose from the plume is calculated for four age groups (adults, children, infants and prenatal children) in each of three concentric annuli representing the zones 0 – 0.25km, 0.25 – 0.5km and 0.5 – 1km from the site perimeter.

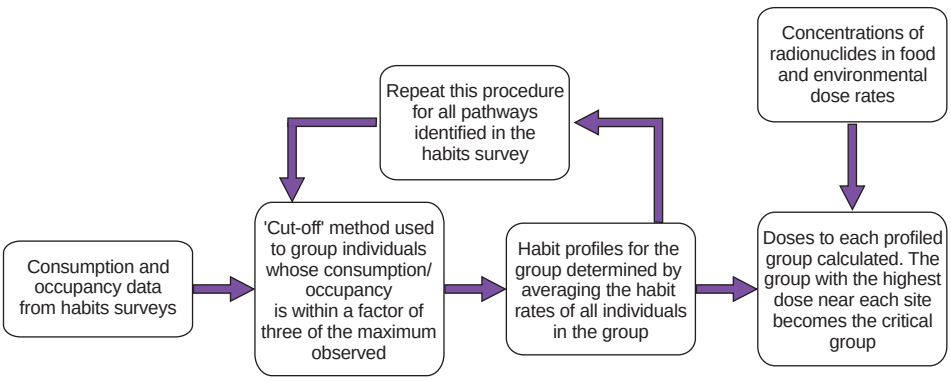

Figure A4.1. Steps in the total dose methodology

A4.4 Results of the assessment of *total dose*

The results of the assessment are summarised in Table A4.2 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 2008 were less than the limit of 1 mSv 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 to seafood consumers at Sellafield, Whitehaven and Drigg, though almost two-thirds of this was due to the legacy of discharges of naturally-occurring radionuclides from a phosphate processing works in Whitehaven. These consumers are common to each of the three sites which are located nearby to each other on the Cumbrian coastline. An increase in the gamma dose rates recorded around Heysham, Hinkley Point and the Springfields houseboats lead to an increase in the dose to the critical groups at these sites. The *total dose* at Capenhurst in 2008, the first time this site has been assessed, was dominated by the dose from direct radiation to the local 10-year-old age group. 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. One exception to this is at Dounreay, where the assessed *total dose* increased in response to a relatively high consumption rate of game meat observed during the 2008 habits survey. Elevated concentrations of caesium-137 in game meat have made this pathway dominant. In 2008, this nuclide contributed 90 per cent of the *total dose* received by consumers of game at this site.

A4.5 Trends in total dose

Total doses have been calculated in RIFE since 2003 using the methodology described in this Appendix. Over this time the number of sites with combined habits survey data has increased from 6 to the current 25. The *total doses* calculated for nuclear sites since 2003 are presented in Table A4.3. The decrease in *total dose* at Cardiff appears to be slowing, although the dose in 2008 is less than a fifth of the *total dose* in 2003. This trend echoes the reductions in tritium levels discharged in liquid wastes, compared with those prior to 2003, and the associated reduction of tritium concentrations in local seafood.

Total dose at Sellafield remains very sensitive to elevated levels of naturally occurring radionuclides in molluscs. In 2008, increased levels of lead-210 and polonium-210 were responsible for raising the *total dose* by 0.10 mSv. The dose attributable to man-made radionuclides has generally reduced, due to reductions in discharges and their effects on food and the environment, but this effect is overlaid on changes to the occupancies and consumption rates of local consumers.

Around nuclear power station sites, *total dose* generally follows the direct radiation dose rate, although high intertidal occupancy outweighs this pathway at Heysham and Hinkley. A continued increase in the dose at Dounreay was driven by the results of a habits survey in 2008 where a higher consumption rate of game meat was observed, and elevated levels of caesium-137 have been found in game.

Table A4.1. Individual radiation exposures - direct radiation pathway, 2008

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.17
Sellafield	<0.002
Springfields	0.025
Research establishments	
Dounreay	<0.010
Harwell	0.020
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	<0.040
Bradwell	0.070
Chapelcross	<0.001
Dungeness	<0.40
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	0.005
Hunterston	0.076
Oldbury	<0.010
Sizewell	<0.030
Torness	<0.020
Trawsfynydd	<0.030
Wylfa	<0.010
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Radiochemical production	
Amersham	0.22
Cardiff	Bgd[a]
Industrial and landfill sites	
Drigg	<0.040

[a] *Doses not significantly different from natural background*

Table A4.2. Individual radiation exposures integrated across pathways, 2008

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 1y	<0.005	Milk, ^{3}H, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Local inhabitants aged 1y (0 - 0.25km)	0.041	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.070	Direct radiation
Capenhurst	Local inhabitants aged 10y (0 - 0.25km)	0.17	Direct radiation
Cardiff	Milk consumers aged 1y	0.006	Milk, ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{137}Cs
Chapelcross	Milk consumers aged 1y	0.021	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Devonport	Prenatal children of green vegetable consumers	<0.005	Fruit, green vegetables, root vegetables, ^{3}H
Dounreay	Adult consumers of game meat	0.078	Game meat, ^{137}Cs
Drigg	Local adult inhabitants (0.25 - 0.5km)	0.048	Direct radiation, fish
Dungeness	Local adult inhabitants (0 - 0.25km)	0.40	Direct radiation
Faslane	-	-	
Hartlepool	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.020	Direct radiation
Heysham	Local adult inhabitants (0.25 - 0.5km)	0.021	Direct radiation
Hinkley Point	Local adult inhabitants (0.5 - 1km)	0.006	Direct radiation
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.077	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Milk consumers aged 1y	0.016	Milk, ^{14}C, ^{60}Co, ^{90}Sr
Sizewell	Adult wild fruit and nut consumers	0.031	Direct radiation
Springfields	Adult mushroom consumers	0.026	Direct radiation
Torness	Prenatal children of root vegetable consumers	0.022	Direct radiation
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.031	Direct radiation
Winfrith	Adult green vegetable consumers	<0.005	Milk, fruit, honey, ^{14}C, ^{137}Cs
Wylfa	Local adult inhabitants (0.5 - 1km)	0.010	Direct radiation
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Adult occupants over sediment	<0.005	Gamma dose rate over sand/stone, fish, ^{137}Cs
Berkeley and Oldbury	Adult occupants over sediment	0.023	Gamma dose rate over sediment
Bradwell	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Capenhurst	Occupants over riverbank aged 10y	0.008	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	0.007	Gamma dose rate over sediment, fish, ^{3}H
Chapelcross	Adult occupants over sediment	0.015	Gamma dose rate over sediment
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult occupants over sediment	0.007	Gamma dose rate over sediment
Dungeness	Adult occupants over sediment	0.010	Gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish, ^{134}Cs
Hartlepool	Adult occupants over sea-coal/sand	0.020	Gamma dose rate over sediment
Harwell	Adult occupants of riverbank	0.005	Gamma dose rate over riverbank
Heysham	Adult occupants over sediment	0.046	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.045	Gamma dose rate over sediment
Hunterston	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and Drigg[d]	Adult mollusc consumers	0.47[c]	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Adult occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.16	Gamma dose rate over sediment
Torness	Adult fish consumers	<0.005	Direct radiation, fish, ^{241}Am
Trawsfynydd	Adult occupants over sediment	0.008	Gamma dose rate over sediment, direct radiation, fish
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult occupants over sediment	0.006	Gamma dose rate over sediment, direct radiation

Table A4.2. continued

Site	Critical group[a]	Exposure, mSv	
		Total	Dominant contributions[b]
C Combined releases from the site			
Aldermaston and Burghfield	Adult occupants of riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Local inhabitants aged 1y (0 - 0.25km)	0.041	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.070	Direct radiation
Capenhurst	Local inhabitants aged 10y (0 - 0.25km)	0.17	Direct radiation
Cardiff	Prenatal children of occupants over sediment	0.007	Gamma dose rate over sediment, fish, ^{3}H
Chapelcross	Milk consumers aged 1y	0.021	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult consumers of game meat	0.078	Game meat, ^{137}Cs
Dungeness	Local adult inhabitants (0.5 - 1km)	0.40	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish, ^{134}Cs
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.026	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.020	Direct radiation
Heysham	Adult occupants over sediment	0.046	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.045	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.077	Direct radiation
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and Drigg[d]	Adult mollusc consumers	0.47[c]	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Adult wild fruit and nut consumers	0.031	Direct radiation
Springfields	Adult occupants on houseboats	0.16	Gamma dose rate over sediment
Torness	Prenatal children of root vegetable consumers	0.022	Direct radiation
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.031	Direct radiation
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult local inhabitants (0.25 - 0.5km)	0.011	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 0.18 and 0.29 mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the Drigg site into the same area*

[d] *Sellafield, Whitehaven and Drigg sites are considered together as their effects are dominated by radioactivity in a common area of the Cumbrian coast*

Table A4.3. Trends in total dose from all sources[a]

Site	2003	2004	2005	2006	2007	2008
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Amersham		0.24	0.24	0.22	0.23	0.22
Berkeley and Oldbury					0.061	0.041
Bradwell					0.070	0.070
Capenhurst						0.17
Cardiff	0.038	0.023	0.023	0.011	0.008	0.007
Chapelcross			0.023	0.024	0.019	0.021
Devonport		<0.005	<0.005	<0.005	<0.005	<0.005
Dounreay	0.012	0.011	0.043	0.029	0.059	0.078
Drigg						0.47
Dungeness			0.55	0.55	0.28	0.40
Faslane				<0.005	<0.005	<0.005
Hartlepool	0.021	0.021	0.021	0.021	0.021	0.026
Harwell					0.026	0.020
Heysham				0.037	0.038	0.046
Hinkley Point				0.048	0.035	0.045
Hunterston		0.10	0.090	0.097	0.090	0.077
Rosyth			<0.005	<0.005	<0.005	<0.005
Sellafield and Whitehaven	0.66	0.58	0.40	0.43	0.37	0.47
Sizewell			0.086	0.091	<0.005	0.031
Springfields				0.13	0.11	0.16
Torness				0.024	0.022	0.022
Trawsfynydd			0.021	0.022	0.018	0.031
Winfrith	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.009	0.011	0.011

[a] *Where no data is given, no assessment was undertaken due to a lack of suitable habit data at the time*

APPENDIX 5. 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, 2002b). 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 2008 is presented in Table A5.1. 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 Food Safety Contaminants 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.gov.uk. A charge may be made to cover costs. Table A5.1 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.

Sea-to-land transfer in Scotland via seaweed

There are three main pathways whereby radioactivity in seaweed can give rise to radiation exposures of man. The first is direct consumption of seaweed and its by-products such as those from the alginate industry. These pathways have long been considered when dealing with the direct effects of Sellafield and the scope of current monitoring is described in Section 2. Studies at Sellafield have also shown the potential importance of two further pathways that is (i) use of seaweed for soil conditioning, and fertiliser and subsequent growing of crops and (ii) consumption of seaweed as an animal feed (Camplin, Rollo and Hunt, 2000). The Food Standards Agency and SEPA have appointed the HPA to investigate these pathways in Scotland where it is considered that local communities may have increased reliance on home grown produce and livestock. The first phase of the project was conducted in 2006. This involved a survey to determine the extent of seaweed usage (as a soil conditioner and animal feed), the variety of crops grown, the management of animals fed seaweed and the quantities of produce consumed that have been treated with seaweed.

The second phase was completed in 2007. Samples of seaweed, treated soils, untreated "control" soils, vegetables and fruit produce and sheep meat and liver were obtained. The first analytical results for soils and seaweed were available in 2007 and a summary was reported in RIFE (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2008). During 2008 analysis of the second phase of samples was undertaken and combined with the habits data from 2006 to produce a series of dose assessments. The study has concluded that the highest levels of dose for groups using seaweed as a soil conditioner or an animal feed were in the range of a few microsieverts and the majority of the doses are at least a factor of 100 lower. The doses estimated from this study do not warrant a programme of continuous monitoring.

Table A5.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Freshwater concentration factors for phosphorus-32	SCO60080	E	In press
Estimating external dose rates to people on houseboats		E	In press
Survey of gamma dose rates in air around the Esk Estuary		E	In press
Determining Capacities for Disposal of VLLW and LLW to Landfills	SCO80027	E	In press
Soil and herbage survey	UKRSR01 and SCO00027	E, S	Dec-09
Transfer from seaweed to terrestrial foods	R04003	F	Oct-09
Total diet studies	ERI015	F	Dec-09
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-13

E *Environment Agency*
F *Food Standards Agency*
S *Scotland and Northern Ireland Forum for Environmental Research or SEPA*

APPENDIX 6. Disposal of dredge material from the Port of Lancaster, Lancashire

In the UK, Defra, Department of the Environment for Northern Ireland, Scottish Government 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 food chain 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 that 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 2008, a specific assessment was conducted for the disposal of dredge material from Glasson Dock at the Port of Lancaster (Leonard, 2008).

The harbour sediments contain artificial radionuclides due to discharges from 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 A6.1. The contributions from individual radionuclides to the total dose for individual crew members and individual members of the public are given in Figures A6.1 and A6.2, respectively. Under the London Convention, only materials with *de minimis* levels of radioactivity may be considered for dumping. Using the conservative generic radiological assessment procedure developed by the IAEA (International Atomic Energy Agency, 2003) to convert radionuclide concentrations in dumped material into radiation doses due to dumping, the total dose (from artificial and naturally-occurring radionuclides) to individual members of the crew and public were both less than 0.005 mSv per year and within the IAEA *de minimis* criteria of 0.010 mSv per year.

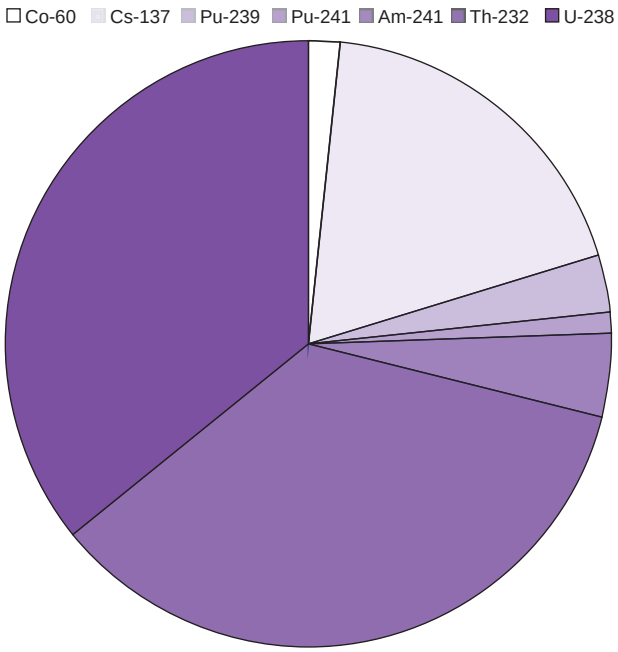

Figure A6.1. Radionuclide contribution to dose to individual crew members due to dredging at Lancaster, 2008

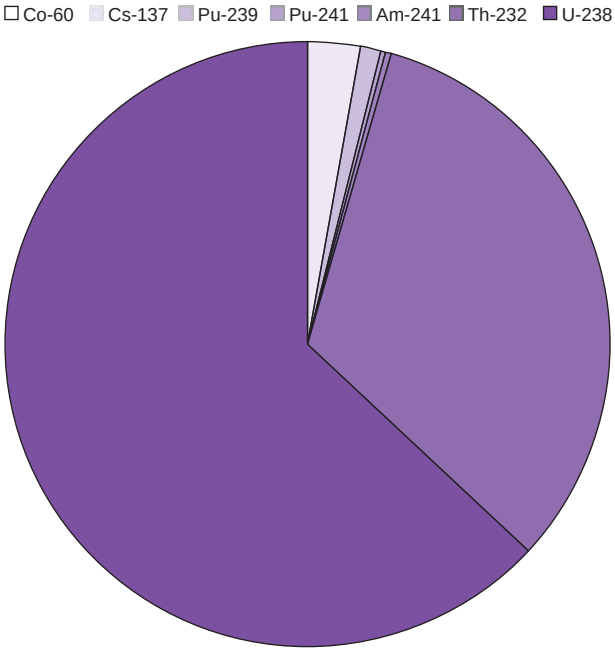

Figure A6.2. Radionuclide contribution to dose to individual members of the public due to dredging at Lancaster, 2008

Table A6.1. Concentrations of radionuclides in sediment from Lancashire, 2008

Sample number	Mean 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
1	<1.5	77	22	23	27	62
2	<1.1	110	19	22	28	91
3	<1.1	74	17	16	18	66
4	<1.0	88	17	23	37	68
5	<1.7	200	21	27	29	160
6	<1.1	120	22	21	23	94
Mean*	1.2	110	20	22	27	91

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

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SCOTTISH ENVIRONMENT PROTECTION AGENCY

Radioactivity in Food and the Environment, 2008 Appendix 1 CD Supplement

RIFE – 14

November 2009

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List of Tables

1. Introduction

This appendix contains a summary of the sampling, measurement, presentation and assessment methods and data used in producing the RIFE report. This information is included as a separate file on the CD accompanying the printed report. Accompanying this file on the CD is a further set of files giving full details of each assessment of *total dose* summed over all sources at each site.

Annexes are provided to this appendix giving further information on:

- Modelling to extend or improve the results of monitoring
- Consumption, occupancy and other habit data
- Dosimetric data
- Estimates of concentrations of natural radionuclides

References in this appendix are given in the printed report.

2. Methods of sampling, measurement and presentation

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 2007 unchanged. The main changes are:

Sampling and measurement

- Sellafield particles – additional discussion of monitoring for radioactive particles on beaches at Sellafield is provided
- Cardiff – analysis of tritium in sludge pellets was introduced
- Special sampling at nuclear sites – this was continued where there were unusual short-term increases in discharges and inadvertent releases
- Uranium – total uranium determinations in terrestrial samples were replaced by increased isotopic determinations
- Dalgety Bay – increased sampling and measurement of particles containing radium-226
- Sediment and groundwater – ad-hoc samples to establish a 'background baseline' for Scotland

Assessment and presentation

- *Total Dose* – two further sites have been assessed using the *Total Dose* assessment methodology – Capenhurst and Drigg
- New charts – are provided of discharge trends at defence sites
- Site maps – maps of sites and sampling locations have been revised and updated. New maps are provided for Dounreay
- New habits data – consumption and occupancy rates for critical groups have been updated with the benefit of recent habit survey results at Capenhurst, Dounreay, Hartlepool and Sellafield
- Cardiff – a new dose assessment has been introduced to determine the effects of the application of sewage sludge pellets containing tritium at Cardiff for agricultural purposes
- New tables of discharges from non-nuclear sites are provided in Section 7 of the main body of the report
- Dredge spoil disposal – an assessment of the impact of dredge spoil disposal from Lancaster Port is provided
- Research related to the monitoring programmes has been reviewed and results relevant to sea to land transfer of radionuclides via seaweed have been presented in Appendix 5

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
- To enable indirect confirmation of compliance with authorisations for disposal of radioactive wastes
- To determine whether undisclosed releases of radioactivity have occurred from sites
- To establish a baseline from which to judge the importance of accidental releases of radioactivity should they occur
- To 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 conducted 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.

Various methods for undertaking sampling and analysis are available. The Environment Agency has supported research to identify and provide guidance on best practice techniques for monitoring programmes related to the Radioactive Substances Act. The outcome of the most recent review has been published recently following a workshop involving UK experts (Leonard, 2007). The programmes are primarily directed at relatively widespread contamination where the likelihood of encounter or consumption is certain. Where a source of potential exposure to particles of radioactivity is concerned, the likelihood of encounter is an important factor. This is considered separately in the main report in site specific programmes targeted at contamination from radioactive particles.

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
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 conducted close to each of the sites shown in Figure 1.1 of the main text. 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 national and international 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.

The European Commission undertakes a verification programme of discharge and environmental monitoring programmes in support of the objectives of Articles 35 and 36 of the Euratom Treaty. The objectives are for Member States to have monitoring programmes to ensure compliance with the Basic Safety Standards (Commission of the European Communities, 1996). The Commission undertakes periodic inspections of operator and Government facilities in the UK and has embarked on a project to investigate the need for harmonisation of procedures across the Community (Hunt *et al.*, 2007). The UK Government is supporting the project and has provided information to the Commission regarding the scope of UK programmes.

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 3.2 of the main report).

The impact of the non-nuclear industry was studied at one main site, Whitehaven in 2008. In addition, a small-scale programme was undertaken near Hartlepool over and above that directed at the effects of the power station itself. In each case the sampling and analysis was directed at materials potentially containing enhanced levels of naturally-occurring radionuclides from non-nuclear industrial activity (i.e. Technologically enhanced Naturally-Occurring Radioactive Materials (TNORM)). There are also occasional specific programmes that consider, for example, the effects of discharges from non-nuclear sites such as hospitals.

Fourteen landfill sites were monitored in Scotland and two in England and two in Wales. The distribution of landfill sites considered in 2008 is shown in Figure 7.1 of the main text. 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 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

In addition, a special sampling exercise was undertaken in 2008 to investigate the effects of disposal of dredged spoil from Lancaster harbour.

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 conducted 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 conducted 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 8 of the main report). 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 to comply with Article 36 the Euratom Treaty*. They account for the 'dense' and 'sparse' networks for mixed diet (Commission of the European Communities, 2000a) required by the EC. 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).

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 2008. 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. In 2008, sampling exercises were undertaken at ports because food consignments had triggered the radiation screening equipment.

Freshwater used for the supply of drinking water was sampled throughout England, Scotland and Wales (Figure 8.2 of the main text). 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 Northern Ireland Environment Agency 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 conducted 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.

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

2.2 Methods of measurement

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

2.2.1 Sample analysis

The analyses conducted on samples vary according to the nature of the radionuclide under investigation. The types of analysis can be broadly categorised into 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 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 2.4 for discussion on limits of detection).

Several 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
- 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
- SL Scientifics Ltd, gamma-ray spectrometry and radiochemistry of environment related samples 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.

In 2007, the analytical and sampling performance of two laboratories was compared and published (Leonard *et al.,* 2007). Cefas and Scientifics Limited conducted collection and subsequent radioanalysis of samples of sediments and seaweed at eight locations near nuclear facilities. Analysis included gamma spectrometry and radiochemistry for tritium and technetium-99. Both laboratories were accredited to ISO 17025. Results of sub samples for gamma emitting radionuclides were found to be reasonably consistent. Some variation was found in results for samples taken separately and this could be due to either difference in the environment or in analytical performance. Some of the larger variations, up to a factor of 2, were found for results for technetium-99 in seaweed but it is known that (i) uptake of this nuclide into seaweed is dependent on local conditions at the time of sampling and (ii) concentrations vary significantly from one part of the plant to another. Overall the exercise showed that the variations in the results of the two laboratories were not excessive when considered against the aims of the monitoring programmes.

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' and equilibrium status) produced as a result of radioactive decay of parent and daughter radionuclides after sample collection is also considered. Corrections to the activity present at the time of measurement are made to take this into account for the radionuclides protactinium-233 and thorium-234.

The analysis of foodstuffs is conducted 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, as 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 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 SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037 μGy 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 riverbanks 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. 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 3 of the main report.

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.

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 the relevant year 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 tropic 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 conducted 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 conducted for a specific radionuclide. In particular, determinations by radiochemical methods are sometimes conducted 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.

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

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 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 for one, or more, of the following reasons: (i) the radionuclide is one which is in the relevant authorisation, (ii) it has been analysed by radiochemistry, (iii) it has been reported as being a positive value in that table in the previous 5 years, (iv) a positive result is detected in any other sample presented in the table in the relevant year. 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). 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 quarterly 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 conducted as part of the research programme described in Appendix 5 of the main report.

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

3. Assessment methods and data

3.1 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 SEPA 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 ICRP issued revised recommendations for a system of radiological protection in 2007 (ICRP, 2007). The implications of the new recommendations in relation to EU and UK radiation protection law and standards are being considered and any changes will be taken into account in future issues of this report.

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. These limits are appropriate for 'certain' exposure situations where the encounter with radioactivity is expected to occur. In situations where this is not certain, 'potential' exposure routes and standards are determined. These are discussed further by Dale *et al.* (2008) in relation to particles of radioactivity. Where contamination due to particles is known in the UK, a site-specific assessment is considered in the relevant section of the main report.

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/foetus 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 has issued guidance on the identification of the people whose exposure should be compared with the dose limit (International Commission on Radiological Protection, 2006). They use the term 'Representative Person' when describing radiological protection of the public. This report retains the term 'critical group' in line with current UK practice based on the ICRP Publication 60.

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. Guidelines for radionuclides in foods following accidental radiological contamination for use in international trade has been published by the Codex Alimentarius Commission (Codex Alimentarius Commission, 2006).

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. Details are provided in section 1.2.4 of the main text of this report.

3.2 Assessment methods

Calculations of exposures to members of the public from waste disposals are primarily based on the environmental monitoring data for the year shown in this report. The methods used have been assessed for conformity with the principles endorsed by the UK National Dose Assessment Working Group (Allott, 2005), and were found to be compatible (Camplin and Jenkinson, 2007). 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, models are used to supplement the monitoring data in four situations:

- Atmospheric dispersion models are used for non-food pathways where monitoring is not an effective method of establishing concentrations or dose rates in the environment.
- Food chain models provide additional data to fill gaps and to adjust for high-limits of detection and
- Modelling of exposures of sewage workers is undertaken for discharges from Amersham and Cardiff
- Modelling of exposures from the use of sewage sludge pellets at Cardiff

Full details are given in Annex 1.

For pathways involving intakes of radionuclides, the data required for assessment 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 fishermen's 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.

3.3 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 in the main text of this report. 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 could 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 3.7).

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.

3.4 Consumption, drinking and inhalation rates

Two basic types of assessment are undertaken. 'Routine' assessments are applied separately to the effects of gaseous and liquid discharges. '*Total dose*' assessments take into account all sources in combination. This subsection considers consumption, drinking and inhalation rates that are applied

in 'routine' assessments. '*Total dose*' assessments are considered further in Section 3.8 and Appendix 4 of the main report.

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 foetal 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 foetal 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 Annex 2. 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 Capenhurst, Dounreay, Hartlepool and Sellafield in 2008. 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.

3.5 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 Annex 3 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 was introduced routinely last 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 foetus 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 prenatal 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 Annex 3.

3.6 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 Annex 2.

3.7 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 Annex 4. 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.

3.8 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 4. Included in this assessment is direct radiation from nuclear sites, which is estimated with the benefit of information provided by the HSE.

3.9 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.

4. References

References for the CD supplement are given in Section 9 of the main report.

Annex 1. Modelling of concentrations of radionuclides in foodstuffs, air and sewage systems

A1.1 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 technetium-99, ruthenium-106, cerium-144, promethium-147 and plutonium-241 using the equations:

$$C_m = F_m Ca\ Q_f \quad \text{and}$$
$$C_f = F_f\ Ca\ Q_f \quad \text{where}$$

C_m is the concentration in milk (Bq l^{-1}),
C_f is the concentration in meat or offal (Bq kg^{-1} (fresh)),
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} (fresh)),
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 X1.1 (Simmonds *et al.,* 1995; Brenk *et al.,* unpublished) and the estimated concentrations in milk, meat and offal are presented in Table X1.2.

The Cardiff East Waste Water Treatment Works provides dried sludge pellets, containing elevated concentrations of tritium, to farms for use as a soil conditioner. The transfer of tritium from treated soil into crops is a potential pathway of exposure. An FSA-funded research project (Ham *et al.*, 2007) estimated the aggregated transfer quotient, relating the concentration in the edible part of the crop to the amount of activity applied to the soil, to be approximately 2 10^{-4}. This assumed a conservative application rate of 2 kg m^{-2}. These values can be used to perform an assessment of exposure from consuming foodstuffs grown in soil conditioned with sludge pellets near Cardiff.

A1.2 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.

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 X1.3.

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 gamma-emitting 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 were assessed using breathing rates. Doses were initially assessed for three age groups: infants (1y), children (10 y) and adults. All ages are assumed to have year-round occupancy at the nearest habitation The inhalation and occupancy rates assumed in this assessment are shown in Table X1.4. The dose to the foetal age group was taken to be the same as that for an adult.

A1.3 Sewage systems

The radiochemical production facilities at Amersham and Cardiff discharge liquid radioactive waste to local sewers. Wastes are processed at local sewage treatment works (STW). The prolonged proximity to raw sewage and sludge experienced by sewage treatment workers could lead to an increase in the dose received, via a combination of external irradiation from the raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides.

An assessment of the dose received by workers at the Maple Lodge STW, near Amersham, and at the Cardiff East Waste Water Treatment Works (WWTW) has been conducted using the methodology and data given in Environment Agency (2006b,c). The flow rate through the sewage works are used to calculate a mean concentration in raw sewage and sludge of each nuclide discharged. These mean concentrations are combined with habits data concerning the workers' occupancy near raw sewage and sludge, external and internal dosimetric data, and physical data such as inhalation rates to provide estimates of dose. Workers are assumed to spend 75 per cent of a working year in proximity to the raw sewage, and the other 25 per cent in proximity to the sewage sludge. Where liquid discharges are not nuclide-specific, a composition has

been assumed based on advice from the operators and concentrations calculated accordingly.

The model parameters and habits data used to assess the dose to sewage treatment workers are given in Table X1.5, and the amounts of radioactivity discharged from each site can be found in Appendix 2 of the main report.

Table X1.1. 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 X1.2. Predicted concentrations of radionuclides from food chain model used in assessments of exposures

Foodstuff	Location	Radioactivity concentration (fresh weight), Bq kg^{-1}			
		^{99}Tc	^{106}Ru	^{144}Ce	^{241}Pu
Milk	Sellafield	a	$7.17\ 10^{-5}$	b	$1.08\ 10^{-5}$
	Ravenglass	a	$1.38\ 10^{-4}$	$1.84\ 10^{-3}$	$1.18\ 10^{-5}$
	Drigg	a	$1.52\ 10^{-4}$	$3.03\ 10^{-3}$	$8.67\ 10^{-6}$
	Isle of Man	a	$1.73\ 10^{-4}$	b	$1.27\ 10^{-5}$
Beef	Sellafield	a	$7.17\ 10^{-2}$	b	$1.08\ 10^{-3}$
	Ravenglass	a	$1.38\ 10^{-1}$	$9.18\ 10^{-2}$	$1.18\ 10^{-3}$
	Drigg	$4.98\ 10^{-2}$	$1.52\ 10^{-1}$	$1.52\ 10^{-1}$	$8.67\ 10^{-4}$
	Isle of Man	$3.47\ 10^{-2}$	$1.73\ 10^{-1}$	b	$1.27\ 10^{-3}$
Sheep	Sellafield	a	$8.28\ 10^{-2}$	b	$4.97\ 10^{-4}$
	Ravenglass	a	$1.59\ 10^{-1}$	$1.06\ 10^{-1}$	$5.44\ 10^{-4}$
	Drigg	a	$1.75\ 10^{-1}$	$1.75\ 10^{-1}$	$4.00\ 10^{-4}$
	Isle of Man	$4.00\ 10^{-2}$	$2.00\ 10^{-1}$	b	$5.84\ 10^{-4}$
Beef offal	Sellafield	a	$7.17\ 10^{-1}$	b	a
	Ravenglass	a	$1.38\ 10^{-1}$	a	a
	Drigg	$1.99\ 10^{-1}$	$1.52\ 10^{-1}$	$3.03\ 10^{1}$	$1.73\ 10^{-1}$
	Isle of Man	$1.39\ 10^{-1}$	$1.73\ 10^{-1}$	b	$2.53\ 10^{-1}$
Sheep offal	Sellafield	a	$8.28\ 10^{-2}$	b	$3.72\ 10^{-2}$
	Ravenglass	a	$1.59\ 10^{-1}$	a	$4.08\ 10^{-2}$
	Drigg	a	$1.75\ 10^{-1}$	a	$3.00\ 10^{-2}$
	Isle of Man	$1.60\ 10^{-1}$	$2.00\ 10^{-1}$	b	$4.38\ 10^{-2}$

[a] *Positive result used, or LoD result used because modelling result greater than LoD*
[b] *No grass or Leafy Green Vegetable data available*

Table X1.3. Air concentrations modelling assumptions

Nuclear site	Stack height, m	Estimated site diameter, km	Estimated distance from stack to nearest habitation, km	Frequency of Pasquill stability catergory D
Aldermaston	15	2	0.3	60
Amersham	20	1	0.3	55
Berkeley	20	1.6	0.4	55
Bradwell	14	0.4	0.3	65
Burghfield	15	0.6	0.3	60
Capenhurst	15	1.1	0.3	65
Cardiff	20	0.4	0.4	60
Chapelcross	30	1.2	0.7	60
Devonport	15	1	0.3	65
Dounreay	15	1	1	75
Dungeness	17	1	0.3	70
Hartlepool	23	0.6	2	70
Harwell	20	1	0.2	55
Heysham	21	1	0.5	70
Hinkley	21	0.8	1	55
Hunterston	15	0.4	0.4	60
Oldbury	20	0.8	0.7	55
Sellafield	93	2	0.5	65
Sizewell	18	0.4	1	70
Springfields	27	1	0.3	70
Torness	72	0.5	0.6	70
Trawsfynydd	18	0.6	0.6	70
Winfrith	15	1.6	0.4	60
Wylfa	17	1	0.4	70

Table X1.4. Inhalation and occupancy data for dose assessment of discharges to air

Age group, y	Inhalation rates, $m^3 h^{-1}$	Fraction of time indoors
1	0.22	0.9
10	0.64	0.8
Adult	0.92	0.7

Table X1.5. Sewage workers dose assessment modelling assumptions and occupancy data

Flow rate, $m^3 d^{-1}$	Amersham (Maple Lodge STW)	$1.5\ 10^{5}$[a]
	Cardiff (Cardiff East WWTW)	$2.6\ 10^{4}$[b]
Occupancy - sewage, $h y^{-1}$		1440
Occupancy - sludge, $h y^{-1}$		480[c]
Inadvertant ingestion rate, $kg h^{-1}$		$5\ 10^{-6}$[d]
Inhalation rate, $m^3 h^{-1}$		1.2[d]
Airborne concentration of sewage or sludge, $kg m^{-3}$		$1\ 10^{-7}$[d]
Density of raw sewage and treated sludge, $kg l^{-1}$		1[d]

[a] *Based on average flow rate of 1.8 $m^3 s^{-1}$ (Jobling et al., 2006)*
[b] *Based on an average flow rate of 0.3 $m^3 s^{-1}$, this has been derived as 5% of the maximum flow rate at the works (McTaggart, 2003)*
[c] *A working year is assumed to be 40 hours per week and 48 weeks per year*
[d] *Parameter values used in Environment Agency methodology (see text for reference)*

Annex 2. Consumption, inhalation, handling and occupancy rates

This annex gives the consumption, handling and occupancy rate data used in the routine assessment of exposures from terrestrial consumption and aquatic pathways. Consumption rates for terrestrial foods are based on Byrom *et al.* (1995) and are given in Table X2.1. 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 X2.2. The site-specific data has been supplemented with generic information from Environment Agency (2002a) and Smith and Jones (2003) where appropriate. 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 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 Annex 1.

Table X2.1. 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
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
Sheep	8	4	0.8	25	10	3
Wild fruit	7	3	1	25	10	2

** These rates are the 97.5th percentile of the distribution across all consumers*

Table X2.2 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 (2007)		14 kg y^{-1} eels and other fish
		2.7 kg y^{-1} shrimps
		900 h y^{-1} over mud, stones and saltmarsh
Bradwell (2007)		25 kg y^{-1} fish
		1.1 kg y^{-1} crabs and lobsters
		2.9 kg y^{-1} Pacific and European oysters
		3100 h y^{-1} over mud
Capenhurst (2008)	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 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 (2008)	A	1700 h y^{-1} handling fishing gear
	B	18 kg y^{-1} fish
		21 kg y^{-1} crab and lobster
		2.1 kg y^{-1} winkles and mussels
		470 h y^{-1} over sand
	C	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

Table X2.2 continued

Site (Year of Last Survey)	Group[a]	Rates
Faslane (2006)		19 kg y^{-1} fish 0.17 kg y^{-1} mussels 570 h y^{-1} over stones
Hartlepool (2008)	A	28 kg y^{-1} fish 19 kg y^{-1} crab and lobster 5.8 kg y^{-1} winkles and whelks 600 h y^{-1} over sand
	B	1200 h y^{-1} over sand and sea coal
Harwell (2007)		1.1 kg y^{-1} fish 1.1 kg y^{-1} crayfish 420 h y^{-1} over riverbank
Heysham (2006)		25 kg y^{-1} fish 16 kg y^{-1} shrimps 4.5 kg y^{-1} cockles, whelks and mussels 1300 h y^{-1} over mud
Hinkley Point (2006)		40 kg y^{-1} fish 12 kg y^{-1} shrimps 1.9 kg y^{-1} whelks 1300 h y^{-1} over mud
Holy Loch (1989)		730 h y^{-1} over mud
Hunterston (2007)		47 kg y^{-1} fish 18 kg y^{-1} *Nephrops* and squat lobsters 21 kg y^{-1} king scallops 440 h y^{-1} over mud, sand or stones
Landfill		2.5 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) (2008)	40 kg y^{-1} cod (25%) and other fish (75%) 17 kg y^{-1} crab (70%), lobster (20%) and *Nephrops* (10%) 31 kg y^{-1} winkles (50%) and other molluscs (50%) 930 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (2008)	980 h y^{-1} handling nets and pots
	C (Bait digging and mollusc collecting) (2008)	960 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) (seafood) (2007)	51 kg y^{-1} fish 15 kg y^{-1} *Nephrops*, crab and lobster 5.7 kg y^{-1} mussels and cockles 780 h y^{-1} over mud
	H (Laverbread) (1972)	47 kg y^{-1} laverbread
	I (Dumfries and Galloway (wildfowling) (2007)	670 h y^{-1} over saltmarsh 22 kg y^{-1} wildfowl
	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

Table X2.2 continued

Site (Year of Last Survey)	Group[a]	Rates
	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	22 kg y^{-1} cod
	2004-2008) (NA)	19 kg y^{-1} other fish
		11 kg y^{-1} crabs
		5.5 kg y^{-1} lobsters
		3.7 kg y^{-1} *Nephrops*
		18 kg y^{-1} winkles
		16 kg y^{-1} other molluscs
		830 h y^{-1} over mud and sand
	O (Typical recreational use over beaches, muddy areas or salt marsh) (NA)	300 h y^{-1} over intertidal substrates
	P (Typical beach user e.g. tourist) (NA)	1 kg y^{-1} fish
		0.2 kg y^{-1} crustaceans
		0.2 kg y^{-1} molluscs
		30 h y^{-1} over sand
	Q (Ravenglass nature warden)	110 h y^{-1} over salt marsh
	(2008)	500 h y^{-1} over mud and sand
		2.7 10^{-3} kg y^{-1} mud by inadvertant ingestion
		5.0 10^{-5} kg y^{-1} mud by resuspension and inhalation
Clyde (small users) (NA)		20 kg y^{-1} molluscs
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 (2006)	54 kg y^{-1} fish
		21 kg y^{-1} shrimps
		350 h y^{-1} over mud
	B (2006)	690 h y^{-1} handling nets
	C (Ribble Estuary houseboats)	3000 h y^{-1} over mud
	(2004-2008) (NA)	
	D (10 year old children) (NA)	30 h y^{-1} over mud
		3 10^{-4} kg y^{-1} mud by inadvertant ingestion
		1.9 10^{-6} kg y^{-1} mud by resuspension and inhalation
	E (Farmers) (2006)	750 h y^{-1} over salt marsh
Torness (2006)	A	29 kg y^{-1} fish
		22 kg y^{-1} crab and lobster
		7.8 kg y^{-1} winkles
		470 h y^{-1} over sand
	B	1100 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

Annex 3. Dosimetric data

The dose coefficients used in assessments in this report are provided in Table X3.1 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.

A3.1 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, cockles and crabs suggested a factor in the range 0.15 to 0.65, close to the ICRP value of 0.5 (Hunt and Rumney, 2004 , 2005 and 2007). Previous assessments have considered the effects of a factor of 0.8 when considering monitoring results in RIFE. In view of the most recent review (Hunt and Rumney, 2007), a value of 0.5 has been adopted for all food, consistent with the ICRP advice.

A3.2 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).

A3.3 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.

A3.4 Tritium

In 2002, the HPA reviewed the use of dose coefficients for tritium associated with organic material (Harrison *et al.*, 2002). Subsequently HPA published a study of the uptake and retention of organically bound tritium in rats fed with fish from Cardiff Bay (Hodgson *et al.*, 2005). These experiments suggested that the dose coefficient for OBT in fish from the Severn Estuary near Cardiff should be 6.0 10^{-11} Sv Bq^{-1}, higher than the standard ICRP value for OBT ingestion. The higher value is used for adults in the assessment of seafood collected near the Cardiff site in this report, and the standard ICRP value for other assessments. This approach is consistent with recent advice from the HPA, (Cooper, 2008) which takes account of the conclusions reached by the HPA Independent Advisory Group on Ionising Radiation concerning relative biological effectiveness and radiation weighting (Health Protection Agency, 2007). However it is more cautious than that implied by the experimental evidence provided by Hunt *et al.* (2009) which indicates that the most appropriate coefficient for adults for tritium in sole from Cardiff Bay might be 1.6 10^{-11} Sv Bq^{-1}.

Table X3.1. 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 X3.1. 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-05	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*

Annex 4. Estimates of concentrations of natural radionuclides

A4.1 Aquatic foodstuffs

Table X4.1 gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis conducted 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.

A4.2 Terrestrial foodstuffs

The values of carbon-14 in terrestrial foodstuffs due to natural sources that are used in dose assessments are given in Table X4.2 (Ministry of Agriculture, Fisheries and Food, 1995).

Table X4.1. Concentrations of radionuclides in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (fresh))[a]									
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	23	27			23					
Lead-210	0.042 (0.0030-0.55)	0.02 (0.013-2.4)	0.24 (0.043-0.76)	0.080 (0.02-0.79)	1.2 (0.18-6.8)	1.5 (0.69-2.6)	1.6 (0.68-6.8)	0.94 (0.59-1.3)	0.39 (0.18-0.61)	1.5 (0.68-4.9)
Polonium-210	0.82 (0.18-4.4)	9.1 (1.1-35)	19 (4.1-35)	5.3 (1.9-10)	17 (1.2-69)	13 (6.1-25)	42 (19-69)	18 (11-36)	6.5 (1.2-11)	8.4 (5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

[a] *Values are quoted as medians with minimum and maximum values given in brackets*

Table X4.2. Carbon-14 in terrestrial foodstuffs due to natural sources

Food Category	% Carbon content (fresh)	Concentration of carbon-14 (Bq kg^{-1} (fresh))
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