RIFE - 13

Radioactivity in Food and the Environment, 2007

2008

ENVIRONMENT AGENCY
FOOD STANDARDS AGENCY
NORTHERN IRELAND ENVIRONMENT AGENCY
SCOTTISH ENVIRONMENT PROTECTION AGENCY

Radioactivity in Food and the Environment, 2007

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December 2008

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Preface

The Environment Agency, the Food Standards Agency, the Northern Ireland Environment Agency and the Scottish Environment Protection Agency work together on the radiological monitoring of food and the environment, and in publishing the results.

Our report provides an in-depth assessment of radioactivity in food and the environment in the UK and the public's exposure to radiation. The report focuses on key information that demonstrates both that food remains safe and that the public's exposure to ionising radiation is within legal limits.

The Food Standards Agency has overall responsibility for food safety throughout the UK. The Environment Agency, Northern Ireland Environment Agency and the Scottish Environment Protection Agency (collectively 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.

This report brings together the results of radiological monitoring conducted by the Environment Agencies and Food Standards Agency during 2007, providing one overall detailed set of information. The report also assesses the total amount of radiation the public is exposed to at the 39 nuclear sites around the UK.

Radioactivity in the environment comes from several sources. These include natural radiation, residues from the Chernobyl accident and atmospheric weapons testing, plus radioactive discharges and emissions from nuclear and non-nuclear sites (authorised premises). The Environment Agencies set limits and regulate the discharges and emissions of radioactive waste from authorised premises. Exposure from non-medical man-made sources are very low, with discharges of radioactive waste contributing less than 0.1 per cent of the total.

Operators of nuclear sites are required to monitor their discharges and the effects on the environment. In England, Wales and Northern Ireland the Food Standards Agency, the Environment Agency and the Northern Ireland Environment Agency conduct their own monitoring programmes, whereas in Scotland SEPA incorporate the requirements of the Food Standards Agency within its own programme. These are important because the Environment Agencies and Food Standards Agency programmes provide an independent assessment of the potential harm resulting from authorised releases of radioactive discharges and act as an additional check to the monitoring programmes conducted by site operators.

The Environment Agencies control public exposure to man-made radioactive substances principally by authorising the amount of material that operators are allowed to discharge into the environment. The monitoring conducted by the Environment Agencies and the Food Standards Agency:

- demonstrates that the public have been adequately protected from radioactivity in food and the environment as a result of authorised releases and discharges;
- establishes long-term information on concentrations and allows trends to be identified so that we can identify any changes and take action if we need to;
- assess the public's total exposure to radiation around nuclear sites.

The year 2007 was the 50th anniversary of two significant events. In March 1957, the Euratom Treaty was signed in Rome. In October 1957, a fire in one of the reactors at Windscale began which resulted in major releases of radioactivity with widespread consequences. Both of these events had a significant impact on radiation protection in the UK. From a monitoring perspective, the Windscale fire taught that it is essential to make information on radioactivity in food and the environment available to the public. The Euratom Treaty has supported an open approach to publishing radiation information. More fundamentally, it has also provided a firm basis for regulating radiation sources.

This publication reports that the public's exposure to radiation around each nuclear site in 2007 was below the legal limit. Concentrations of radionuclides in food and the environment around nuclear licensed sites were similar to previous years. At many sites, radionuclide concentrations were low and, in some cases, so low they could not be positively detected using the techniques utilised.

In some places, concentrations of radioactivity were lower than in the past and these appear to be falling year on year. For example, concentrations of tritium in seafood around Cardiff continued to fall in 2007 from the highest levels seen in 2001. Technetium-99 concentrations around Sellafield have continued to decrease**.** Having previously met the target set in the UK National Discharges Strategy for 2006, discharges of technetium-99 from Sellafield were again reduced.

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 2007, nine of the eleven Magnox power stations (the first generation of nuclear power stations in the UK) had been permanently closed, leaving only Oldbury, Wylfa and the British Energy nuclear power stations still operating at the start of 2007. Closure of Dungeness A and Sizewell A in late 2006 has substantially reduced discharges and direct radiation doses to members of the public close to these sites.

The Environment Agencies and Food Standards Agency have conducted detailed investigations in a number of specific places. At the end of 2006, it was requested that the beaches around Sellafield were monitored further for radioactive particles. This increased monitoring was also conducted in 2007 and continues in 2008.

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

Technical summary

The technical summary is divided into sections which 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, and
- 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. 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 concentrations and dose rates. However, in some years doses are affected by changes in people's habits, in particular their consumption of food, which are identified by habits surveys.

Figure S.1 and Table S.1 show the assessed doses due to the effects of waste discharges for those groups that are the most exposed to radiation near all major nuclear licensed sites in the UK. In 2007, 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 0.52 mSv in 2007. 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 0.24 mSv to this dose in 2007, similar to the contribution to dose in 2006 of 0.23 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. Technetium-99 in seafoods contributed 0.004mSv (about 2 per cent) to the 0.24 mSv dose, a reduction from 0.006 mSv (about 3 per cent) of 0.23 mSv in 2006. Doses from technetium-99 have been falling for several years as a result of decreasing discharges from Sellafield.

Most liquid radioactive discharges from Sellafield have fallen in recent years. Concentrations in fish and shellfish of some radionuclides have also shown reductions or are largely unchanged. However, the consumption of fish and shellfish by people (seafood consumer group) in the area have significantly increased since 2000 and as a result, doses have also increased.

As well as the radiation from Sellafield discharges, the people who consumed seafood also received 0.28 mSv from what is known as 'technologically enhanced naturally-occurring radioactive material'. There can be an increase in concentrations of some radionuclides that occur naturally due to industrial operations, in this case previous discharges from a phosphate processing works at Whitehaven. The dose increased from 0.22 mSv in 2006 to 0.28 mSv in 2007. 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 from the decay of radium-226 and lead-210 in past discharges. Altogether, the group who consumed the seafood received a dose from radiation exposure of 0.52 mSv in 2007, which is well within the EU and UK limit for members of the public of 1 mSv per year. Doses due to gaseous discharges from Sellafield were much lower than those from liquid discharges at 0.023 mSv in 2007 and similar to the dose of 0.029 mSv in 2006. Doses to people who had consumed crops grown on land fertilised by seaweed from around Sellafield were also assessed. Their estimated dose for 2007 was 0.012 mSv (0.013 mSv in 2006). Doses to people using the beaches and other intertidal areas were less than 0.020 mSv.

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 2007, their dose was 0.073 mSv (similar to the dose in 2006, of 0.075 mSv). Most of this exposure was due to external dose from radionuclides from Sellafield in intertidal sediments.

The next group most affected in terms of exposure to radiation were those people on the Dumfries and Galloway coast who consumed seafood. It was estimated that they received 0.060 mSv in 2007. Most of this dose was due to americium-241 and plutonium from Sellafield in shellfish. A change in the type of shellfish consumed accounted for their increase in dose from 0.037 mSv in 2006. This was the group most exposed 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 2007, the most exposed group, with an estimated dose of

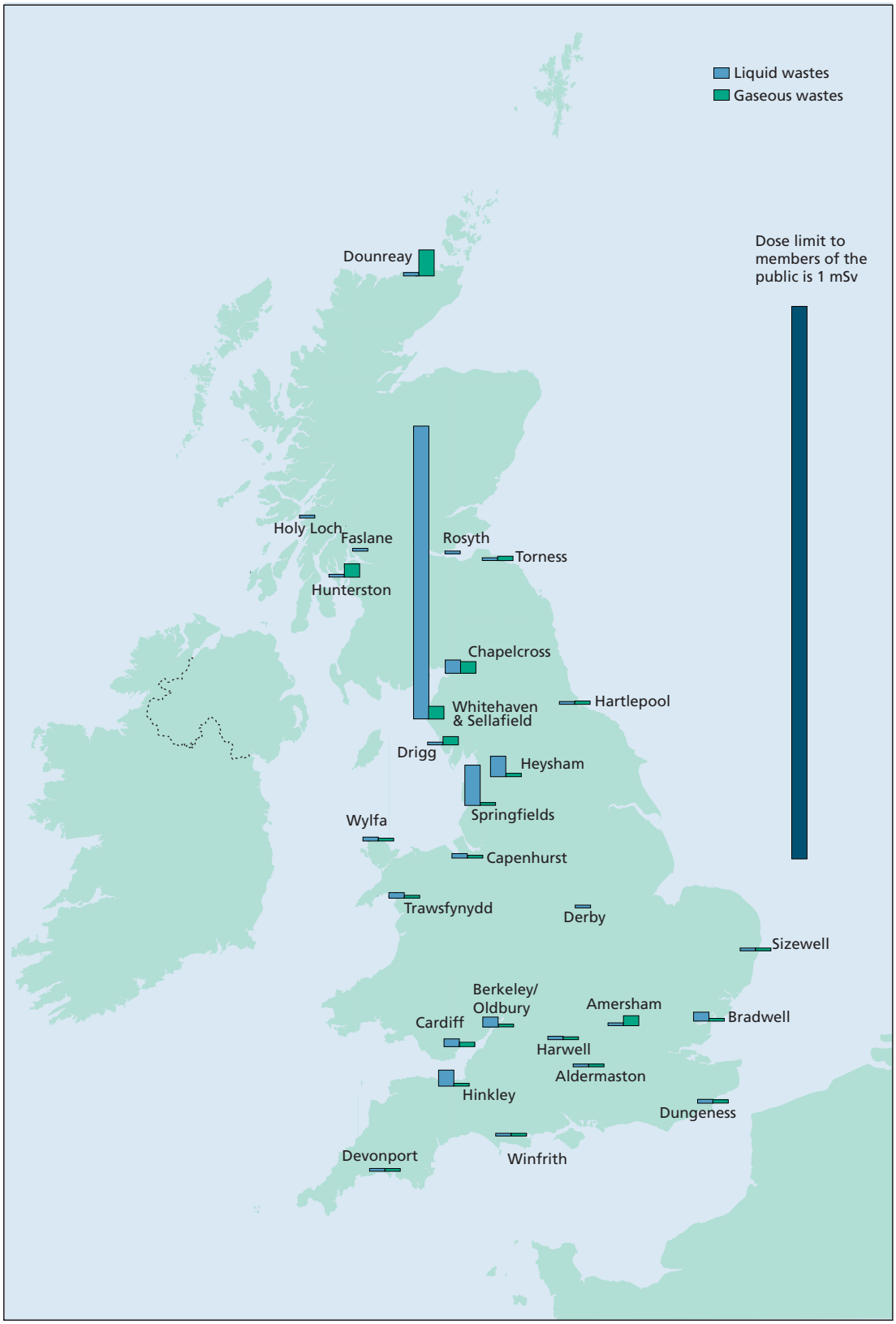


Figure S1. Radiation exposures in the UK due to radioactive waste disharges, 2007 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S1. Radiation doses due to discharges of radioactive waste in the United Kingdom, 2007[a]

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	0.007	Ext
	Terrestrial foods[i]	G	<0.005	
Springfields	External (skin) to fishermen	L	0.045[f]	Beta
	Fish and shellfish consumption	L	0.016	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site	G	<0.005[h]	^{234}U
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	0.073	Ext
	External in intertidal areas (farmers and wildfowlers)	L	0.017	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2003-2007 surveys) (excluding naturally occurring radionuclides)[k]	L	0.24	$^{239/240}$Pu ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2003-2007 surveys) (including naturally occurring radionuclides)[l]	L	0.52	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2007 surveys) (excluding naturally occurring radionuclides)[k]	L	0.21	$^{239/240}$Pu ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.023	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.014	
	External in intertidal areas (Ravenglass)[a]	L	0.027	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)	L	0.073	Ext
	External (skin) to bait diggers	L	0.083[f]	Beta
	Handling of fishing gear	L	0.036[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield	L	0.012	^{99}Tc
Research establishments				
Culham	Water consumption[n]	L	<0.005	
Dounreay	Fish and shellfish consumption	L	<0.005	
	External in intertidal areas	L	0.006	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.047	
Harwell	Fish consumption and external to anglers	L	0.006	Ext ^{137}Cs
	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	G	<0.005	^{3}H ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.018	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	0.017	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	^{3}H ^{14}C
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.024	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.021	^{90}Sr
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext ^{241}Am
	Occupancy of houseboats	L	0.007	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{14}C ^{60}Co
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{14}C ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{35}S
Heysham	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	^{35}S
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.029	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Hunterston	Fish and shellfish consumption	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.024	^{35}S ^{90}Sr
Sizewell	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 ^{35}S

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	^{137}Cs ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.008	^{35}S ^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.010	Ext ^{137}Cs
	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	0.007	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{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	G	<0.005[h]	^{234}U
Derby	Water consumption[n]	L	0.007	
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	
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
	Terrestrial foods, external and inhalation near site[i]	G	0.020	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[o]	L	0.014	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.008	^{3}H
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	
Industrial and landfill				
Drigg	Terrestrial foods[j]	G	0.015	^{90}Sr
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.28	^{210}Po ^{230}Th
	Fish and shellfish consumption[m]	L	0.52	^{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*

0.014 mSv, were unborn children of women consuming seafood. The dose was due to the consumption of fish from the Severn Estuary that contained tritium and carbon-14, and a significant contribution due to external radiation (0.007 mSv). Overall, the estimated dose reflects further lowering of the tritium in fish in 2007. The dose to adults was similar to that of unborn children at 0.012 mSv. Doses at this site have been steadily reducing since 2000 in line with lower discharges. In 2006, relatively high doses were also estimated at Dungeness and Sizewell power stations. Both Dungeness A and Sizewell A power stations stopped power production in 2006 and their argon-41 discharges, and consequently their radiation impact, reduced substantially in 2007.

The dose estimates above apply to discharges from nuclear and other sites. The public are 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 pathway 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 2007, *total doses* to the public were assessed at 23 nuclear site locations. The results are shown in Figure S.2 and Table S.2. In 2007, *the total doses* at these sites were all less than the annual EU and UK limit of 1 mSv, with direct radiation doses in 2007 at Dungeness A and Sizewell A much reduced from previous years following their closure at the end of 2006. These types of site assessments will be extended to all major nuclear sites in future *Radioactivity in Food and the Environment* reports, as the necessary information becomes available.

Radioactivity concentrations in samples collected around nuclear sites

The previous section highlighted changes in doses in 2007. These were not necessarily due to variations in concentrations of radioactivity in samples, with some due to changes in people's dietary patterns. This section summarizes any changes in concentrations of radioactivity in food or the environment, given in Bq per kilogramme (Bq kg^{-1}) or Bq per litre (Bq l^{-1}).

The UK Radioactive Discharge Strategy was published in 2002. It describes how the UK will implement the agreements of the meetings of the Oslo and Paris Convention on radioactive discharges to the North-East Atlantic marine area. 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 2007, the Environment Agency and the Scottish Environment Protection Agency issued new authorisations with tighter conditions and limits on disposing of radioactive waste for 12 sites (Aldermaston, Burghfield, Capenhurst, Devonport Naval Base and eight British Energy power stations in England and Scotland). The UK Government and Devolved Administrations are modernising the discharge strategy and a public consultation exercise to seek stakeholder views began in June 2008.

Reductions in discharges, either by reducing discharge limits or through operator initiatives, can lead to reductions in concentrations in food and environmental samples near the site. Reductions in discharges from GE Healthcare at Cardiff continue and are reflected in reduced concentrations of tritium in fish and other molluscs since their peak levels, approximately a decade ago. Similarly, reductions in discharges of technetium-99 from the Sellafield site have led to reductions in technetium-99 in local food and the environment since the peaks seen in 1997. Concentrations of thorium-234 in sediment in the Ribble Estuary were much reduced in 2007 compared with 2006. This was due to significant reductions in discharges from the Springfields site. Apart from these, there were no major variations in concentrations of radioactivity in 2007 compared to those in 2006.

In 2007, the highest concentrations of tritium in seafood from near Cardiff were in the range 2,300 to 2,400 Bq kg^{-1} in sole and flounder, down from the range of 4,400 to 4,600 Bq kg^{-1} in 2006. The 2007 concentrations are less than 10 per cent of the levels seen in 2000, when tritium in flounder concentrations 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 2007, discharges of technetium-99 from Sellafield continued at the lower level achieved 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 showed a systematic decrease from those in 2006. There was a small scale transfer of technetium-99 from sea to land as seaweed was harvested to use as a soil conditioner and fertiliser.

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 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. This was not seen in 2007. These trends are unlikely to be associated with changes in discharges. Concentrations of americium-241 will have increased due to

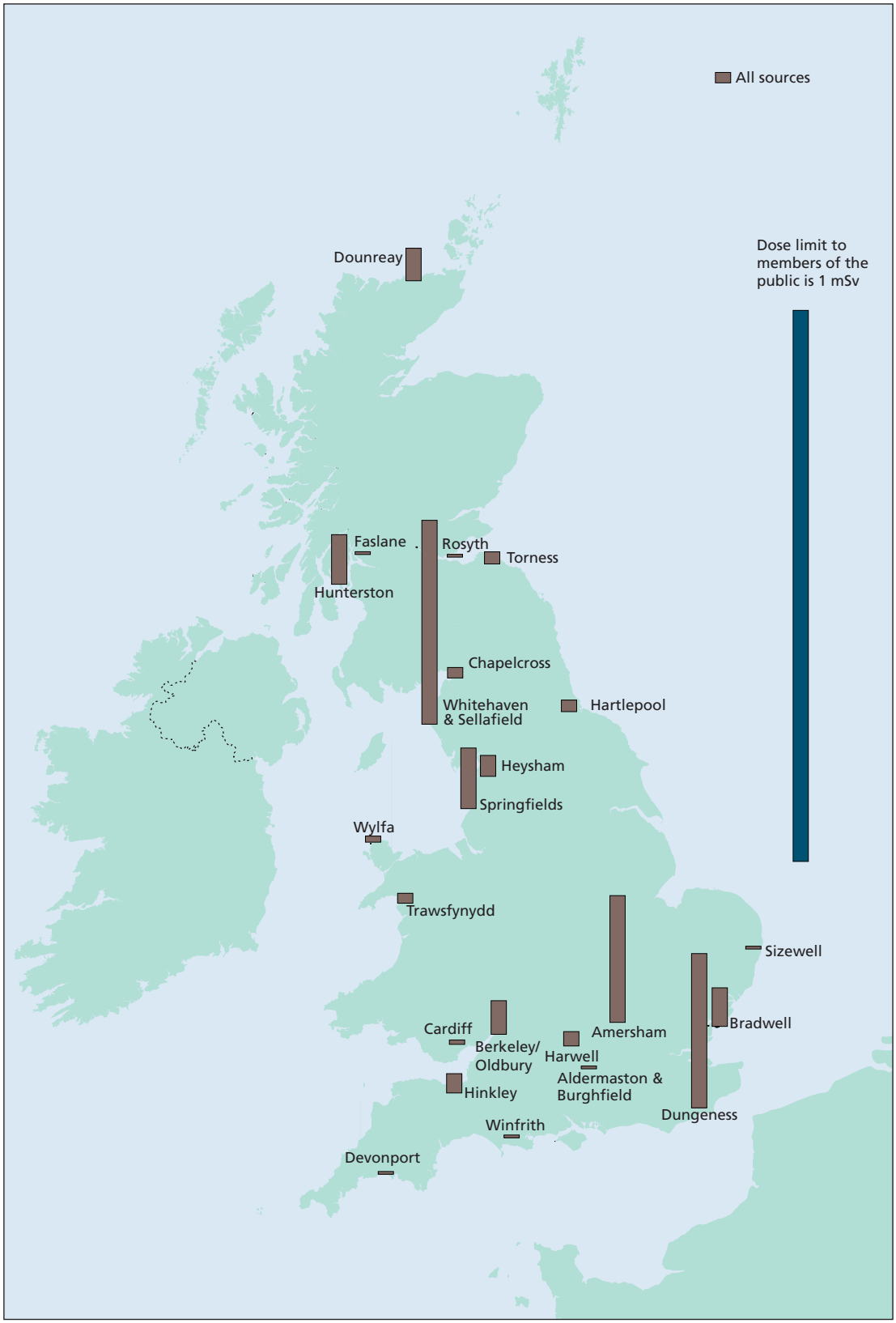


Figure S2. Total radiation exposures in the UK due to radioactive waste disharges and direct radiation, 2007 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S2. Radiation doses due to all sources at major UK sites, 2007[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	Not assessed	
Springfields	0.11	Gamma dose rate over sediment
Sellafield[d]	0.37	Molluscs, ^{210}Po, ^{241}Am
Research establishments		
Culham	Not assessed	
Dounreay	0.059	Game meat, ^{137}Cs
Harwell	0.026	Direct radiation
Winfrith	<0.005	Fish, ^{137}Cs, ^{241}Am
Nuclear power stations		
Berkeley and Oldbury	0.061	Direct radiation
Bradwell	0.070	Direct radiation
Chapelcross	0.019	Milk, ^{90}Sr, ^{241}Am
Dungeness	0.28	Direct radiation
Hartlepool	0.021	Direct radiation
Heysham	0.038	Gamma dose rate over sediment
Hinkley Point	0.035	Gamma dose rate over sediment
Hunterston	0.090	Direct radiation
Sizewell	<0.005	Direct radiation
Torness	0.022	Direct radiation
Trawsfynydd	0.018	Direct radiation, milk
Wylfa	0.011	Direct radiation
Defence establishment		
Aldermaston and Burghfield	<0.005	Gamma dose rate over sand
Derby	Not assessed	
Devonport	<0.005	Gamma dose rate over sediment
Faslane	<0.005	Gamma dose rate over mud, fish
Holy Loch	Not assessed	
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.23	Direct radiation
Cardiff	0.008	Gamma dose rate over sediment, fish, ^{3}H, ^{14}C
Industrial and landfill		
Drigg	Not assessed	
Whitehaven[d]	0.37	Molluscs, ^{210}Po, ^{241}Am

[a] *Includes the effects of waste discharges and direct radiation from the site. Doses calculated according to profiled habit rates – see Appendix 4 for details. 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 0.19 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven*

'in-growth' from plutonium-241 in the environment. Remobilization of historical sediments containing higher activity concentrations or the increased presence of finer-grained sediments with high activity concentrations will also play a part in this trend. The changes are small and are not easy to detect in fish and shellfish samples from Cumbria.

In 2007, releases of argon-41 gas from Dungeness A and Sizewell A Magnox power stations stopped and ceased a local effect on concentrations in the air near the station. At some nuclear sites concentrations of radionuclides in food and the environment are near or below analytical limits of detection.

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 2007, compared with 2006. 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 reductions in dose rates were seen in the Ribble Estuary between 2006 and 2007 due to reduced discharges from the Springfields site.

Nuclear site incidents and non-routine surveys

During 2007, radioactive items were detected on beaches on the Cumbrian coastline, where 261 particles and contaminated pebbles/stones from Sellafield were removed.

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

There was one other occasion where 'special' sampling (referred to as *ad hoc* sampling) was needed because of concerns about site operations or because of higher than normal discharges, triggering reporting procedures that are a condition of the operator's authorisation. This was at Sizewell B where some of the discharge sampling equipment for tritium and carbon-14 failed for a two week period. Although other indications at the same station showed that discharges were not increased during the period, environmental sampling was prioritised as a precaution. In 2006 there were five *ad hoc* sampling events when for reassurance purposes, extra analyses were required from samples from the routine monitoring programmes which were collected earlier, and analysed more quickly than scheduled.

In Scotland, special samples were taken to investigate the use of mussel shells as a fertiliser at Faslane and to check whether there was any pre-existing contamination of the Chapelcross cooling towers prior to their demolition. In both cases no significant impacts were identified.

In 2007, the diets and occupancy habits of people near nuclear sites at Berkeley, Bradwell, Harwell, Hunterston, Oldbury, Sellafield and South West Scotland were surveyed. The findings were used to 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 people in the general population were mostly exposed to radioactivity from naturally-occurring sources. Man-made radionuclides only contributed a small proportion of the total public radiation dose in general diet.

Monitoring of 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.

Concentrations of naturally-occurring radionuclides in fish and shellfish near the former phosphate processing works in Whitehaven have previously been found to be higher than the maximum of the expected ranges due to natural sources. This year the increase above background was difficult to detect and limited to a few samples. The enhanced levels arise from past discharges of phosphogypsum, which used to be discharged as liquid slurry into the Irish Sea. Radionuclides that are released from non-nuclear industrial activity, such as those from phosphogypsum plants, are referred to as 'technologically enhanced naturally-occurring radioactive material'. The discharges from the phosphogypsum plant contained thorium and uranium. This site stopped operating at the end of 2001 and the plant has been subsequently demolished. Estimates of the concentrations of these naturally-occurring radionuclides in seafood near this site have been made by subtracting the expected concentration of these radionuclides in UK seafood. As noted above, polonium-210, which is naturally occurring, may also be present in seafood as the result of past discharges of radium-226 and lead-210. People consuming large quantities of seafood were estimated to receive a dose of 0.28 mSv due to these naturally-occurring radionuclides enhanced through non-nuclear industrial activity. The same group of consumers would also be exposed to artificial radionuclides in the Irish Sea due to discharges from Sellafield. The dose to this group from both artificial radionuclides and Technologically enhanced Naturally-Occurring Radioactive Material was estimated to be 0.52 mSv.

To understand the effects of enhanced concentrations of radioactivity at other non-nuclear sites a programme of monitoring and assessment was conducted at Dalgety Bay in

Fife by Defence Estates. The environmental monitoring of intertidal and residential areas confirmed earlier studies and found items that contain radium-226. The source of these items is not certain but it is likely to be due to wastes generated from past military operations at the Royal Naval Air Station Donibristle, which closed in 1959. Further work is planned in 2008 to characterise the contamination and to provide data for a determination, in accordance with the Scottish Government's Statutory Guidance on The Radioactive Contaminated Land (Scotland) Regulations 2007.

Small amounts of liquid radioactive waste are discharged under authorisation to sewers from hospitals, research establishments and other industries. In 2007, SEPA carried out sampling to investigate the effects of these multiple discharges to a single waste water treatment plant in Glasgow and Dundee. Sampling was targeted to coincide with the timing of expected disposals. Doses from anthropogenic radionuclides, for several different critical groups, including sewer workers, were measured in the range of 0.004 to 0.066 mSv per year.

Food imported into the UK may contain radioactive contamination and a monitoring system is in place to detect such consignments. The Food Standards Agency analysed samples of fruit products in 2007 that had been imported into Dover and Felixstowe via Germany and Holland. The maximum concentration determined was of 1300 Bq kg^{-1} (fresh weight) caesium-137. The legal requirement is comparison of the concentration in the final food product with the Community Food Intervention Level, which is 1200 Bq kg^{-1}. In this case, the fruit products were not for direct consumption and the subsequent dilution in production of the final retail product would have ensured final concentrations were well within limits. Consequently, no further action was needed by UK authorities.

Concentrations of tritium were found in leachate from some landfill sites but only at levels that were of very low radiological significance. This is likely to be 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 2007. There are still restrictions on the moving, selling and slaughtering of sheep in some upland areas of the UK but the effects were limited to 369 farms in 2007, compared with 9700 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 an essential base of 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 2007, a proposal for the disposal of sediment from Heysham in Lancashire was considered by Defra. Samples of the dredge spoil were analysed for radioactivity and an assessment was made of potential radiation doses. Doses to members of public were all less than the 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 seven 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 Northern Ireland Environment Agency, the Food Standards Agency and the Scottish Environment Protection Agency (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 2007.

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). There is more information about all programmes described in this report from the sponsoring agencies. You can find details of how to contact them 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 behaviour of organically bound tritium in sewage sludge and the potential effects of discharges to the sewer. Results of the completed studies are in Appendix 5. The agencies are also funding work to improve the methods for estimating public exposure, including site-specific surveys of people's dietary habits and way of life.

1. Introduction

1.1 Background

1.1.1 Purpose and scope of the monitoring programmes

This report details the results of programmes for the monitoring of food and environmental materials for radioactivity in the UK during 2007. Food monitoring in England and Wales is conducted by the Food Standards Agency. Environmental and dose rates monitoring in England and Wales is conducted by the Environment Agency. 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 monitoring is carried out by the Northern Ireland Environment Agency (NIEA). 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 conduct nationwide monitoring of whole diet, milk and crops remote from nuclear sites. The marine environment of the whole of the British Isles away from nuclear sites is monitored for Defra.

The Food Standards Agency has responsibility for food safety throughout the UK. The Environment Agency, the NIEA and SEPA, referred to collectively as the Environment Agencies in this report, are responsible for environmental protection matters 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 with time and distance from the nuclear licensed sites. The results are also used to confirm the safety of the food chain. Monitoring of the environment provides indicators of radionuclide dispersion around each site. Environmental and food results are used to make an assessment of dose to the public to compare with the UK statutory dose limits. Most of the monitoring conducted and presented in this report concerns the local effects of discharges from nuclear licensed sites in the UK. Other work conducted includes the Chernobyl monitoring, which provides the authorities with information on caesium-137 concentrations in affected areas and whether restrictions are still required.

Key points

- The report represents collaboration across the UK by regulatory bodies
- Is an independent assessment of radioactivity in food and the environment around nuclear and some non-nuclear sites
- Provides a check on safety of food and the food chain
- Monitoring results are used to calculate dose to the public and assessed against standards for the public
- Monitoring programme results contribute to the UK meeting its international treaty obligations
- Monitoring programmes are set against national and international policies which are described in this chapter

Monitoring is also conducted in food and the environment remote from nuclear licensed sites, providing information on background concentrations of radionuclides.

In 2006, an independent panel considered the Food Standards Agency's radiological monitoring programme for England, Wales and Northern Ireland and concluded that the programme met the Agency's remit to protect public health and to ensure that doses of man-made and natural radioactivity in foods did not pose an unacceptable risk to consumers (Food Standards Agency, 2006a). The panel recommended a few minor alterations to the programmes and these were implemented for the 2007 programme. The Commission of European Communities is undertaking a review of the way Article 35 of the Euratom Treaty is implemented by signature states, of which the UK is one. 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 undertaken by a number of UK laboratories, including those

listed below. These laboratories also undertook most of the sample collection for the programmes.

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

1.1.2 Dose assessments

The majority of the monitoring was conducted to check the effect of discharges from nuclear and non-nuclear operators on the environment. The results are also used to make an assessment of doses to the public that can then be compared with the relevant dose limits. The dose assessments are retrospective in that they apply to 2007, using monitoring results for that year. The radioactivity concentrations reported are the accumulation of all past discharges made up to the time of sampling.

In this report, two main types of dose assessment are made. One type is a retrospective assessment to groups of people (or a single representative person) near nuclear sites from radioactivity in food and the environment. The group that receives the highest dose near each site is considered to be the critical group from past discharges and these are calculated for specific pathways.

The other type of assessment is similar but includes exposure to direct radiation from nuclear sites and can cover multiple pathways. This gives an estimate of *total dose* to the critical group around the nuclear sites. Direct radiation can be significant close to operating Magnox 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 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). Habit data is now available at 23 nuclear licensed sites and *total dose* assessments have been made at all these. In 2008 habit data will become available for one additional site (Capenhurst) and be updated at three more sites to enable *total dose* can be calculated at these sites.

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. 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 the 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 and as such are presented elsewhere. They are derived using modelling techniques. The European Commission (EC) 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).

Dose to some specific groups of workers are included in the assessment of doses from nuclear sites. The groups of workers are those who may be exposed incidentally, where their employment is not explicitly related to work with ionising radiation. Such workers include fishermen, farmers, sewage workers, nature wardens, etc. Their doses are compared 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 activities should be assessed as part of their employment.

1.2 Disposals of radioactive waste

1.2.1 Radioactive waste disposal from nuclear sites

As part of their operations, discharges of radioactive wastes as liquids and/or gases are made from nuclear sites in the UK. In addition, solid low level wastes (LLWs) from nuclear sites can be transferred to the low level waste repository (LLWR) 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).

The nuclear licensed sites that are sources of waste containing man-made radionuclides are shown in Figure 1.1. Nuclear licensed sites are authorised to dispose of radioactive wastes (United Kingdom – Parliament, 1993). Nuclear licensed sites 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, the presence of radioactivity in the environment resulting from such discharges is detected within this programme. For example, iodine-131 originating from hospitals is occasionally detected in some marine samples. Small amounts of very low level solid 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, such as radionuclides discharged from the former phosphate processing plant at Whitehaven, and

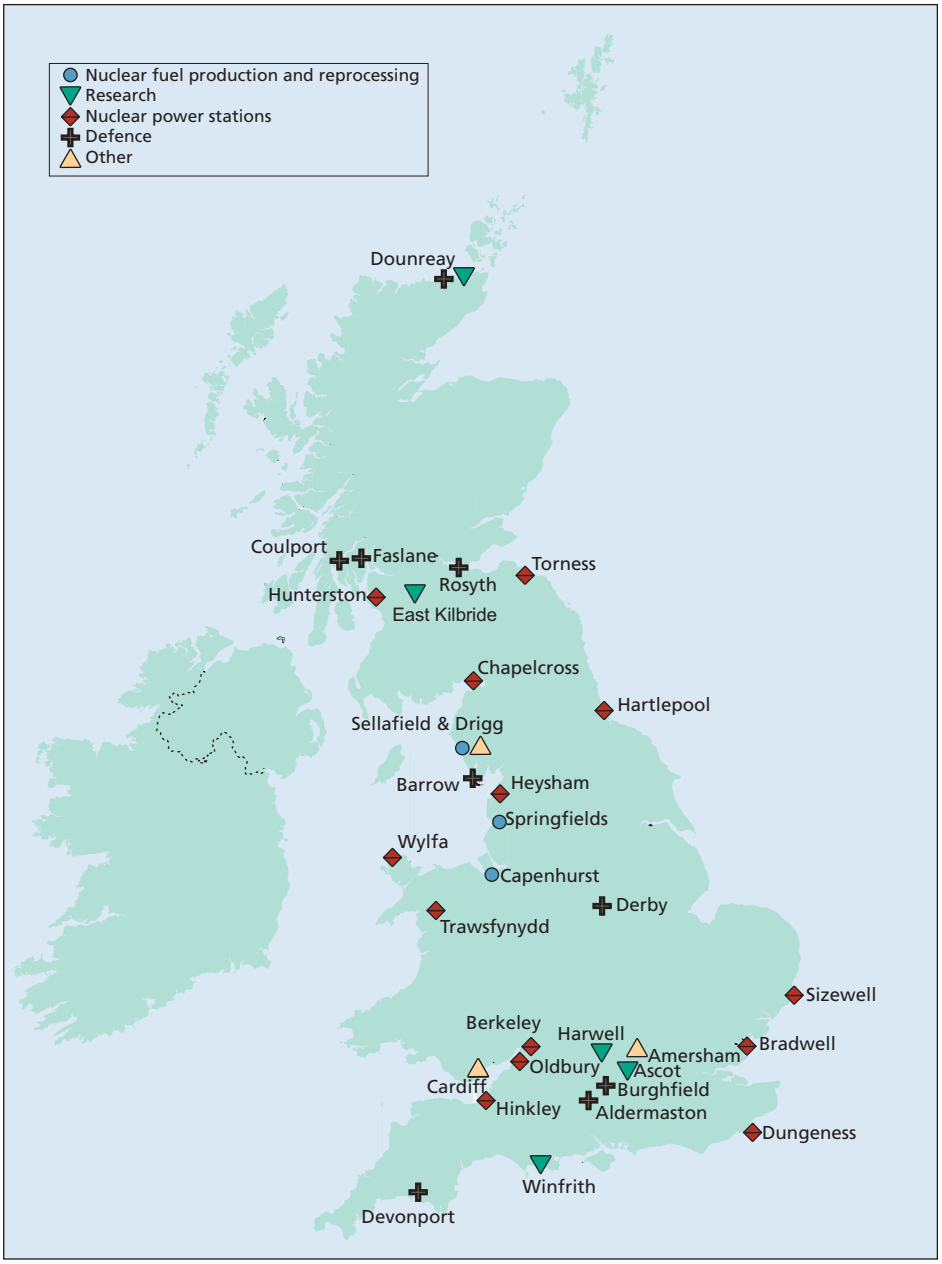


Figure 1.1. Principal sources of radioactive waste disposal in the UK. (Showing main initial operation. Some operations are undergoing decommissioning)

monitoring is therefore undertaken near this site. Discharges from other terrestrial non-nuclear sites are generally considered insignificant and as such environmental monitoring of their effects is usually not required for the purposes of protection of public health. However, this situation is reviewed from time to time and where appropriate surveys are included in the programme. Discharges of radioactive substances by the non-nuclear industry into the sea have been reviewed by the parties who are members of the Oslo and Paris (OSPAR) Convention (OSPAR, 2002).

Appendix 2 presents a summary of the discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2007. 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 some cases, the authorisations specify limits in greater detail than can be summarized in a single table: in particular, periods shorter than one year are specified at some sites. In 2007, all discharges and disposals were below the authorised limits. The tables show the percentage of the limit actually discharged in 2007.

The discharge limits are set through an authorisation assessment process which can be initiated by either the operator or the relevant environment agency. 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 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 2007, 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 are required to 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. The events of this type which occurred in 2007 are summarized in appendix Table A2.4. Where monitoring was initiated because of these events, the results are presented and discussed in the relevant site text later in this report.

The UK Government and Devolved Administrations initiated a consultation process on standardised approaches to reporting of radioactive discharges in 2007 and its findings have now been published (Department for Environment, Food and Rural Affairs, 2008a). The aim of the proposed changes is to standardise reporting across EU member states, such 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, such that instances of over- and under-reporting of radioactive discharges are minimised and to ensure that the regulatory approach across the UK and industry is consistent. There was general agreement that there is benefit in standardising reporting and the main concern expressed was the need for further cost-benefit analysis to confirm that the costs of implementing new systems did not outweigh the benefits. The UK Government will now arrange for trials of the new systems and, in light of the results, will publish its finalised policy and provide guidance to the Environment Agencies.

1.2.2 International agreements and the UK discharge strategy

This subsection presents information on the context of UK radioactive discharges as they relate to international agreements. The UK has ratified the Convention for the Protection of the Marine Environment of the North-East Atlantic (often referred to as the "OSPAR Convention"), which provides a framework for the prevention and elimination of pollution in the north-east Atlantic, including the seas around the UK (OSPAR, 2000a). 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 provided a description of how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the strategy relate to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes. They are:

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

The strategy stated that due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target would be set for this industrial sector, presuming that these discharges would continue to be tightly controlled and reduced wherever practicable (Watson *et al*., 2005). The Scottish Government has consulted on its Statutory Guidance to be issued to SEPA on the application of the Strategy in Scotland (Scottish Executive, 2005). A public consultation was held on an earlier draft of the statutory guidance to the Environment Agency in October 2000. Statutory Guidance was issued to SEPA in early 2008.

Defra and the Devolved Administrations are revising the strategy and supporting approaches. Defra has published a consultation document covering a revised strategy for 2006-2030 including the potential effects of new nuclear power stations (Department for Environment, Food and Rural Affairs, the Scottish Government, Welsh Assembly Government, the Department of the Environment, 2008). Defra also began consultation on its 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) Environment Principles (RSR Environment 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 draft principles 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). 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, 2008). 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.

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, 2007). The Directive has a target date for transposition into national law by 15th 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 taking an integrated approach to stewardship of the marine environment has been recognised in the UK and the strategy to achieve this aim has been published (Department for Environment, Food and Rural Affairs, Department of Environment, Northern Ireland, Scottish Executive and Welsh Assembly Government, 2002). The report "Safeguarding Our Seas" considers conservation and sustainable development of the marine environment and sets out how the UK is addressing those issues in relation to radioactive and other substances and effects. The UK completed a fully integrated assessment of the marine environment in 2005 (Department for Environment, Food and Rural Affairs, 2005a, 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 harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. UK's first national report, demonstrating compliance with the Convention, was provided to the International Atomic Energy Agency (IAEA) in May 2003 (Department for Environment, Food and Rural Affairs, 2004a). An updated UK national report was submitted to the IAEA in October 2005 (Department for Environment, Food and Rural Affairs, 2005c).

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up. The Energy Act 2004, which was enacted in 2004, has enabled the establishment of the Nuclear Decommissioning Authority (NDA) which began operation in April 2005. The NDA has taken responsibility for nuclear sites 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 2007/08 is available (Nuclear Decommissioning Authority, 2007). 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 which includes (Department for Environment, Food and Rural Affairs, 2007b):

- 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 low level waste from the nuclear industry, including consideration of whether a replacement (or replacements) of the national disposal facility near Drigg in Cumbria might be required
- Initiating a UK wide strategy for the management of LLW from non-nuclear industries
- Waste minimisation

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's approach to siting a facility is one of partnership and alongside publication of the White

Paper, communities were invited to voluntarily open up discussions with Government, without commitment, on the possibility of hosting a geological disposal facility at some point in the future.

The Scottish Government has decided not to be involved on progressing geological disposal as they do not accept that geological disposal 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).

Some low level radioactive wastes, mostly from non-nuclear sites, and some very low level wastes are currently disposed of to landfill by controlled burial (Chapter 7). There is still a considerable volume of solid low level radioactive wastes which will require disposal. Some will be sent to the LLWR near Drigg, and the LLW from Dounreay will be disposed of at a new facility close to the site, and further alternative disposal options are 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). The documents will consider separately surface and deep geological disposal facilities. Workshops have been held in October and December 2006 and June 2007 to involve stakeholders in planning the scope and content of the guidance. The Environment Agencies have now begun consultation on their draft guidance on requirements for authorisation of near surface on land (Environment and Heritage Service, Scottish Environment Protection Agency and Environment Agency, 2008a) and deep geological disposal facilities (Environment and Heritage Service, Scottish Environment Protection Agency and Environment Agency 2008b).

1.2.4 Regulator strategies and reviews

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

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

Under the Habitats Regulations, the Environment Agency and SEPA have obligations to review new and existing permits to ensure that they do not have an adverse effect on the integrity of Natura 2000 sites. The assessment of impact on habitats is undertaken as a staged approach:

- 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 conducted 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 (phytoplankton) in a Natura 2000 site was 520 μGy h^{-1} in the Ribble and Alt Estuaries Special Protection Areas – affected by Springfields discharges. This was a conservative assessment based on the assumption that Springfields discharges were made at the site permit levels. The second highest was the Drigg Coast Special Areas of Conservation, at 41 μGy h^{-1} 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 in excess of the agreed 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 which concluded that new authorisation limits for the Springfields Fuels Ltd site (in 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 worst affected organism for the Drigg Coast Special Areas of Conservation was reduced to 20 μGy h^{-1}. 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 undertook a Pressures and Impacts Assessment on Scotland's Water Environment from radioactive substances. The report concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data from some locations to support this conclusion. The report is available from:

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

1.2.5 Solid radioactive waste disposal at sea

In the past, disposals of packaged solid waste of low specific activity were mainly made to an area of the deep North Atlantic Ocean. The last such disposal was in 1982. The UK Government announced the permanent cessation of disposal of such material at sea at the OSPAR Ministerial meeting in 1998. At that meeting, Contracting Parties agreed that there would no longer be any exception to a prohibition on the dumping of radioactive substances, including wastes (OSPAR, 1998). The environmental impact of the deep ocean disposals was predicted by detailed mathematical modelling and has been shown to be negligible (Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985). Disposals of small amounts of waste also took place from 1950 to 1963 in a part of the English Channel known as the Hurd Deep. The results of environmental monitoring of this area in 2007 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 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 materials 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) and which has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2007, a specific assessment was conducted for the disposal of dredged material in the vicinity of the Port of Heysham, 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. Incidents involving the transport of radioactive materials in the UK have been assessed by the HPA (Hughes *et al.*, 2006). Submarine berths in the UK are monitored by the MoD (DSTL, 2007). General monitoring of the British Isles is undertaken as part of the programmes described in this report. This would detect any gross effects from the sources above. No such effects were found in 2007. 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 Environment Protection Act 1990 provides the basis, through the Environment Act 1995, for a regulatory regime for the identification and remediation of contaminated land. Implementation of the regime initially focused on non-radioactive contamination. In 2006 the regime was extended to provide a system for identification and remediation of land, where contamination is causing lasting exposure to radiation of human beings 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 given rise to 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 II 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 and 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 with the exception that clear criteria are set for discrete point sources for the designation of Radioactive Contaminated Land. Akin to the situation in England and Wales, the regime does not currently apply to radioactive contamination from nuclear licensed sites, but a second phase of regulation will be implemented in due course.

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 in the terrestrial environment. Where this is found, appropriate comments are made in this report.

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

1.2.7 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 retarding food spoilage organisms and inhibit ripening, germination or sprouting of certain food products. Irradiation may also be used as a phytosanitary measure to rid plants or plant products of harmful organisms.

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

- New authorisation was issued to Sellafield Limited in September 2007. New authorisation for Urenco expected to follow in 2008
- Discharges, concentrations and dose rates were generally similar to 2006
- Doses (Table 2.1) were less than 1 per cent of dose limit

Springfields, Lancashire

- In 2007, Springfields Fuels Limited (SFL) operated under new management
- Discharges were similar to 2006, except for a significant reduction in discharges classified as gross beta
- Concentrations of Th-234 (discharged under gross beta) were much reduced in 2007. Gamma and beta dose rates also reduced
- Doses to wildfowlers and anglers over salt marsh and fishermen handling nets decreased
- Other doses from discharges (Table 2.1) were similar to 2006
- The total dose from all sources was 11 per cent of the dose limit, reduced from 13 per cent in 2006

Sellafield, Cumbria

- Sellafield Limited were new operator for Sellafield appointed in 2007
- Top level review of authorisations to dispose of radioactive waste from Sellafield published in 2007 by Defra and Department of Health (DH)
- Operation of THORP restarted in July 2007
- Report produced to assess the availability of technetium-99 to marine foodstuffs from contaminated sediments
- Discharges to atmosphere were similar to 2006, except antimony-125 which decreased
- Liquid discharges of tritium, carbon-14, cobalt-60, ruthenium-106 and iodine-129 were slightly lower in 2007
- New surveys of local diet and occupancy rates, including activities carried out on beaches
- Concentrations and dose rates were generally similar to those in 2006. Strontium-90 concentrations in milk were lower and antimony-125 in terrestrial samples were all below LoDs. Technetium-99 continued to decline in shellfish; some decreases in radionuclide concentrations in finer coastal sediment and lower beta dose rates
- Dose to seafood consumers (0.24 mSv) from artificial radionuclides was similar to 2006. Dose from gaseous discharges (0.023 mSv) was reduced in 2007 (from 0.029 mSv, 2006) (Table 2.18)
- The *total dose* from all sources, including the legacy of phosphate processing, was reduced to 37 per cent of the dose limit, from 43 per cent in 2006

There are four sites in the UK associated with 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, 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. The Windscale nuclear site, also owned by the NDA, is located on the Sellafield site and both are licensed separately to Sellafield Limited. Windscale is discussed in Section 3.4. The 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 2007, 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, 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. Urenco (then known

as Urenco (Capenhurst) Limited) operated a facility involving centrifuge enrichment of uranium.

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, 2006d) and in February 2007 for Urenco (Environment Agency, 2007b). A new authorisation for Sellafield Limited was issued in September 2007.

Gaseous discharges and terrestrial monitoring

Uranium was the main radioactive constituent of gaseous discharges from Capenhurst in 2007, with small amounts of tritium and other radionuclides present in discharges by Sellafield Limited, mainly from the incinerator. The main focus for terrestrial sampling was on the tritium, technetium-99 and uranium content of milk, crops, fruit, silage, grass and soil. Results for 2007 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 2001, and reflects the reductions in discharges of technetium-99 from recycled uranium. In future Urenco is expecting to increase their enrichment of reprocessed uranium, which may lead to increases in discharges of technetium-99 and neptunium-237 (without increasing existing limits).

Liquid waste discharges and aquatic monitoring

The new authorisation held by Sellafield Limited places limits on liquid waste discharges to the Rivacre Brook of 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 2007 are presented in Table 2.2(a) and (b). Concentrations of radionuclides and dose rates were very low and similar to those in 2006. 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. Variations in concentrations in sediment from the Brook are to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in waters were also very low. Measured dose rates were slightly enhanced relative to natural background near to the discharge point. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides; these reflected the distant effects of discharges from Sellafield.

Doses to the public

The measured concentrations of radionuclides and dose rates were used to assess doses to the public due to the Capenhurst

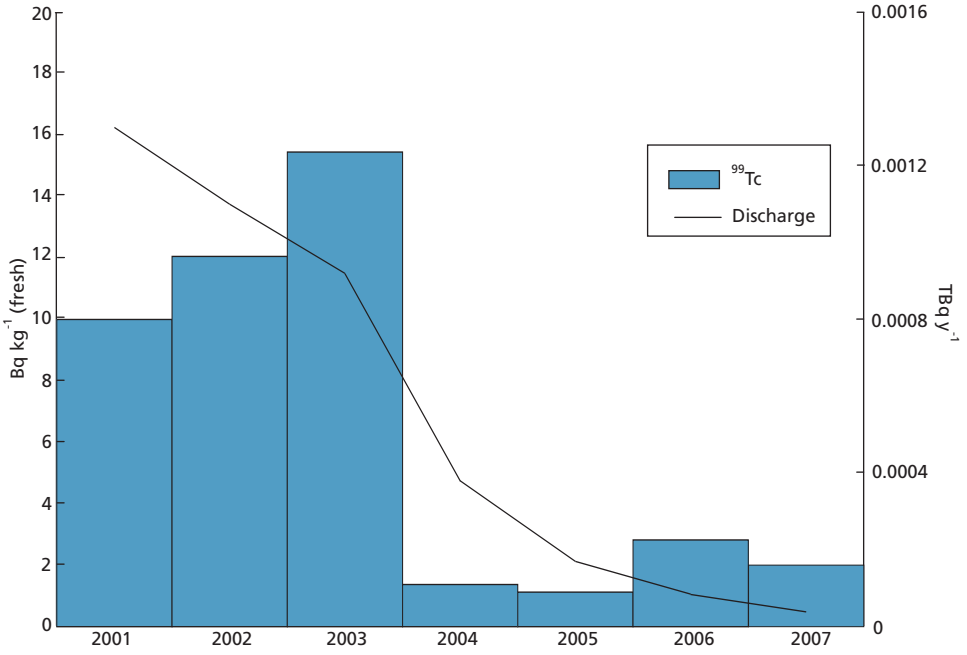
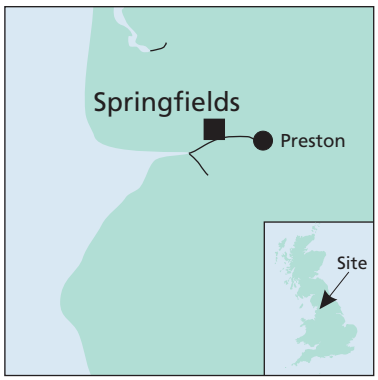


Figure 2.1. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2001-2007

sites' operations. Doses were estimated for children playing in and around Rivacre Brook and consumers of local milk and vegetables. The highest dose was 0.007 mSv for children who play near the Brook and may also inadvertently ingest water and sediment (Table 2.1), and the value was similar to 2006 (0.008 mSv). 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. Doses to consumers of locally grown food were much less than 0.005 mSv in 2007.

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.

The most recent habits survey was undertaken in 2006 and the results of the survey used in the dose assessment. 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

For many years the site has been authorised to discharge small amounts of uranium to the atmosphere. Authorisations also set limits on discharges of tritium, carbon-14, and other alpha and beta radionuclides from research and development facilities.

Monitoring of foods around the site included sampling of milk, fruit and vegetables and these were analysed for; tritium, carbon-14, strontium-90, iodine-129, and isotopes of uranium, thorium, plutonium and americium. Gamma-ray spectrometry was also conducted and the 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 2007 are shown in Table 2.3(a). As in previous years, slightly elevated concentrations of uranium isotopes, compared with those at 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 are made from the Springfields site to the Ribble Estuary by two pipelines. The most recent authorisation in November 2004 set limits on gross alpha and beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides. In 2007, the largest discharge was of short half-life beta-emitting radionuclides, mostly thorium-234. In 2007, the amount of beta-emitting radioactivity discharged was 3 TBq, reduced from 21 TBq in 2006 (see Figure 2.3). The reduction in discharge was because the Uranium Ore Concentrate (UOC) purification process ended in 2006. The site's authorisation was varied in 2007 with new reduced discharge limits in place from January 2008.

The Ribble Estuary monitoring programme consisted of *in situ* measurement of dose rates, and the collection and analysis of sediments for isotopes of uranium and thorium and for gamma emitting radionuclides. Locally obtained fish, shellfish and samphire were sampled and analysed by gamma-ray spectrometry and radiochemically for isotopes of uranium, thorium and plutonium.

Results for 2007 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 2007, thorium-234 concentrations were much reduced compared to recent years as a result of the reduction in discharges (Figure 2.3).

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

Gamma dose rates in the estuary were generally elevated above those to be expected due to natural background (the UK average for muddy estuaries is 0.07 μGy h^{-1}). The elevated dose rates are due to the presence of the gammaemitting radionuclides caesium-137 and americium-241, from Sellafield. Gamma dose rates in the estuary were generally slightly lower in 2007 than those in 2006. Gamma dose rates taken for houseboat assessments were also slightly lower in 2007 than 2006. Beta dose rates on fishing nets were also enhanced above

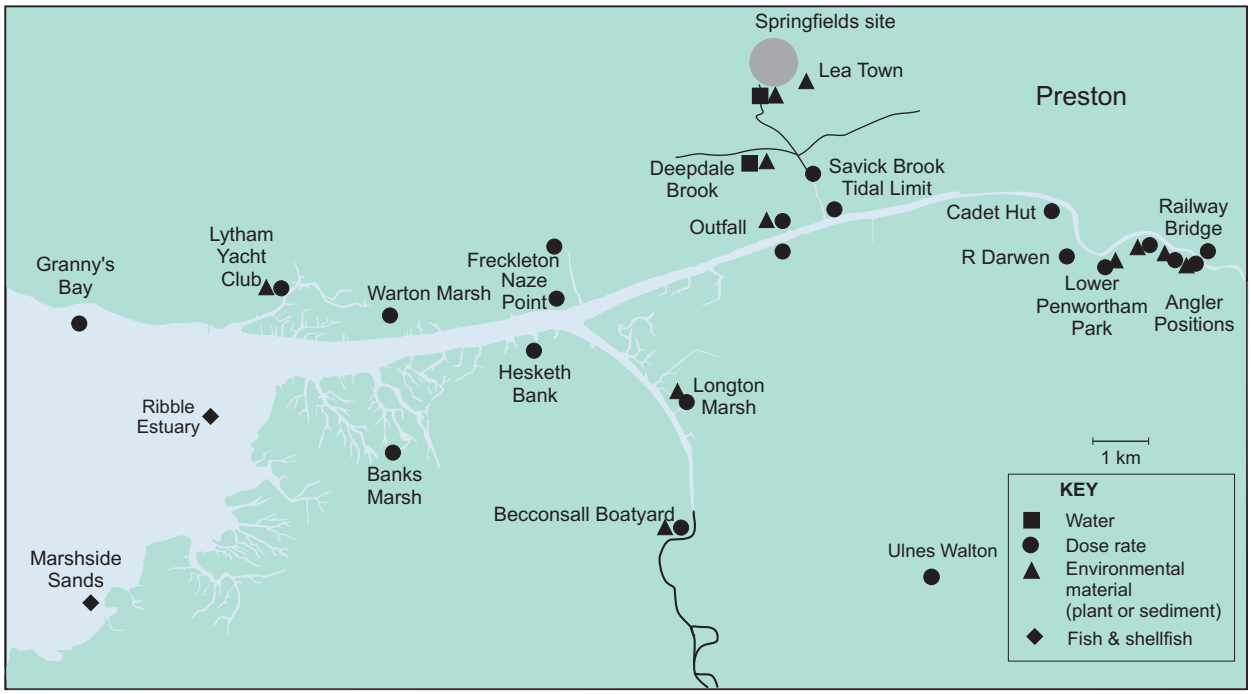


Figure 2.2. Monitoring locations at Springfields (not including farms)

those expected due to natural background. This was due to the concentrations of beta-emitting radionuclides such as thorium-234 and protactinium-234m from Springfields. Beta dose rates in 2007 were generally lower than those in 2006 due to the reduction in discharges.

Solid waste disposals and related monitoring

The Springfields and Capenhurst authorisations permit disposal of solid LLW by controlled burial at Clifton Marsh landfill site. The results of Environment Agency monitoring of waters near the landfill site are shown in Section 7, Table 7.4 (Landfill Sites).

Until 1983, BNFL had also disposed of LLW to the Ulnes Walton landfill site. The Environment Agency monitors waters from near the landfill site at Clifton Marsh. The results are shown in Section 7, Table 7.4 (Landfill Sites).

Doses to the public

Concentrations of radioactivity in environmental materials and dose rates have been used together with the most recent habits data (in 2006) to assess doses to a number of groups of the public who might be subject to higher rates of exposure. Doses were calculated to the following groups (Table 2.1): those consuming foods such as fruit and vegetables grown around

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

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 2007, the dose to high-occupancy houseboat dwellers in the Ribble Estuary was 0.073 mSv, less than 8 per cent of the 1 mSv dose limit for members of the public. The assessed dose to houseboat dwellers in 2007 was similar in 2006 (0.075 mSv). In 2007, it was not possible to take gamma dose rate measurements aboard a houseboat, so dose rates were derived by using 2006 measurements, normalised with 2007 occupancy rates. This information was directly applicable to the locations where high-rate occupancy was taking place. The trend in doses over the period 2001 – 2006 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.

The dose to high-rate seafood consumers in 2007, including a contribution from external exposure, was 0.016 mSv, which was less than 2 per cent of the dose limit for members of the public of 1 mSv, of which 0.010 mSv was from external exposure and 0.007 mSv was from eating fish and shellfish. The total dose in 2007 was reduced from 0.022 mSv in 2006. The majority of the change in dose in 2007 was because external dose rates in the Ribble were reduced from 0.015 mSv in 2006, whilst the dose from eating fish was unchanged. 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 river-banks was less than 0.005 mSv. The skin dose for fishermen handling nets was estimated to be 0.045 mSv, much less than the skin dose limit of 50 mSv. The reduction from 0.075 mSv (in 2006) to 0.045 mSv in 2007 was attributed to lower measured beta dose rates, resulting from decreased discharges of short half-life beta-emitting radionuclides. The dose to wildfowlers and farmers from exposure over salt marsh was 0.017 mSv, which was less than 2 per cent of the dose limit for members of the public of 1 mSv. The decrease in dose from 0.033 mSv (in 2006) was due to lower gamma dose rates over marsh. The dose to the group consuming terrestrial foods grown around the site was less than 0.005 mSv. In 2007, the dose from non-food pathways arising from discharges to air was also assessed. After allowing for atmospheric plume related pathways, using the methods and data given in Appendix 1, the critical group dose in 2007, from the consumption of terrestrial food, 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 *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.11 mSv or 11 per cent of the dose limit.

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

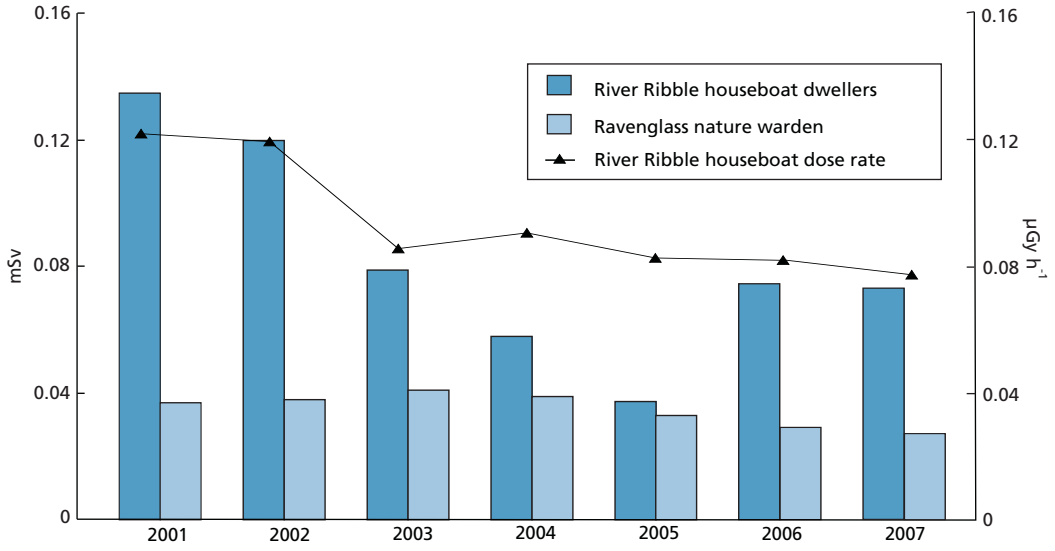


Figure 2.4. Individual radiation exposures to groups affected by external gamma dose, 2001-2007

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 and is now being decommissioned. The Windscale site is located on the Sellafield site, and is discussed in Section 3.

The operation of THORP remained suspended throughout 2006 as a result of the discovery in April 2005 of the leak of radioactive material from primary into secondary containment. 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 (Health and Safety Executive, 2007b). The operation of THORP restarted in July 2007 with a limited campaign (33 tonnes) of spent oxide fuel reprocessed, which represented the total amount for the year. The reprocessing of spent Magnox fuel continued during 2007 with a total of 374 tonnes of fuel reprocessed, compared to 720 tonnes reprocessed in 2006.

A number of minor occurrences are recorded for 2007 at Sellafield in Appendix 2 Table A2.4 and where relevant these are referred to later in this section.

Defra and the DH jointly carried out a review of the Environment Agency's decisions following its reviews in August 2002 and August 2004 of the authorisations to dispose of radioactive wastes from the Sellafield site of British Nuclear Fuels plc (BNFL). In August 2007, Defra and Department of Health jointly published their decision document. They concluded that it is not necessary or appropriate at this time for them to exercise their powers of direction under section 23 of the Radioactive Substances Act 1993 in respect of the existing Sellafield authorisations (Department for Environment, Food and Rural Affairs and Department of Health, 2007).

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. Discharges of gaseous wastes from Sellafield in 2007 (summarized in Appendix 2) were much less than the authorised limits, and included a reduction in antimony-125 discharges (in comparison to 2006).

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 Food Standards Agency and by SEPA for marine and terrestrial samples collected in Scotland. 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 2007 including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials such as grass and soil. Samples were obtained from different locations around the site to allow for variations due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses undertaken included gamma-ray spectrometry and specific measurements for tritium, carbon-14, strontium-90, technetium-99, iodine-129, uranium and transuranic radionuclides.

The results of monitoring in 2007 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 2006. Concentrations of strontium-90 in milk were lower than in 2006.

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

A wide range of fruit and vegetables was sampled in 2007 including apples, blackberries, broccoli, cabbage, carrots, cauliflower, elderberries, potatoes, beans, beetroot and carrots. The results 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 LoDs in all terrestrial samples in 2007, including grass, consistent with reduced discharges.

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 2007 are summarised in Appendix 2. The current authorisation sets limits on gross alpha and beta, and

15 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 tritium, carbon-14, cobalt-60, ruthenium-106 and iodine-129 were slightly lower in 2007 compared with those in 2006. This reflects the reduced amounts of fuel reprocessed because of the THORP and Magnox reprocessing plant shutdowns in recent years.

A variation to the authorisation was introduced in April 2006 to reduce the annual technetium-99 discharge limit (to 10 TBq). Discharges of technetium-99 were similar in 2007 to those in 2006, but 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 (TetroPhenylPhosphonium bromide – TPP) in EARP to remove technetium-99 from the historic stock of MAC. This was completed in November 2007.

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2007. 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 recent changes in liquid discharges from the site and their effects.

Monitoring of fish and shellfish

Concentrations of beta/gamma activity in fish from the Irish Sea and from further afield are given in Table 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 is taken from this area. Specific Cefas 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.

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. Earlier time trends are reported in RIFE-12 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007). Concentrations generally continue to reflect changes in discharges, over time periods characteristic of radionuclide mobility and organism uptake. There is variability from year to year, particularly for the more mobile species. For the transuranics (Figures 2.11 – 2.12), the long-term trends in reductions of concentrations, from earlier reported discharges, appear to be slowing, although this was not consistent with a slightly elevated concentration of plutonium-239/240 in lobsters in 2007.

Beta/gamma-emitting radionuclides detected in fish included: tritium, carbon-14, cobalt-60, strontium-90, caesium-137 and plutonium-241. Concentrations of caesium-137 in fish were generally similar in 2007 to those in 2006. 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.

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. Concentrations of tritium in local seawater at St Bees are less than 5 Bq l^{-1} (Table 8.19). 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). Some of the winkles, mussels and limpets sampled were provided by consumers who collect in the Sellafield coastal area. 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

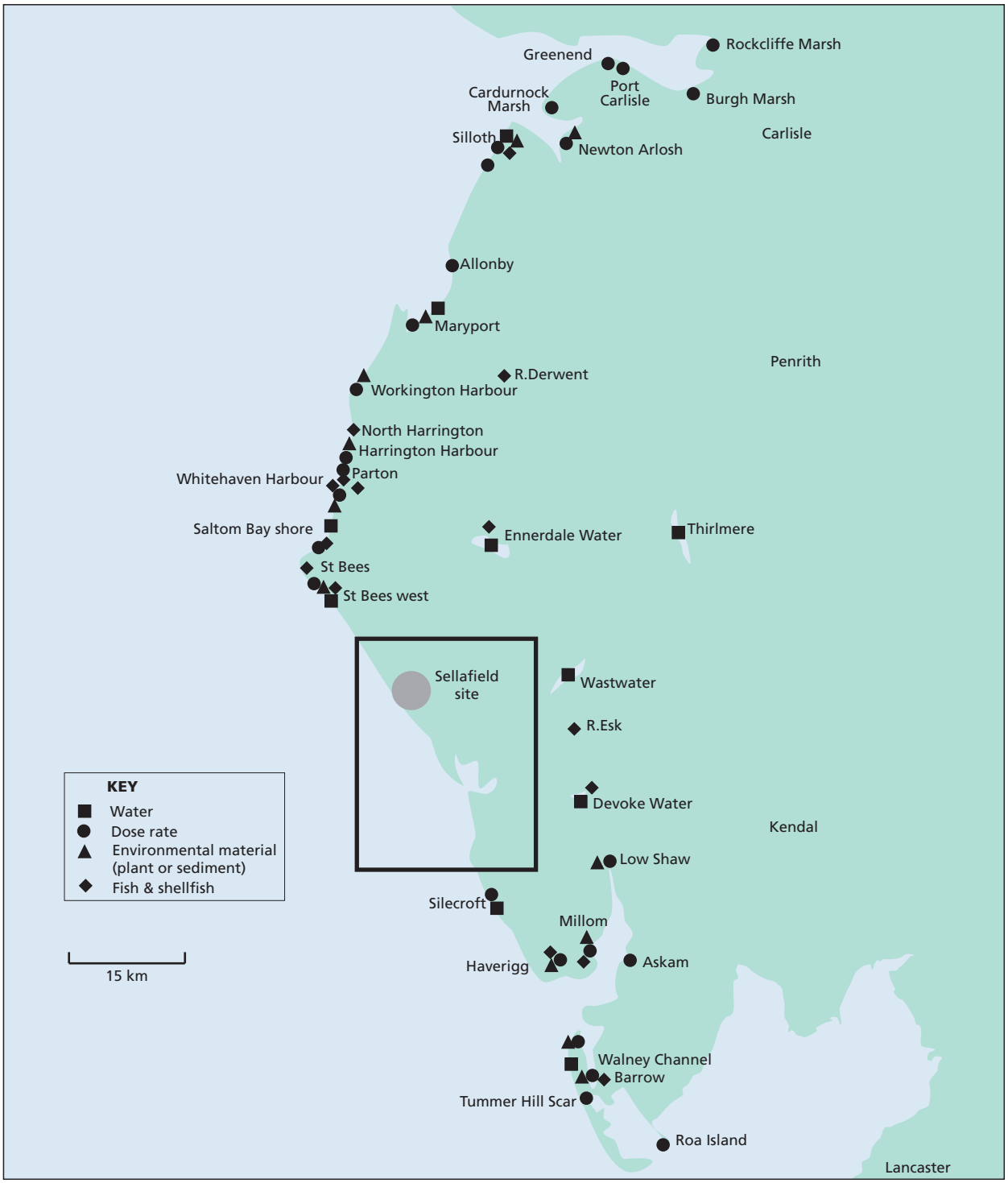


Figure 2.5. Monitoring locations in Cumbria (not including farms)

Sellafield discharges are of tritium, carbon-14, and technetium-99. Comparing 2007 and 2006 data across a wide range of sampling locations and shellfish species, concentrations of radionuclides were reduced for technetium-99, cobalt-60 and carbon-14 due to progressive reductions in discharges. Concentrations of others 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 2007 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 2007 were generally similar to those in 2006; those from the north-eastern Irish Sea were the highest concentrations of transuranics found in foodstuffs in the UK. In comparison to 2006 data, slightly higher concentrations were measured for plutonium radionuclides and americium-241 at selected locations. At the Sellafield coastal area, slightly elevated concentrations were observed in lobsters and a range of molluscs. Also, in comparison to 2006 data, higher concentrations were also measured for

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

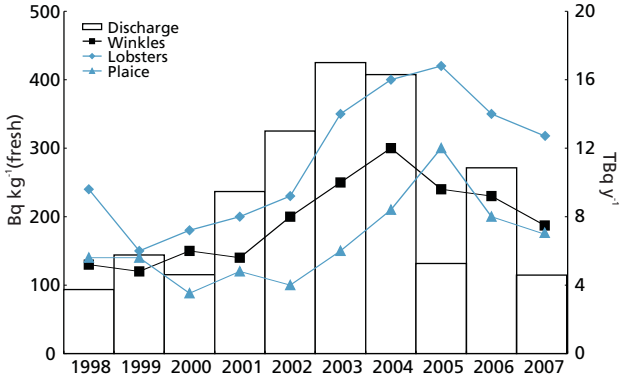


Figure 2.7. Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

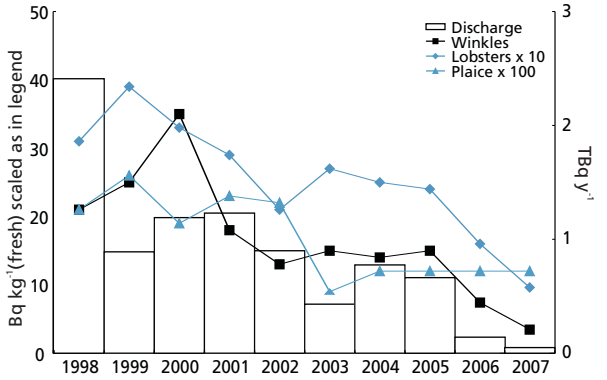


Figure 2.8. Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

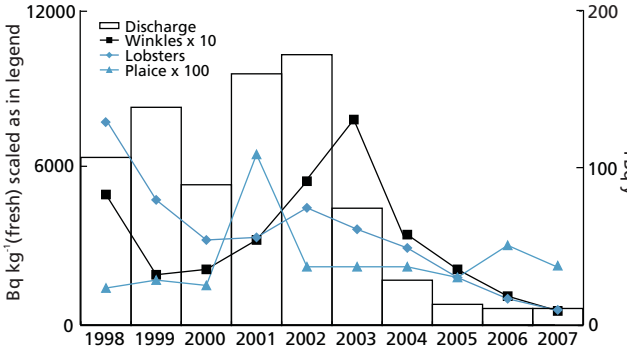


Figure 2.9. Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

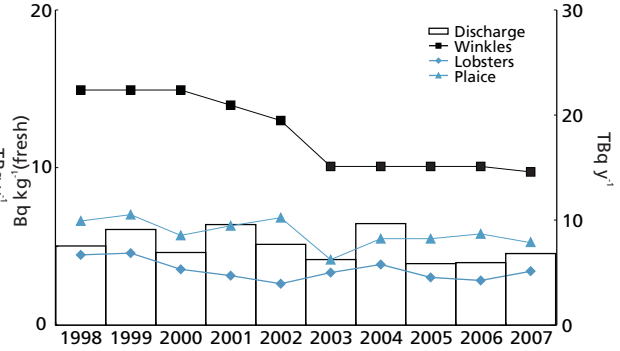


Figure 2.10. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

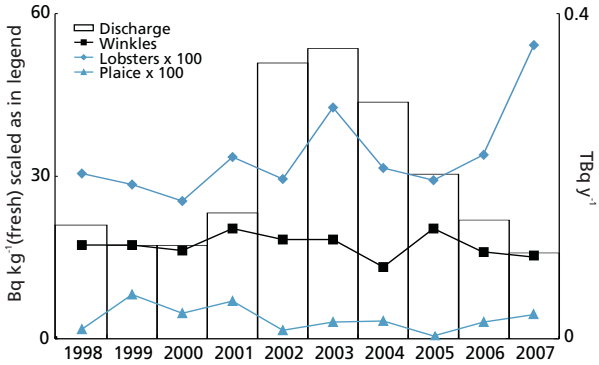


Figure 2.11. Plutonium-239/240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

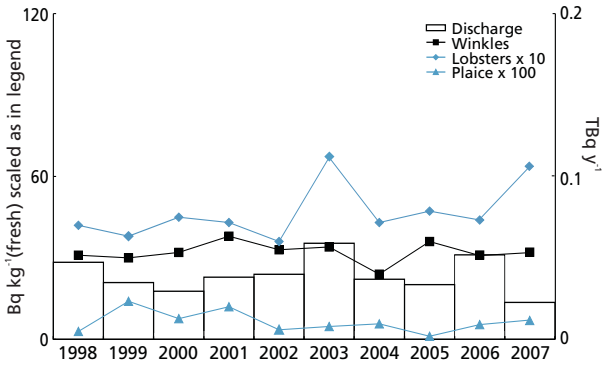


Figure 2.12. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

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. 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 2007 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 2007 were generally similar to those in 2006, with some slight reduction in levels of caesium-137 and transuranic elements in finer sediments (Newbiggin and River Mite Estuary) in comparison to most recent years.

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 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007). Discharges of cobalt-60 have been variable in recent years, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration for the earlier part of the decade (Figure 2.15).

Over the last decade, caesium-137 and transuranic levels in sediments have generally remained constant with the lowest levels reported in 2007 (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. This result could be due to remobilization 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 as yet 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.

A research project was commissioned by the Food Standards Agency to assess the availability of technetium-99 to marine foodstuffs from contaminated sediments. The study concluded that the impact of technetium-99 remobilization from sediments upon concentrations in the water (hence

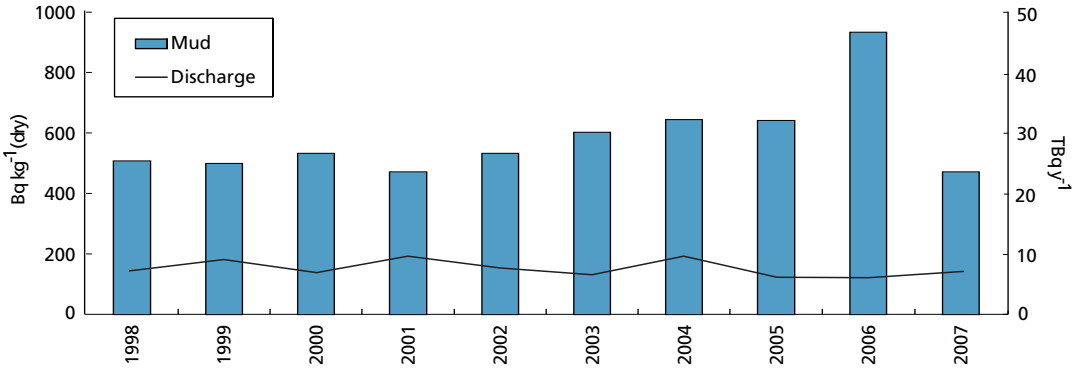


Figure 2.13. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass

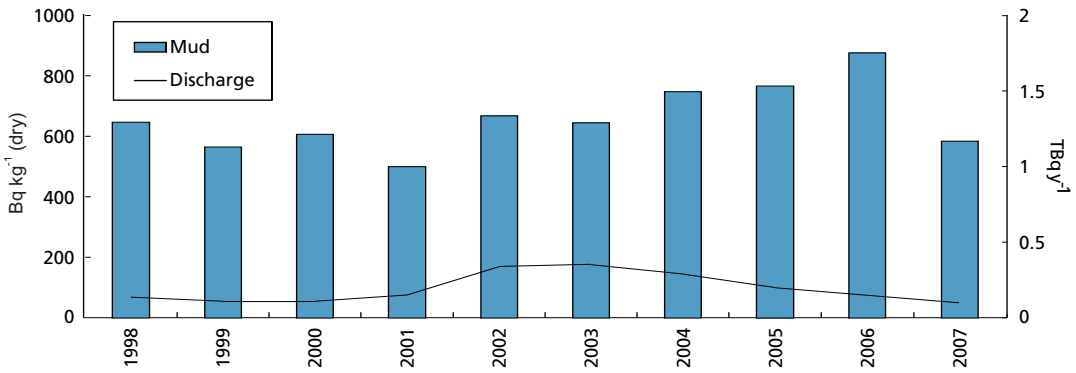


Figure 2.14. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass

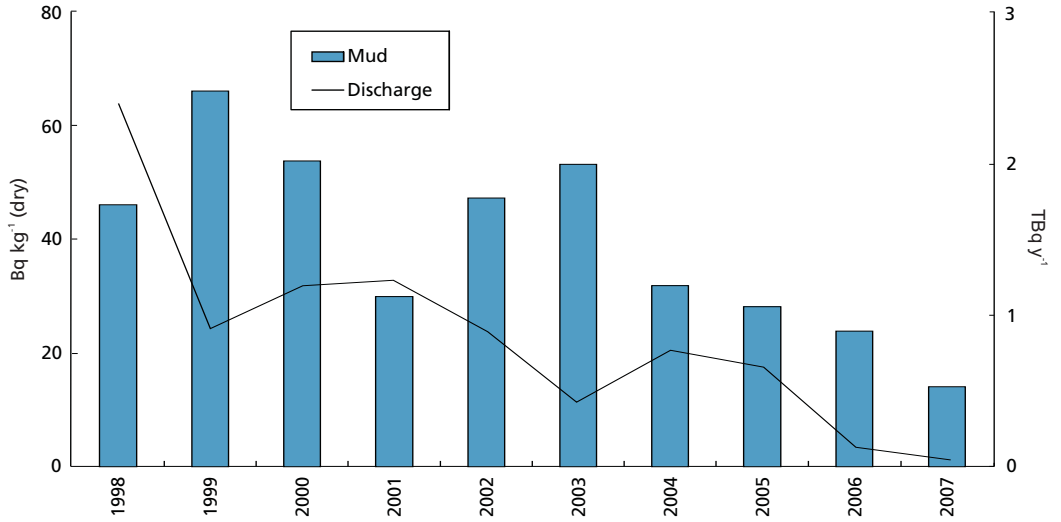


Figure 2.15. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass

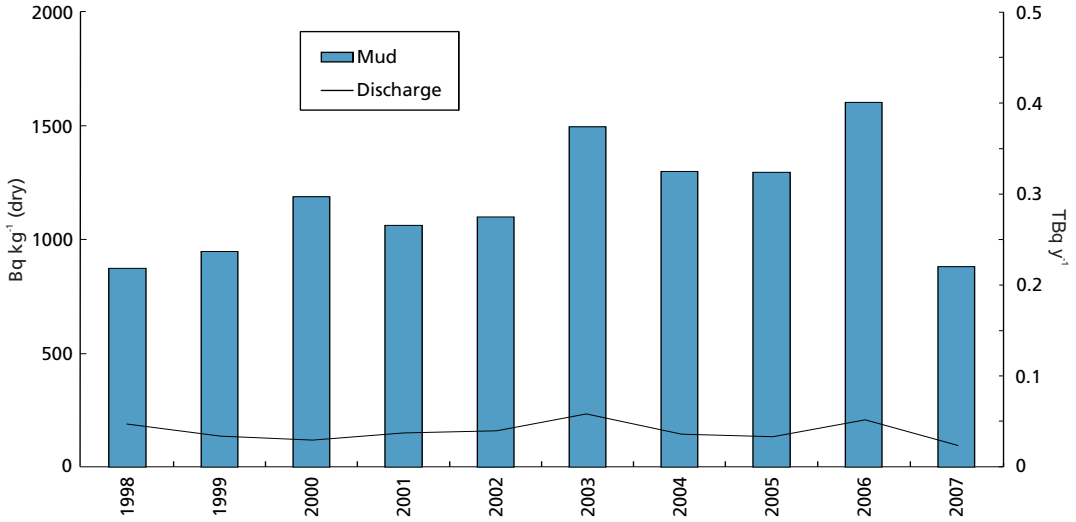


Figure 2.16. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass

concentrations in fish and shellfish in the Irish Sea) is predicted to be minimal and likely to remain broadly similar to those in 2005 in the short to medium term (up to 2012) (McCubbin *et al*., 2008).

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 2007 were similar to those data for the same locations in 2006. Slightly higher gamma dose rates from the Ravenglass estuary (River Mite) were measured in 2007, than in 2006. 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 a 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.

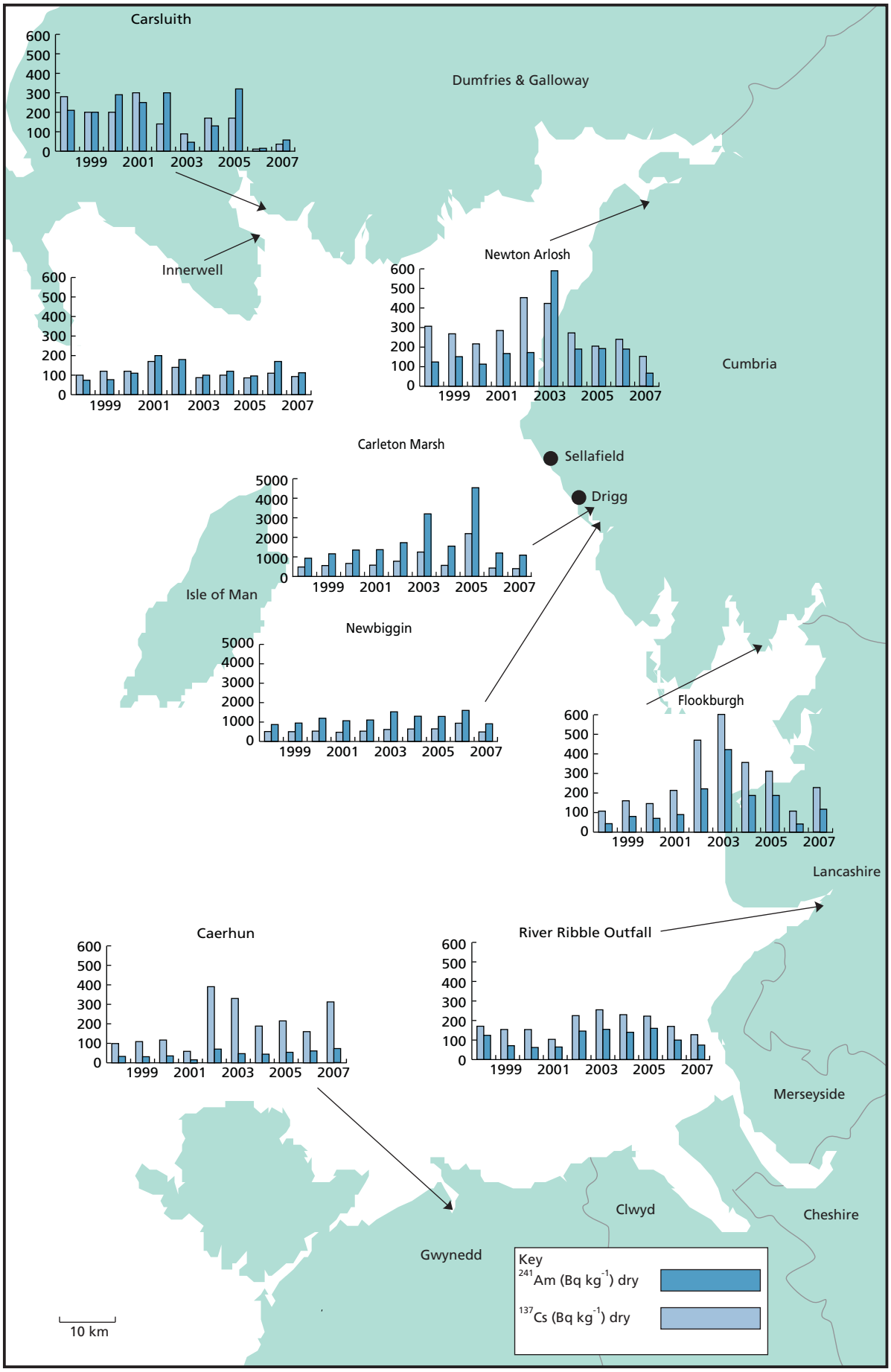


Figure 2.17. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 1998-2007. (Note different scales used for Newbiggin and Carleton Marsh)

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 2007 are presented in Table 2.10. Measured dose rates were generally lower than those in recent years with a number of LoDs reported, due to some individual measurements not detecting beta activity.

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments, using contamination monitors, to allow the exposure to be estimated for people who handle sediments regularly are presented in Table 2.11. Dose rates were reduced (significantly in some locations) at the majority of sites in comparison to recent years, with some measurements not detecting beta activity.

More general beta/gamma monitoring 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 2007, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

In November 2006 and February 2007, trials were carried out using improved and more effective radiation detection equipment mounted on a small tractor-like vehicle. The trials were successful and routine monitoring using this new specialised equipment began in May 2007, following the operator's own statutory environmental monitoring programme.

The monitoring conducted in 2007 covered areas of the beach between Drigg Point and the Solway Firth, but has mainly focussed on areas close to Sellafield itself. During 2007, 261 radioactive items (small particles, pebbles and stones) were recovered. The finds contained a range of radionuclides, but in terms of activity were principally caesium-137 (maximum activity in a single find up to 900 kBq), with some containing mainly americium-241 (maximum activity in a single find up to 640 kBq) and associated plutonium isotopes. A number of these finds were identified for detailed analysis, which will be completed in 2008. Identification of the precise origin of these finds is in progress, but it is highly likely that the vast majority, if not all, are related to past events and incidents at Sellafield. A large number of the finds are of an average dimension of 1 cm or less and some of these particles are the size of sand grains. The rest are stones and pebbles. The majority of the finds have been found buried at depths of up to 20 cm in sand close to the Sellafield site. Monitoring along the Cumbrian coast is set to continue as part of the routine environmental monitoring programme in 2008.

Between May and September 2007 a habits survey was conducted, on behalf of the Environment Agency, to provide information about activities carried out by members of the public on beaches in the vicinity of the Sellafield nuclear site, in particular those which may affect their potential exposure to radioactive particles.

Based on information available to date, HPA considers that no special precautionary actions are necessary at this time regarding access to or use of these beaches. However, the HPA and EA 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's website at: http://www.environment-agency.gov.uk/regions/northwest/850243/871159/?version=1&lang=_e (Environment Agency, 2008g). Further detail on the monitoring data compiled so far, and a map of the locations of the finds, can be obtained from Sellafield Limited – see their website – http://www.sellafieldsites.com/search/BEACH+MONITORING. Future work includes a review of particle dispersion and transport models, focused on the Eastern Irish Sea and Solway Firth, as a contribution to a

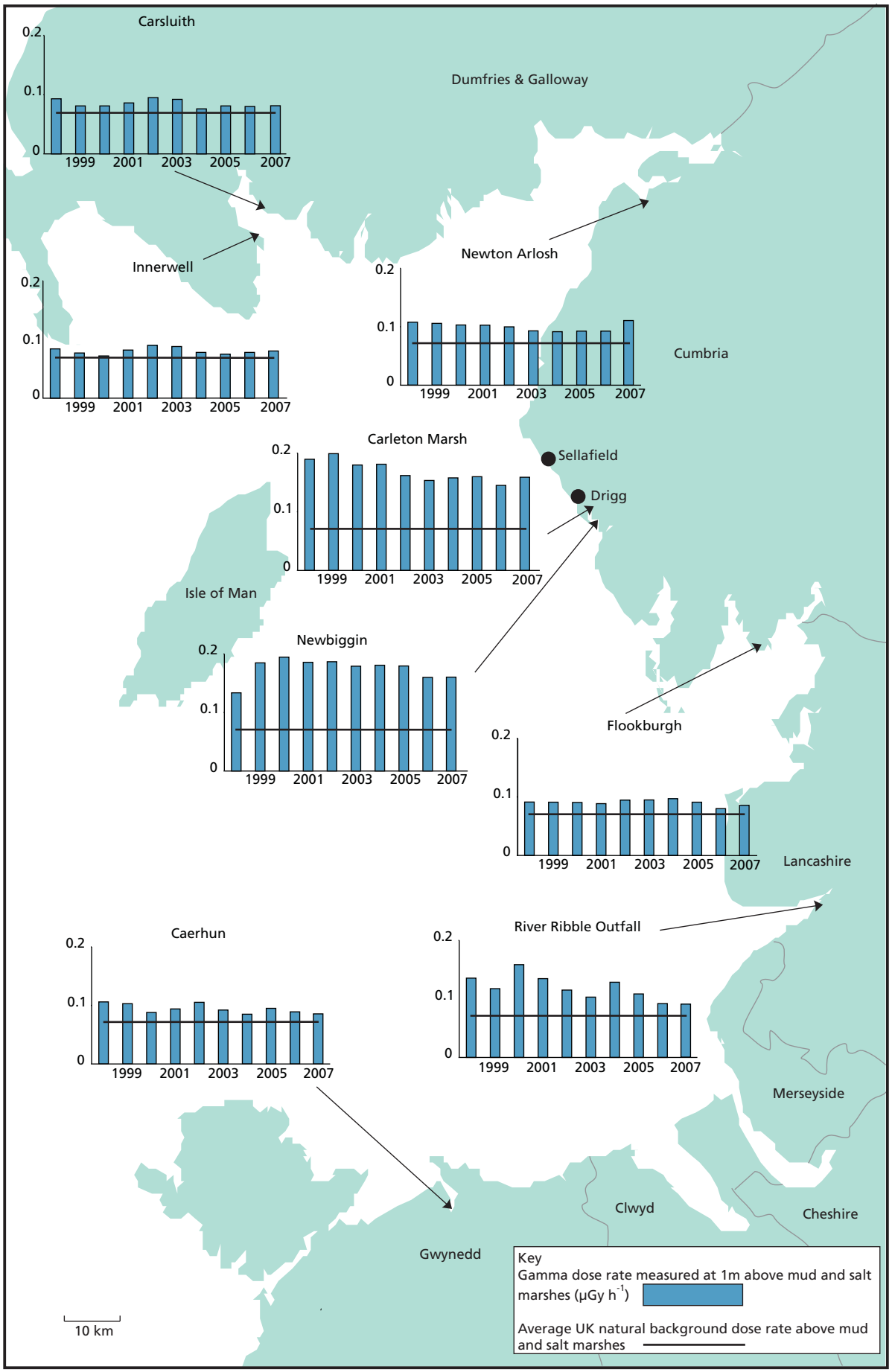


Figure 2.18. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 1998-2007

wider work programme investigating the distribution and behaviour of Sellafield-related particles.

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, 2007c). 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. However, as there remains uncertainty in many issues relating to the Sellafield particles, SEPA are keeping the issue under review to determine if further monitoring is required in 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 2007 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, over the last decade, are shown in Figure 2.19. Earlier time trends are reported in RIFE-12 (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007). 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. The previously increased levels at Fishguard over the last three years were not observed in 2007, however elevated levels continued at Cemaes Bay on the Isle of Anglesey. At Carlingford Lough in Ireland technetium-99 concentrations in *Fucus* continued to fluctuate over recent years. These effects were most likely the result of complex hydrographic 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).

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

Seaweeds are sometimes used as fertilisers and soil conditioners and this potential pathway for the transfer of radionuclides into the food chain continues to be investigated. The results in 2007 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 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 2006. Concentrations of gamma-emitting radionuclides were below the LoD in vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2007; 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 2007 are presented in Table 2.12. *Porphyra* from the Cumbrian coast clearly showed reduced concentrations of ruthenium-106 compared 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 2007 are also presented in Table 2.12; concentrations of radionuclides were mostly undetectable, or close to the LoD.

In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. The Food Standards Agency and SEPA are part way through a three-year study to investigate the potential transfer of radionuclides to the food chain, from seaweed that is used as a soil conditioner, compost or animal feed in Scotland. Further information is given in Chapter 8,

with results for soils and seaweed given in Table 8.20. Investigations have shown that, excluding use for a limited number of allotments, this does not take place to a significant extent in the Sellafield area.

Monitoring of seawashed pasture

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow-up sampling of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2006 suggested that this dose estimate remains valid.

Monitoring of sea to land transfer

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

The results of measurements in 2007 are presented in Table 2.14. In general, the data are similar to those for 2006 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. The evidence for sea to land transfer is limited, but higher than expected results were observed for technetium-99 in cabbage and grass. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. However, results for transuranic elements in sheep offal, and technetium-99 in cabbage, were higher than expected. 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.

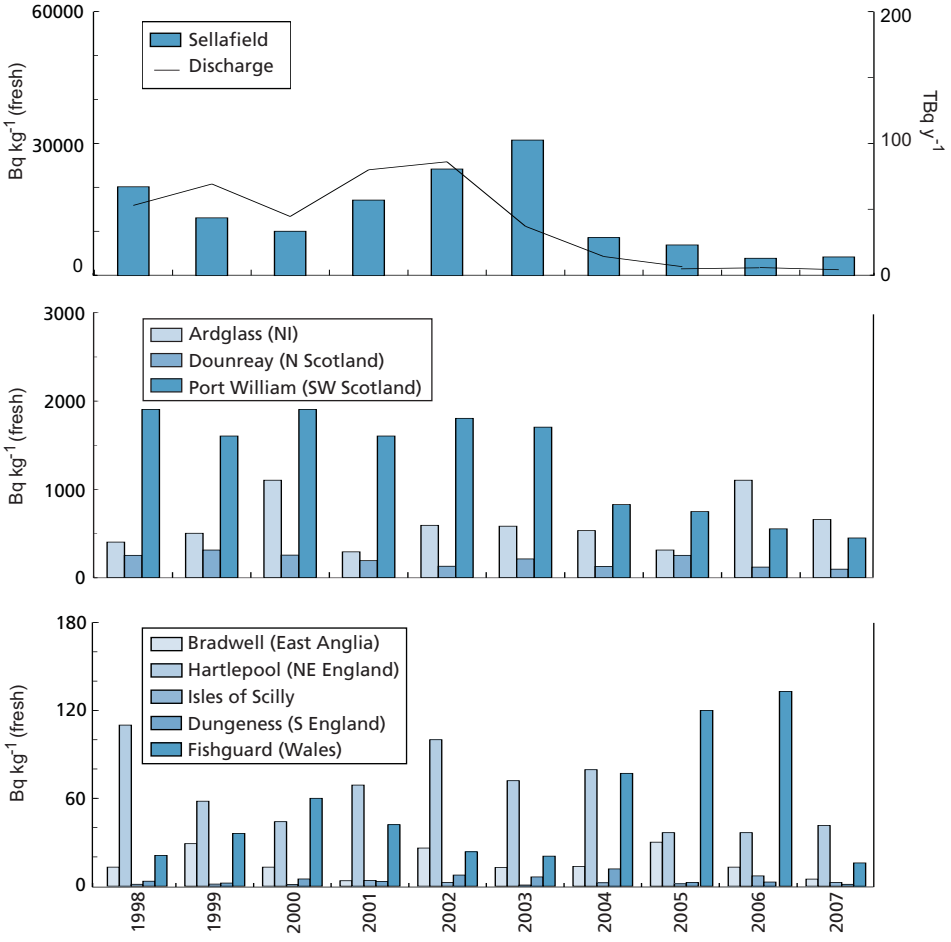


Figure 2.19. Technetium-99 liquid discharge from Sellafield and concentration in seaweed, *Fucus vesiculosus*

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 2007 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 2007 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 2007 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 2007 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon was very low in 2007 (0.35 Bq kg^{-1}), in comparison to the value reported 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 2007, samples were taken from the same drains as in previous years. The results of analyses in 2007 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 0.023 mSv (adult: 0.014; 10y: 0.017; prenatal: 0.012). The most significant contributions to infants' dose were from strontium-90 and ruthenium-106, but it should be noted that the dose assessment used ruthenium-106 concentrations in foods at the limits of detection and are therefore likely to be a maximum value. The most important foodstuff was domestic fruit, which accounted for 44 per cent of the dose.

The estimated dose from high-rate food consumption by infants in 2007 was (0.023 mSv), which is slightly less than the corresponding dose in 2006 (0.028 mSv), mostly attributed to a reduction in concentrations of strontium-90 in milk. 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 – 2007 are shown in Figure 2.20. The trend has been a generally declining one with reductions in doses of about 10 per cent over the last 5 years. The downward trend is mainly due to the permanent shut down of Calder Hall and the resulting cessation of discharges of argon-41 and sulphur-35.

Doses from liquid discharges

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

Doses from seafood consumption

The consumption and occupancy rates of the local critical group were reviewed in 2006; small changes were found in the amounts and mixes of species consumed, with a decrease in mollusc consumption and an increase in occupancy rates over sediments. The 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 (2007 habits survey). The second was based on a five-year rolling average using habit data gathered from 2003 to 2007. Aquatic pathway habits are normally the most important in terms of dose at Sellafield and are surveyed every year. This allows generation of a unique yearly set of aquatic habits data and also rolling five-year averages for aquatic habits. The rolling averages are intended to smooth the effects of sudden changes in habits and provide an assessment of dose that follows more closely changes in radioactivity concentrations in food and the environment. The five-year averages are used for the main assessment of doses from liquid discharges and follows the recommendations of the report of the Consultative Exercise on Dose Assessments (Food Standards Agency, 2001a).

Table 2.18 summarizes doses to seafood consumers in 2007. The dose to the local critical group of high-rate consumers from artificial radionuclides, using the rolling average habits data, was 0.24 mSv. This dose includes a contribution due to external radiation exposure over sediments. This is slightly higher than the dose reported for 2006 (0.23 mSv), and the increase was largely attributed to increases in concentrations of americium-241 in both winkles and other molluscs. Most of this dose was due to historic discharges from Sellafield. The increase in dose is consistent with the suggestion of the recent increases in some radionuclide concentrations in sediments close to 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 about

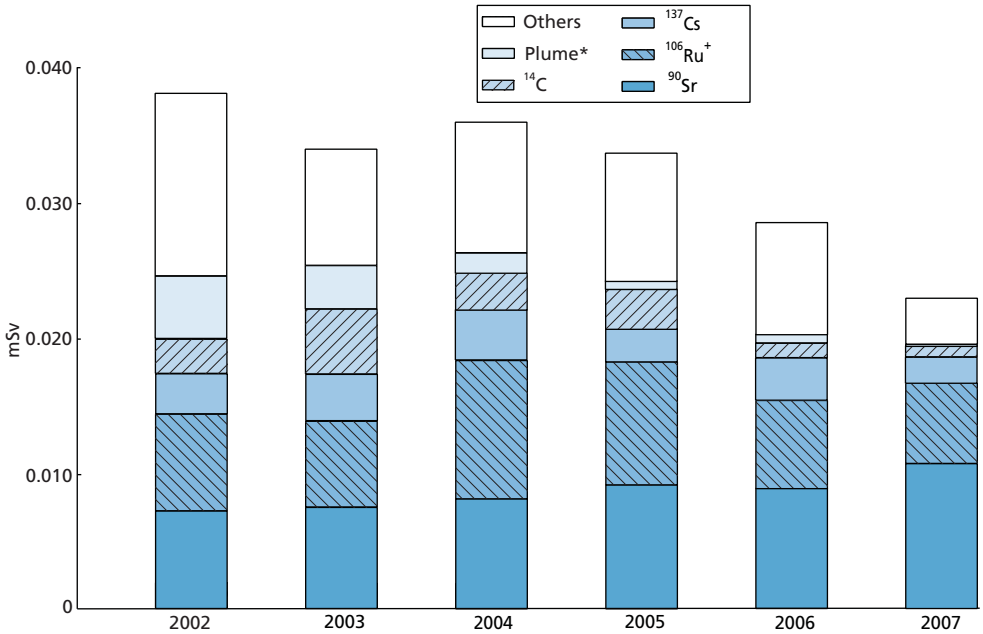


Figure 2.20. Contibutions to dose from gaseous discharges from Sellafield, 2002-2007
(* External and inhalation pathways, based on limits of detection for concentrations in foods)

2 per cent (3 per cent in 2006) of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose (79 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 another west Cumbrian source, the former phosphate works at Whitehaven, are also considered here. These works were demolished in 2004 and the authorisation to discharge radioactive wastes revoked. The increase in concentrations of naturally-occurring radionuclides due to the historic discharges is difficult to determine above a variable background (see Appendix 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 2007 was estimated to be 0.28 mSv. Most of this was due to polonium-210. Slightly higher concentrations of polonium-210 in mollusc and crustacean samples contributed to the increase in dose from 2006 (0.22 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 0.24 mSv dose from artificial radionuclides from Sellafield this gives, when rounded again to two significant figures, a combined dose to the critical group of 0.52 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.

A single-year dose assessment for the Sellafield seafood consumers based on consumption rates and habits survey data for 2007 is provided in Table 2.18 for comparison with the assessment using the five year average habits data.

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). A habits survey along the Dumfries and Galloway coast was undertaken in July/August 2007. In comparison with the previous survey (in 2002), small variations were generally found in the amounts of species consumed, with a slightly increased occupancy rate over sediments. Mollusc consumption for the assessment changed from whelks and king scallops to mussels and cockles. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1. 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 small changes (slight reduction overall) in the doses in each area when compared with those in 2006 (given in Figure 2.22 and Table 2.17), except at the Dumfries and Galloway coast. At this location, in 2007, the dose was 0.060 mSv (0.037 mSv in 2006). The increase was largely attributed to the inclusion of new habits information for the consumption of molluscs and hence the contribution of americium-241 from the North Solway coast. 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.

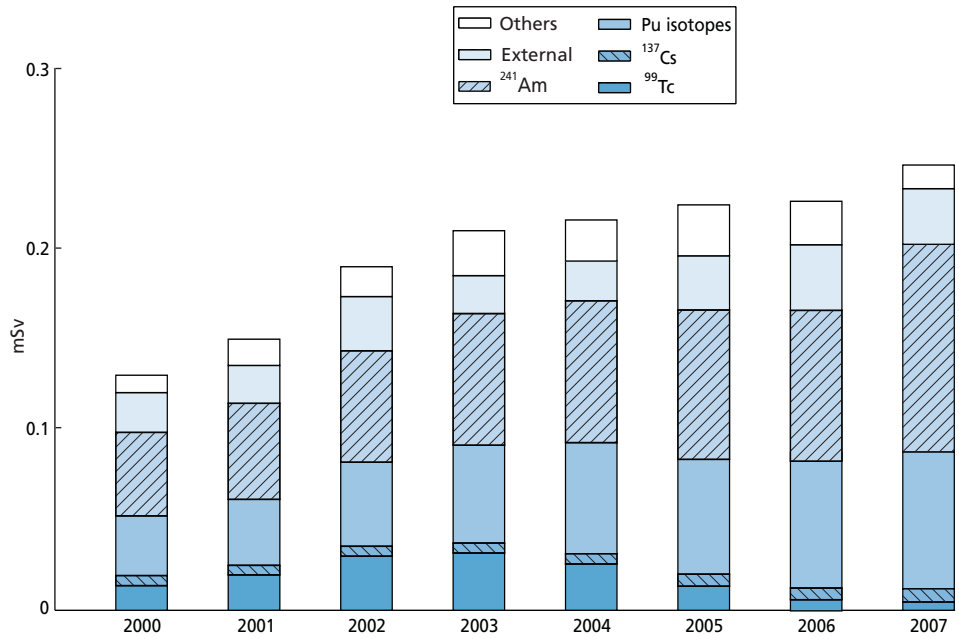


Figure 2.21. Contributions to dose to seafood consumers at Sellafield, 2000-2007

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. The dose to such a person was very low, less than 0.005 mSv in 2007.

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 2007 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 2007, their dose was 0.073 mSv or less than 8 per cent of the dose limit for members of the public (see Section 2.2 Doses to the public). Other groups received lower external doses in 2007. The most important of these was found in the Ravenglass estuary

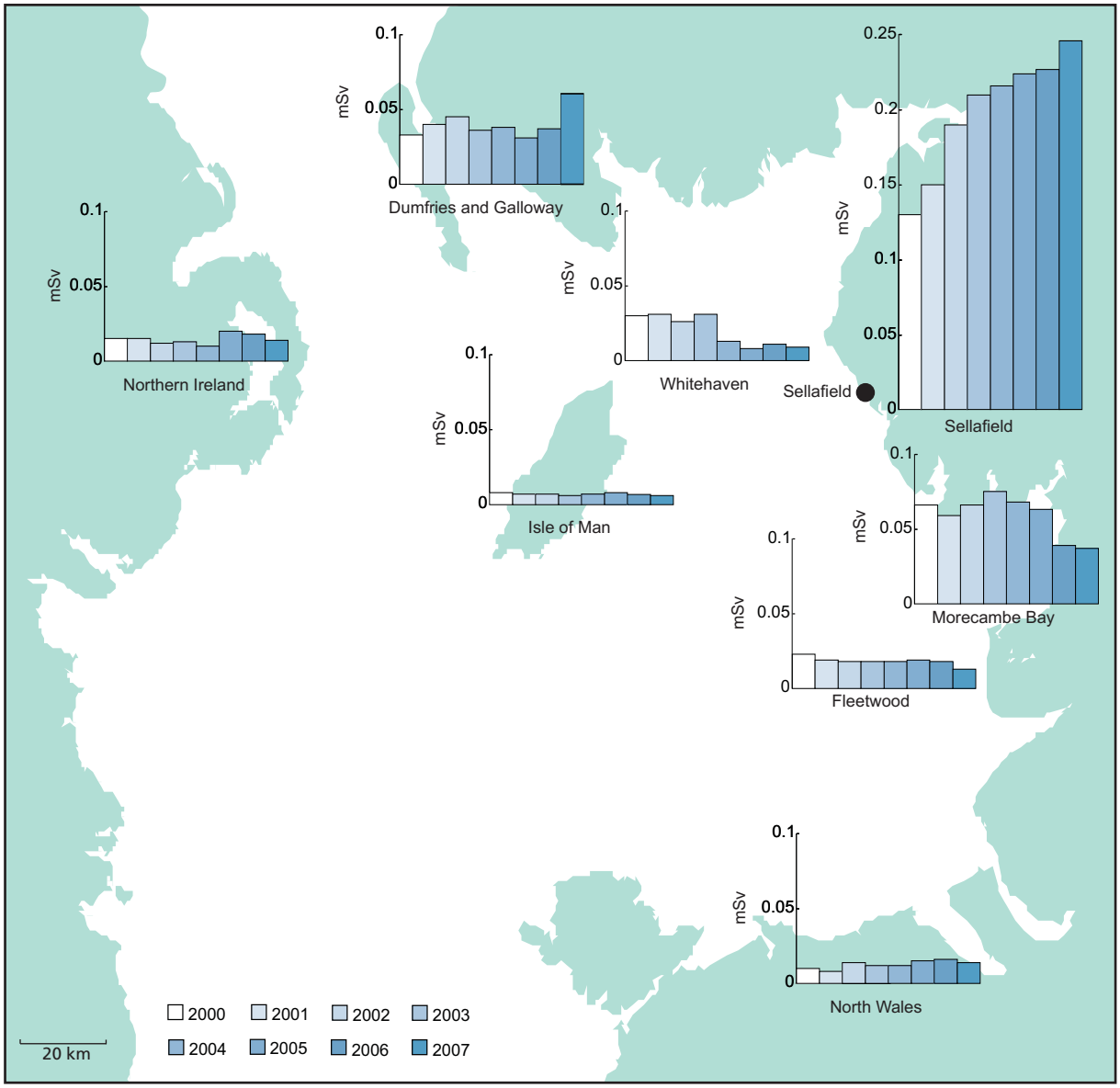


Figure 2.22. Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2007

where exposure is represented by a nature warden (0.027 mSv). Dose rates 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 who were exposed to external radiation whilst on salt marshes. The total exposure to wildfowlers including external dose was 0.008 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 2.18).

In 2007, the doses received from a number of other activities (not previously presented) were estimated. Firstly, 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. Typical doses to residents visiting selected local beaches from Sellafield and Northern Cumbria (Whitehaven to Solway) were both 0.010 mSv, whilst residents from Lancashire and North Wales both received doses of 0.006 mSv. Residents visiting the Isle of Man received a dose of 0.008 mSv. Typical doses to residents visiting local muddy areas or salt marsh near Sellafield were 0.019 mSv; those visiting Lancashire and Northern Cumbria (Whitehaven to Solway) received 0.007 mSv, whilst residents from North Wales and Dumfries and Galloway received doses that were less than 0.005 mSv. These doses are represented spatially in Figure 2.23. Secondly, 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 less than 0.005 mSv.

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; for those most exposed, a time handling nets and pots of 730 h per year was appropriate. The skin dose from handling of fishing gear in 2007, including a component due to naturally-occurring radiation, was 0.036 mSv, which was less than 0.5 per cent of the appropriate annual dose limit of 50 mSv specifically for skin. Handling of fishing gear is therefore a minor pathway of radiation exposure. The skin dose to bait diggers and shellfish collectors, based on a time handling sediment of 1,000 h per year, was 0.083 mSv in 2007 which was also less than 0.5 per cent of the skin dose limit. The decrease in dose from 2006 (0.19 mSv) was attributed to the reduction in measured dose rates at the majority of sites in 2007.

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 2007 is given in Table 2.18. The infant age group received the highest exposures, the largest contribution of dose was from strontium-90 in milk. Although results for transuranic elements in sheep offal, and technetium-99 in cabbage, were higher than expected, these were not major contributors to the dose through terrestrial food consumption. 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 2006. 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 2007 was estimated to be 0.012 mSv similar to the value in 2006 (0.013 mSv). Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales is 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 2007 (Ministry of Agriculture,

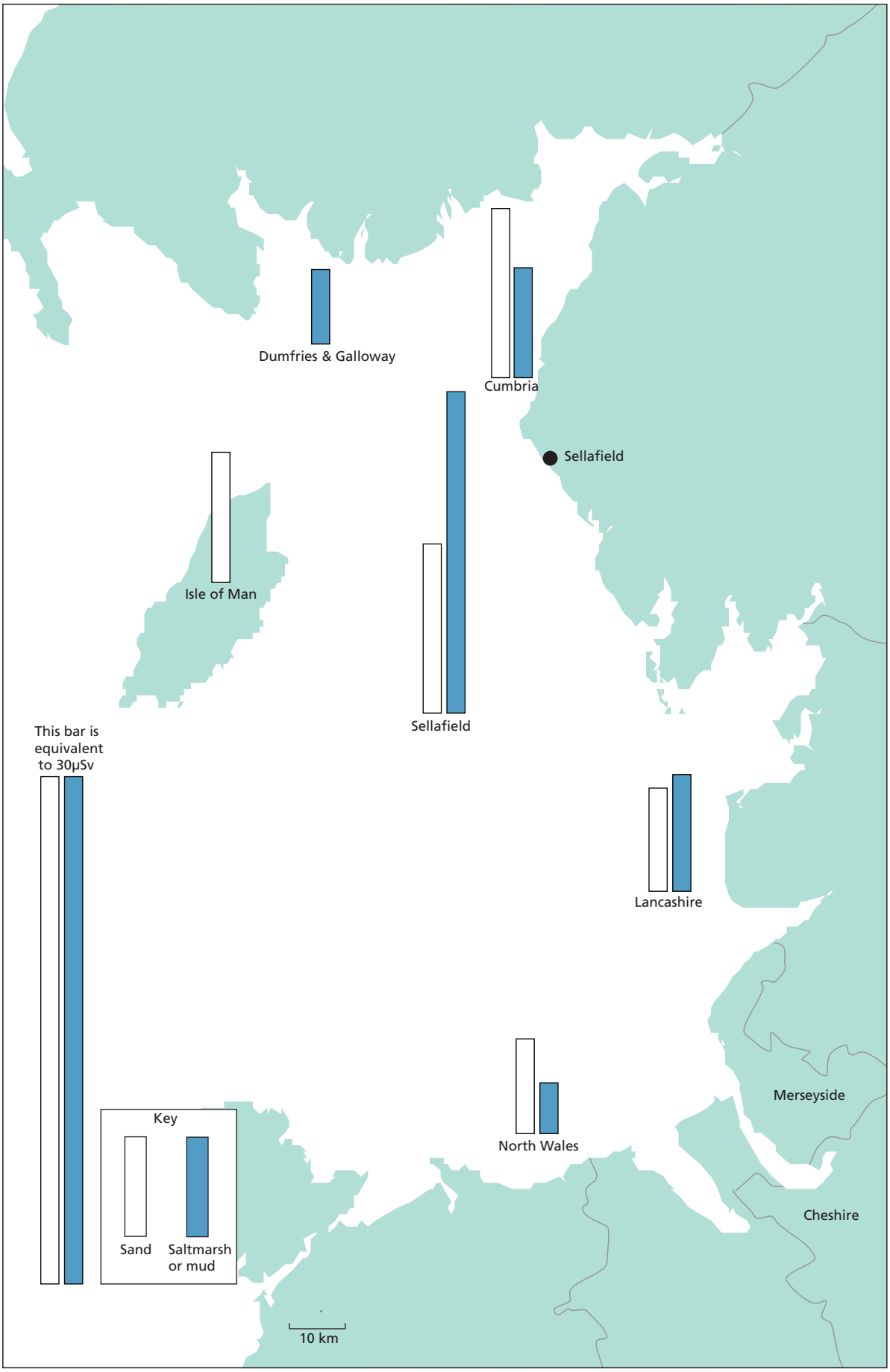


Figure 2.23. Individual radiation exposures to typical residents visiting beaches and other intertidal areas, 2007

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. Further details are given in Appendix 5.

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 2007 was 0.37 mSv to the shellfish consumer group. This is a decrease from 0.43 mSv in 2006 and is largely attributed to a reduced consumption rate of molluscs by this group, decreasing from 40 kg in 2006 to 30 kg in 2007. The *total dose* was made up of 0.18 mSv from radionuclides from Sellafield, and 0.19 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, 2007

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]	<0.005	-	<0.005	-	-	-
	Children playing at Rivacre Brook[d]	0.007	-	-	0.006	<0.005	-
Springfields	Seafood consumers	0.016	0.007	-	0.010	-	-
	Houseboat occupants	0.073	-	-	0.073	-	-
	Fishermen handling nets or pots[c]	0.045	-	-	0.045	-	-
	Children playing at Lower Penwortham[d]	<0.005	-	-	<0.005	<0.005	-
	Farmers and wildfowlers	0.017	-	-	0.017	-	-
	Inhabitants and consumers of locally grown food[e]	<0.005	-	<0.005	-	-	<0.005
	All sources[f]	0.11	-	-	-	-	-

[a] *Adults are the most exposed group unless otherwise stated*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50mSv 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, 2007

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											
Plaice	Liverpool Bay	1	<25								
Plaice	Mersey Estuary	1	<25								
Dab	Liverpool Bay	1	<25								
Dab	Mersey Estuary	1	<25								
Shrimps	Wirral	2	<25	<0.06	0.59	<0.61	<0.16	1.9	*		
Mussels	Liverpool Bay	2	<25								
Mussels	Mersey Estuary	2	<25								
Cockles	River Dee	4		<0.17	5.6	<1.7	<0.37	1.6	*		
Sediment	Rivacre Brook	1[E]			1300			8.5	270	300	15
Sediment	Rivacre Brook (1.6 km downstream)	2[E]			73			2.9	25	31	1.2
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			20			1.2	<10	14	<0.80
Sediment	Rossmore (4.3 km downstream)	1[E]			43			2.1	21	26	1.2
Freshwater	Rivacre Brook	2[E]	<8.2		0.30					0.12	<0.0055
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.5		<0.40					0.049	<0.0050
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.0		<0.40					0.042	<0.0050
Freshwater	Rossmore (4.3 km downstream)	1[E]	<4.0		<0.20					0.044	<0.0050
Freshwater	Dunkirk Lane Pond	2[E]	<4.0		<0.45					<0.0070	<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					<0.24				
Cockles	River Dee	4			0.17	0.95	2.7	*	*		
Sediment	Rivacre Brook	1[E]	180	<1.0						620	1500
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	20	<1.0						280	790
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	10	<1.0						140	560
Sediment	Rossmore (4.3 km downstream)	1[E]	16	<1.0						260	410
Freshwater	Rivacre Brook	2[E]	0.058	<0.10						0.18	0.47
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	0.025	<0.10						<0.084	0.28
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	0.026	<0.10						<0.075	0.38
Freshwater	Rossmore (4.3 km downstream)	1[E]	0.027	<0.10						0.090	0.34
Freshwater	Dunkirk Lane Pond	2[E]	<0.0070	<0.10						<0.055	1.4

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	^{234}U	^{235}U	^{238}U	Total U
Terrestrial samples								
Milk		5	<2.5	<0.0025				<0.0061
	max		<3.0					
Cabbage		1						<0.031
Gooseberries		1		<0.011				0.048
Potatoes		1		<0.013				<0.030
Grass		4		<0.015				<0.058
Grass	max			0.022				0.13
Grass/herbage	North of Ledsham	1[E]		<3.0	0.27	<0.20	0.34	
Grass/herbage	South of Capenhurst	1[E]		<2.0	<0.20	<0.070	<0.20	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<1.0	0.69	<0.20	0.68	
Grass/herbage	East of station	1[E]		<2.0	<0.40	<0.20	<0.30	
Silage		2		<0.015				0.15
Silage	max							0.21
Soil		1[#]			12	0.52	12	
Soil	North of Ledsham	1[E]		<4.0	20	<0.70	19	
Soil	South of Capenhurst	1[E]		<3.0	14	0.74	15	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		<2.0	16	<1.0	17	
Soil	East of station	1[E]		<2.0	16	<0.90	19	

** 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 concentration*

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Concrete	2	0.095
Rivacre Brook 1.5 km downstream	Grass and mud	2	0.075
Rivacre Brook 3.1 km downstream	Grass and mud	1	0.080
Rivacre Brook 3.1 km downstream	Grass	1	0.071
Rossmore Road West 4.3 km downstream	Mud and pebbles	1	0.074

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2007

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										
Flounder	Ribble Estuary	1			<0.08			<0.21		6.2
Salmon	Ribble Estuary	1			<0.09			<0.19		0.31
Sea trout	Ribble Estuary	1			<0.12			<031		10
Bass	Ribble Estuary	1			<0.30			<0.69		6.1
Grey mullet	Ribble Estuary	2			<0.21			<0.47		7.0
Shrimps	Ribble Estuary	2		58	<0.06		0.75	<0.13		2.2
Cockles	Ribble Estuary	1			0.24			<0.30		1.5
Mussels	Ribble Estuary	2			<0.06			<0.14		0.95
Wild fowl	Ribble Estuary	1	37	35	<0.04	<0.032		<0.13	<1.5	1.1
Samphire	Marshside Sands	1			<0.04			<0.11		0.77
Sediment	River Ribble outfall	4[E]			<0.74					130
Sediment	Lea Gate	1[E]			<0.61					120
Sediment	Lower Penwortham Park	4[E]			<1.8					290
Sediment	Penwortham rail bridge	4[E]			<0.99					120
Sediment	Penwortham rail bridge - West bank	2[E]			<1.6					380
Sediment	Penwortham position 1	4[E]			<0.85					160
Sediment	Penwortham position 2	1[E]			<0.83					200
Sediment	Lytham Yacht Club	1[E]			<0.59					130
Sediment	Becconsall	4[E]			<2.2					230
Sediment	Longton Marsh	1[E]			<1.7					340

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										
Shrimps	Ribble Estuary	2	0.0061	0.0055	0.0025	*				0.00035
Cockles	Ribble Estuary	1	0.10	0.3	0.14	*				
Mussels	Ribble Estuary	2	0.16	0.19	0.074	*				
Wild fowl	Ribble Estuary	1	<0.00029	0.025	0.0052	*				
Sediment	River Ribble outfall	4[E]	22	36	18	210	16	<1.1	15	
Sediment	Lea Gate	1[E]	21	46	16	260	22	1.1	24	
Sediment	Lower Penwortham Park	4[E]	37	97	26	780	27	<1.2	24	
Sediment	Penwortham rail bridge	4[E]	21	41	18	1100	18	<0.78	16	
Sediment	Penwortham rail bridge - West bank	2[E]	39	170	30	130	31	2.0	27	
Sediment	Penwortham position 1	4[E]	24	58	19	660	25	0.92	22	
Sediment	Penwortham position 2	1[E]	34	62	25	430	22	1.3	21	
Sediment	Lytham Yacht Club	1[E]	14	33	17	86	15	<0.90	16	
Sediment	Becconsall	4[E]	28	63	23	<260	22	<1.1	22	
Sediment	Longton Marsh	1[E]	21	61	16	<110	22	0.8	22	

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									
Flounder	Ribble Estuary	1			<0.09				
Salmon	Ribble Estuary	1			<0.10				
Sea trout	Ribble Estuary	1			<0.12				
Bass	Ribble Estuary	1			<1.0				
Grey mullet	Ribble Estuary	2			<0.14				
Shrimps	Ribble Estuary	2	0.0019	0.012	0.021	*	0.000040		
Cockles	Ribble Estuary	1	0.11	0.63	2.1	*	0.0038		
Mussels	Ribble Estuary	2			0.98				
Wild fowl	Ribble Estuary	1	0.0036	0.021	0.034	*	0.000024		
Samphire	Marshside Sands	1			0.46				
Sediment	River Ribble outfall	4[E]			75			460	860
Sediment	Lea Gate	1[E]			58			400	1400
Sediment	Lower Penwortham Park	4[E]			130			840	2200
Sediment	Penwortham rail bridge	4[E]			62			<440	1800
Sediment	Penwortham rail bridge - West bank	2[E]			180			1400	1300
Sediment	Penwortham position 1	4[E]			72			510	1600
Sediment	Penwortham position 2	1[E]			99			470	1300
Sediment	Lytham Yacht Club	1[E]			76			290	640
Sediment	Becconsall	4[E]			120			500	1400
Sediment	Longton Marsh	1[E]			130			700	1800

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	^{129}I	^{137}Cs	Total Cs
Terrestrial samples									
Milk		5							
Apples		1	4.0	13	<0.20	0.012	<0.030		0.027
Beetroot		1							
Blackberries		1	<5.0	15	<0.10	0.068	<0.031		0.063
Cabbage		1	7.0	14	<0.10	0.32	<0.025		0.093
Onions		1	<5.0	9.0	<0.20	0.055	<0.024		0.044
Potatoes		1	<5.0	11	<0.20	0.066	<0.035		0.053
Rabbit		1	8.0	19	<0.30	0.018	<0.026		0.097
Runner beans		1	<4.0	13	<0.30	0.042	<0.026		0.047
Sediment	Deepdale Brook	2[E]			<1.3			2.4	
Grass		1			<0.20			3.2	

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	Total U
Terrestrial samples									
Milk		5							<0.0061
Apples		1	0.0019	<0.00090					<0.024
Blackberries		1	0.0016	<0.00080					0.074
Cabbage		1	0.0062	<0.0020					0.17
Onions		1	0.0012	<0.00070					<0.032
Potatoes		1	0.0020	0.00090					<0.030
Rabbit		1	0.0087	<0.0014		<0.0023	0.00060	<0.0023	
Runner beans		1	0.0020	<0.0015					<0.029
Sediment	Deepdale Brook	2[E]			140	110	4.7	110	
Grass		1							0.33
Grass	Site fence	1[E]				<0.60	<0.30	<0.40	
Grass	Opposite site entrance	1[E]				0.42	<0.10	0.28	
Grass	Opposite windmill	1[E]				1.3	<0.20	1.2	
Grass	Deepdale Brook	1[E]				1.5	<0.20	1.3	
Grass	Lea Town	1[E]				0.42	<0.090	0.36	
Grass	N of Lea Town	1[E]				<0.30	<0.060	<0.30	
Silage		1							0.73
Soil		1[#]				19	0.72	19	
Soil	Site fence	1[E]				95	3.3	84	
Soil	Opposite site entrance	1[E]				140	5.6	130	
Soil	Opposite windmill	1[E]				70	2.8	68	
Soil	Deepdale Brook	1[E]				100	4.3	97	
Soil	Lea Town	1[E]				31	1.5	33	
Soil	N of Lea Town	1[E]				38	1.6	39	
Freshwater	Deepdale Brook	4[E]				0.38	<0.014	0.35	

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	<0.00030	0.00010	<0.040	0.00020		
Blackberries		1	0.00040	<0.00020	<0.064	0.00040		
Cabbage		1	<0.00030	0.00060	<0.080	0.00090		
Onions		1	0.0021	0.00020	<0.057	<0.00010		
Potatoes		1	<0.00030	<0.00030	<0.085	0.00050		
Rabbit		1	<0.00010	<0.00030	<0.075	<0.00020		
Runner beans		1	<0.00030	<0.00020	<0.041	<0.00020		
Sediment	Deepdale Brook	2[E]					400	1300
Grass		1				1.8		
Freshwater	Deepdale Brook	4[E]					0.35	0.55

* *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, 2007

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	1	0.094
Warton Mud Marsh	Grass and mud	1	0.10
Warton Mud Marsh	Salt marsh	1	0.10
Warton Mud Marsh	Salt marsh[a]	1	0.11
Warton Salt Marsh	Salt marsh and mud	1	0.10
Warton Salt Marsh	Salt marsh	1	0.095
Naze Point	Salt marsh and mud	1	0.10
Naze Point	Grass	1	0.10
Banks Marsh	Salt marsh	2	0.099
Banks Marsh	Salt marsh[a]	1	0.11
Hesketh Bank	Salt marsh	1	0.099
Becconsall Boatyard	Grass and mud	3	0.082
Becconsall Boatyard	Grass	1	0.073
Becconsall (vicinity of houseboats)	Grass	2	0.075
Longton Marsh	Salt marsh and mud	1	0.083
River Ribble outfall	Mud	2	0.090
River Ribble outfall	Salt marsh	1	0.091
River Ribble outfall	Grass	1	0.093
Savick Brook, confluence with Ribble	Mud	1	0.080
Savick Brook, confluence with Ribble	Salt marsh	1	0.084
Savick Brook, Lea Gate	Grass and mud	1	0.084
South bank opposite outfall	Grass	1	0.11
Penworthham Bridge cadet hut	Mud	1	0.075
Penworthham Bridge cadet hut	Grass and mud	1	0.076
Lower Penwortham Park	Grass and mud	1	0.078
Lower Penwortham Park	Grass	3	0.074
Lower Penwortham Railway Bridge	Mud	3	0.074
Lower Penwortham Railway Bridge	Grass and mud	1	0.079
River Darwen	Grass and mud	2	0.073
River Darwen	Grass	2	0.075
Riverbank Angler location 1	Mud	1	0.073
Riverbank Angler location 1	Grass and mud	1	0.073
Riverbank Angler location 1	Grass	2	0.072
Riverbank Angler location 2	Grass and mud	1	0.071
Ulnes Walton, BNFL area survey	Grass and salt marsh	1	0.079
Ulnes Walton, BNFL area survey	Grass	2	0.080
Mean beta dose rates			μSv h^{-1}
Lytham - Granny's Bay	Sand	1	*
Ribble Estuary	Gill net	2	<0.022
Ribble Estuary	Shrimp net	2	0.13
Banks Marsh	Salt marsh	1	*
Warton Mud Marsh	Salt marsh	1	0.10
Warton Salt Marsh	Salt marsh	1	0.10

[a] *15cm above substrate*

* *Not detected by the method used*

Table 2.4. Concentrations of radionuclides in terrestial food and the environment near Sellafield, 2007

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
Milk[d]		16	<5.5	<5.8	14	<0.19	0.068	<0.0035	<1.3	<0.40	<0.0087
Milk[d]	max		<8.7	8.7	16	<0.22	0.17		<1.4	<0.46	<0.0098
Apples		2	<5.0	<5.0	13	<0.30	0.12	<0.026	<1.1	<0.40	<0.032
Apples	max						0.14		<1.4		<0.035
Barley		1		<8.0	87	<0.30	0.82		<1.3	<0.50	<0.037
Beef kidney[e]		1	<8.0	<8.0	37	<0.20	0.43	<0.015	<1.2	<0.40	<0.036
Beef liver		1	8.0	11	19	<0.20	0.025	<0.014	<1.3	<0.50	<0.036
Beef muscle		1	<5.0	<5.0	17	<0.10	<0.0070	<0.015	<1.5	<0.20	<0.028
Beetroot		1	<5.0	5.0	18	<0.30	0.33		<0.80	<0.50	<0.028
Blackberries		2	<6.5	8.0	20	<0.15	1.3		<0.85	<0.40	<0.034
Blackberries	max		<9.0	9.0	21	<0.20	1.6		<0.90	<0.50	<0.037
Blackcurrants		1	4.0	7.0	17	<0.30	0.078		<1.6	<0.70	<0.027
Broccoli		1	<4.0	<4.0	10	<0.20	0.12		<1.3	<0.40	<0.026
Cabbage		1	<4.0	<4.0	7.0	<0.20	0.095		<0.90	<0.30	<0.025
Carrots		1	<5.0	<5.0	11	<0.20	0.15	<0.023	<0.90	<0.50	<0.024
Cauliflower		1	<5.0	<5.0	8.0	<0.20	0.12		<2.1	<0.50	<0.026
Duck		1	<7.0	<7.0	97	<0.30	0.027	<0.022	<0.90	<0.40	<0.028
Eggs		1	<6.0	<6.0	28	<0.20	0.019		<0.60	<0.40	<0.035
Elderberries		1	3.0	9.0	19	<0.20	0.39		<1.6	<0.70	<0.031
French beans		1	<4.0	<4.0	11	<0.20	0.11		<1.8	<0.50	<0.028
Honey		1		<8.0	57	<0.20	0.047		<1.2	<0.30	<0.025
Onions		1	<6.0	6.0	8.0	<0.20	0.10		<0.60	<0.30	<0.029
Pheasants		1	<6.0	<6.0	28	<0.10	0.023	<0.026	<0.80	<0.30	<0.027
Potatoes		1	<5.0	<5.0	17	<0.30	0.075		<1.8	<0.70	<0.030
Rabbit		1	<7.0	6.0	19	<0.10	0.032	<0.025	<1.0	<0.30	<0.054
Rhubarb		1	<5.0	<5.0	7.0	<0.20	1.2		<2.0	<0.40	<0.026
Sheep muscle		2	<7.5	<9.0	43	<0.20	0.070	<0.024	<1.7	<0.60	<0.044
Sheep muscle	max		9.0	12	59		0.075	<0.027			<0.050
Sheep offal		2	<10	<12	24	<0.25	0.31	<0.023	<1.3	<0.55	<0.095
Sheep offal	max		12	16		<0.30	0.38		<1.6	<0.60	0.16
Sloe berries		1	<13	10	22	<0.20	1.4		<1.3	<0.40	<0.062
Swede		1	<4.0	<4.0	8.0	<0.30	0.20		<1.5	<0.50	<0.026
Wheat		1		<7.0	71	<0.20	0.62		<1.3	<0.50	<0.046
Wood pigeon muscle		2	<7.0	8.0	28	<0.20	<0.0085		<1.0	<0.30	<0.054
Wood pigeon muscle	max		7.0	9.0	33		0.0090		<1.4		0.074
Grass		5				<0.23		0.053	<0.90	<0.43	
Grass	max					<0.40		0.078	<1.8	<0.60	
Soil		3				<0.27			<1.6	<0.73	
Soil[f]	max					<0.30			<1.8	<0.80	

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	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk[d]		16	<0.20	<0.23	0.20		<0.00015	<0.00016	<0.034	<0.00014
Milk[d]	max		<0.22	<0.40	0.38		<0.00018	<0.00018	<0.039	<0.00018
Apples		2			0.13		<0.00025	<0.00050	<0.036	<0.00060
Apples	max				0.19		<0.00030	0.00080		0.0010
Barley		1			0.35		0.00090	0.013	0.053	0.0089
Beef kidney[e]		1			0.44		<0.00020	<0.00030	<0.099	0.0026
Beef liver		1			0.41		0.00060	0.0054	<0.092	0.0067
Beef muscle		1			0.78		<0.00030	<0.00060	<0.15	0.00050
Beetroot		1			0.12		<0.00010	0.00040	<0.041	0.00020
Blackberries		2			0.43		<0.00020	0.0012	<0.054	0.00085
Blackberries	max				0.44			0.0015	0.070	0.0011
Blackcurrants		1			0.097		<0.00020	0.00020	<0.064	0.00090
Broccoli		1			0.033		<0.00020	<0.00020	<0.076	0.00040
Cabbage		1			0.024		<0.00020	<0.00020	0.051	<0.00020
Carrots		1			0.13					
Cauliflower		1			0.056	0.055	<0.00020	0.00040	<0.052	0.00030
Duck		1			0.31		<0.00010	0.00030	0.057	0.00030
Eggs		1			0.086		<0.00030	<0.00020	<0.059	<0.00020
Elderberries		1			0.23		0.0012	0.0043	0.061	0.012
French beans		1			0.093	<0.032				
Honey		1			1.2		<0.00020	0.00040	<0.077	0.00040
Onions		1			0.095					
Pheasants		1			0.60		<0.00080	<0.00080	0.57	<0.00060
Potatoes		1			0.098					
Rabbit		1			0.72		<0.00010	<0.00050	<0.097	0.0015
Rhubarb		1			0.21		0.00040	0.00080	<0.069	0.0016
Sheep muscle		2			2.6		<0.00010	<0.00030	0.068	0.00035
Sheep muscle	max				2.9			0.00030	0.089	0.00040
Sheep offal		2			0.77	<0.031	<0.00025	0.0021	<0.054	0.0016
Sheep offal	max				0.81	0.031	0.00030	0.0021	<0.058	0.0021
Sloe berries		1			1.8		0.00040	0.0028	<0.043	0.0047
Swede		1			0.27					
Wheat		1			0.36		<0.00070	0.0016	<0.11	0.0016
Wood pigeon muscle		2			0.32		<0.0025	<0.00060	<0.12	0.00055
Wood pigeon muscle	max				0.35		<0.00030	0.00080	0.14	0.00060
Grass		5	<0.17	0.93						<0.12
Grass	max		<0.20	1.2						0.14
Soil		3	<0.20	50						4.1
Soil[f]	max			55						4.9

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

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

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

[d] *The mean concentration of ^{131}I was <0.0050 Bq l^{-1} and the maximum was <0.0058 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.0083, 0.0012 and 0.0059 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 22, 1.0 and 21 Bq kg^{-1} respectively*

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2007

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				<0.08		<0.39	<0.63	
River Derwent	Sea trout	1				<0.23		<0.70	<0.91	
Parton	Cod	4				<0.07		<0.31	<0.49	
Whitehaven	Cod	4			76	<0.09	0.033	<0.35	<0.49	
Whitehaven	Plaice	4				<0.09	0.034	<0.37	<0.55	
Whitehaven	Skates/rays	4				<0.15		<0.82	<1.5	
Whitehaven	Sole	4				<0.12		<0.66	<1.2	
River Ehen	Salmon	1				<0.11		<1.8	*	
River Ehen	Sea trout	1				<0.10		<0.45	<0.70	
Sellafield coastal area	Cod	8				<0.09		<0.46	<0.86	
Sellafield coastal area	Plaice	4	<61	<83		<0.12		<0.42	<0.64	
Sellafield coastal area	Bass	1				<0.11		<0.49	<0.66	
Sellafield coastal area	Grey mullet	1				<0.08		<0.62	<1.5	
Sellafield offshore area	Cod	1				<0.12		<0.45	<0.62	
Sellafield offshore area	Plaice[a]	2			180	<0.12	0.091	<0.48	<0.71	22
Sellafield offshore area	Dab	1				<0.17		<0.67	<0.95	
Sellafield offshore area	Flounder	1				<0.20		<1.1	<2.1	
Sellafield offshore area	Lesser spotted dogfish	2				<0.13		<0.72	<1.2	
Sellafield offshore area	Grey mullet	1				<0.10		<0.63	<1.0	
Sellafield offshore area	Skates/rays	2			97	<0.08	<0.044	<0.42	<0.76	<0.82
River Esk	Salmon	2				<0.13		<0.71	<1.3	
River Calder	Sea trout	1				<0.16		<1.2	<2.6	
Ravenglass	Cod	6				<0.09		<0.46	<0.83	
Ravenglass	Plaice	4	52	61		<0.12		<0.37	<0.53	
Morecambe Bay (Flookburgh)	Flounder	4			64	<0.09		<0.44	<0.73	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.09		<0.57	<1.2	
Morecambe Bay (Morecambe)	Bass	2				<0.09		<0.60	<1.2	
Morecambe Bay (Morecambe)	Flounder	4	<32	35		<0.10	0.032	<0.59	<1.1	1.80
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.08	0.069	<0.31	<0.46	
Fleetwood	Cod	4			61	<0.05	0.021	<0.32	<0.60	<0.78
Fleetwood	Plaice	4				<0.06		<0.40	<0.63	
Ribble Estuary	Flounder	1				<0.08		<0.35	<0.51	
Ribble Estuary	Grey mullet	2				<0.21		<2.6	<1.9	
Ribble Estuary	Salmon	1				<0.09		<0.65	<1.4	
Ribble Estuary	Sea trout	1				<0.12		<0.50	<0.74	
Ribble Estuary	Bass	1				<0.30		<1.5	<2.9	
Liverpool Bay	Plaice	1		<25						
Liverpool Bay	Dab	1		<25						
Mersey Estuary	Plaice	1		<25						
Mersey Estuary	Dab	1		<25						
Scotland										
Shetland	Fish meal	3				<0.24	<0.24	<1.4	<2.6	
Shetland	Fish oil	3				<0.13		<0.79	<1.4	
Minch	Herring	1				<0.10		<0.17	<0.12	
Minch	Mackerel	1			55	<0.12	<0.034	<2.6	*	
West of Scotland	Mackerel	1				<0.15		<4.1	*	
West of Scotland	Farmed salmon	1				<0.09		<0.72	<1.8	
Kirkcudbright	Plaice	4			66	<0.25		<1.7	<5.7	1.3
North Solway	Cod	1	<25	<25	74	<0.05	0.028	<0.27	<0.44	0.59
Inner Solway	Flounder	4			60	<0.15	<0.10	<0.41	<0.38	0.63
Inner Solway	Salmon	1		<5.0		<0.23		<1.1	<1.5	
Inner Solway	Sea trout	1		<5.0		<0.20		<2.2	<6.5	

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	<0.79	<0.19	<0.08	3.5	<0.44	<0.19	
River Derwent	Sea trout	1	<2.2	<0.45	<0.20	2.6	<0.82	<0.32	
Parton	Cod	4	<0.74	<0.21	<0.08	7.8	<0.46	<0.20	
Whitehaven	Cod	4	<0.85	<0.21	<0.09	5.5	<0.41	<0.17	
Whitehaven	Plaice	4	<0.84	<0.21	<0.09	3.8	<0.46	<0.20	
Whitehaven	Skates/rays	4	<1.7	<0.37	<0.17	6.2	<0.74	<0.31	
Whitehaven	Sole	4	<1.3	<0..27	<0.12	3.4	<0.54	<0.21	
River Ehen	Salmon	1	<1.4	<0.29	<0.13	0.24	<0.67	<0.20	
River Ehen	Sea trout	1	<0.98	<0.22	<0.10	0.20	<0.44	<0.18	
Sellafield coastal area	Cod	8	<0.88	<0.24	<0.10	9.0	<0.50	<0.21	200
Sellafield coastal area	Plaice	4	<1.1	<0.27	<0.11	4.9	<0.57	<0.24	170
Sellafield coastal area	Bass	1	<1.1	<0.32	<0.12	10	<0.71	<0.33	
Sellafield coastal area	Grey mullet	1	<0.90	<0.23	<0.08	6.4	<0.56	<0.21	
Sellafield offshore area	Cod	1	<0.97	<0.25	<0.11	5.7	<0.49	<0.20	
Sellafield offshore area	Plaice[a]	2	<1.0	<0.27	<0.11	5.3	<0.50	<0.19	
Sellafield offshore area	Dab	1	<1.4	<0.34	<0.16	4.3	<0.65	<0.25	
Sellafield offshore area	Flounder	1	<2.3	<0.53	<0.21	11	<1.2	<0.52	
Sellafield offshore area	Lesser spotted dogfish	2	<1.5	<0.33	<0.14	6.5	<0.74	<0.28	
Sellafield offshore area	Grey mullet	1	<1.1	<0.31	<0.12	10	<0.71	<0.31	
Sellafield offshore area	Skates/rays	2	<0.83	<0.23	<0.09	4.9	<0.57	<0.25	
River Esk	Salmon	2	<1.3	<0.29	<0.13	<0.17	<0.63	<0.26	
River Calder	Sea trout	1	<1.9	<0.43	<0.19	7.4	<1.1	<0.43	
Ravenglass	Cod	6	<0.84	<0.23	<0.09	8.3	<0.49	<0.20	
Ravenglass	Plaice	4	<0.83	<0.23	<0.09	4.3	<0.47	<0.20	
Morecambe Bay (Flookburgh)	Flounder	4	<1.1	<0.30	<0.10	15	<0.65	<0.29	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<0.98	<0.22	<0.09	7.4	<0.43	<0.16	
Morecambe Bay (Morecambe)	Bass	2	<0.94	<0.24	<0.09	8.5	<0.51	<0.20	
Morecambe Bay (Morecambe)	Flounder	4	<1.1	<0.26	<0.11	7.6	<0.55	<0.21	
Morecambe Bay (Sunderland Point)	Whitebait	1	<0.73	<0.20	<0.08	5.3	<0.47	<0.20	
Fleetwood	Cod	4	<0.56	<0.14	<0.06	3.7	<0.36	<0.14	
Fleetwood	Plaice	4	<0.63	<0.15	<0.06	3.3	<0.31	<0.12	
Ribble Estuary	Flounder	1	<0.76	<0.21	<0.08	6.2	<0.41	<0.17	
Ribble Estuary	Grey mullet	2	<2.5	<0.47	<0.22	7.0	<0.92	<0.29	
Ribble Estuary	Salmon	1	<0.94	<0.19	<0.09	0.31	<0.47	<0.17	
Ribble Estuary	Sea trout	1	<1.3	<0.31	<0.13	10	<0.57	<0.22	
Ribble Estuary	Bass	1	<3.2	<0.69	<0.29	6.1	<1.6	<0.72	
Scotland									
Shetland	Fish meal	3	<2.5	<0.54	<0.26	<0.49	<1.3	<0.52	
Shetland	Fish oil	3	<1.4	<0.36	<0.15	<0.13	<0.79	<0.28	
Minch	Herring	1	<0.85	<0.21	<0.10	0.21	<0.35	<0.18	
Minch	Mackerel	1	<1.6	<0.30	<0.15	<0.11	<0.71	<0.21	
West of Scotland	Mackerel	1	<2.2	<0.44	<0.20	<0.15	<1.6	<0.53	
West of Scotland	Farmed salmon	1	<0.97	<0.20	<0.10	0.30	<0.42	<0.15	
Kirkcudbright	Plaice	4	<2.2	<0.55	<0.22	5.3	<1.3	<0.48	
North Solway	Cod	1	<0.55	<0.14	<0.06	4.6	<0.34	<0.16	
Inner Solway	Flounder	4	<1.3	<0.37	<0.14	16	<0.79	<0.34	
Inner Solway	Salmon	1	<2.4	<0.59	<0.24	<0.23	<1.4	0.52	
Inner Solway	Sea trout	1	<2.2	<0.52	<0.21	5.3	<1.4	<0.43	

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				<0.06		<0.36	<0.73	
Isle of Man	Herring	3				<0.08		<0.36	<0.59	
Isle of Man	Mackerel	1				<0.11		<0.79	<1.6	
Wales										
North Anglesey	Skates/rays	4				<0.12		<0.69	<1.4	
North Anglesey	Plaice	2	<25	<25	53	<0.10		<0.45	<0.74	
North Anglesey	Bass	1				<0.05		<0.19	<0.25	
Northern Ireland										
North coast	Spurdog	5				<0.09		<0.72	<0.81	
Ardglass	Herring	2				<0.09		<0.60	<1.2	
Kilkeel	Cod	4			35	<0.11		<0.71	<1.5	
Kilkeel	Plaice	4				<0.06		<0.48	<0.58	
Kilkeel	Spurdog	3				<0.07		<0.49	<0.45	
Kilkeel	Haddock	4				<0.09		<0.60	<0.90	
Glenarm	Farmed salmon	1				<0.19		<0.98	<1.5	<1.2
Further afield										
Baltic Sea	Cod	3				<0.14		<0.95	<2.0	
Baltic Sea	Herring	3				<0.10		<0.62	<1.3	
Barents Sea	Cod	1				<0.07		<0.34	<0.49	
Barents Sea	Haddock	1				<0.07		<0.34	<0.61	
Norwegian Sea	Cod	2				<0.13		<0.55	<0.79	
Norwegian Sea	Saithe	2				<0.07		<0.36	<0.64	
Norwegian processed	Cod	1			16	<0.06		<0.52	<1.4	
Iceland area	Cod	1				<0.06		<0.39	<0.83	
Skagerrak	Cod	3				<0.12		<0.60	<1.0	
Skagerrak	Herring	3				<0.05		<0.35	<0.72	
Northern North Sea	Cod	3				<0.06	<0.032	<0.43	<1.1	
Northern North Sea	Plaice	2				<0.10		<0.50	<0.80	
Northern North Sea	Haddock	3			23	<0.07		<0.60	<1.5	
Northern North Sea	Herring	1				<0.07		<0.16	<0.13	
Northern North Sea	Whiting	1				<0.05		<0.41	<1.0	
Mid North Sea	Cod	2			24	<0.04	<0.023	<0.19	<0.29	
Mid North Sea	Plaice	3			22	<0.13	<0.021	<0.77	<1.4	
Mid North Sea	Whiting	1				<0.04		<0.33	<0.78	
Gt Yarmouth (retail shop)	Cod	3				<0.04		<0.21	<0.37	
Gt Yarmouth (retail shop)	Plaice	3				<0.05		<0.31	<0.58	
Southern North Sea	Cod	3				<0.05	<0.022	<0.24	<0.41	
Southern North Sea	Plaice	2				<0.06	<0.025	<0.25	<0.40	
Southern North Sea	Sole	1				<0.17		<0.68	<0.98	
Southern North Sea	Herring	1				<0.07		<0.87	*	
English Channel-East	Cod	2				<0.05		<0.31	<0.65	
English Channel-East	Plaice	2				<0.12		<0.69	<1.4	
English Channel-East	Whiting	1				<0.05		<0.27	<0.53	
English Channel-East	Dab	1				<0.08		<0.46	<0.96	
English Channel-West	Mackerel	3				<0.11		<0.55	<0.95	
English Channel-West	Plaice	3			19	<0.12		<0.70	<1.4	
English Channel-West	Whiting	3				<0.06		<0.30	<0.53	
Celtic Sea	Cod	2			47	<0.05	<0.026	<0.24	<0.40	
Celtic Sea	Haddock	1				<0.06		<0.32	<0.59	
Celtic Sea	Whiting	2				<0.15		<0.81	<1.4	
Northern Irish Sea	Dab	1				<0.17		<1.0	<2.1	
Northern Irish Sea	Lesser spotted dogfish	1				<0.15		<0.79	<1.4	
Northern Irish Sea	Skates/rays	1				<0.19		<1.6	<4.4	

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
Isle of Man								
Isle of Man	Cod	4	<0.58	<0.13	<0.06	2.3	<0.30	<0.12
Isle of Man	Herring	3	<0.76	<0.17	<0.08	0.92	<0.36	<0.14
Isle of Man	Mackerel	1	<1.3	<0.31	<0.13	0.82	<0.77	<0.30
Wales								
North Anglesey	Skates/rays	4	<1.3	<0.26	<0.12	1.8	<0.49	<0.19
North Anglesey	Plaice	2	<1.0	<0.23	<0.10	2.0	<0.50	<0.22
North Anglesey	Bass	1	<0.46	<0.13	<0.05	3.9	<0.30	<0.14
Northern Ireland								
North coast	Spurdog	5	<0.99	<0.22	<0.10	2.2	<0.53	<0.20
Ardglass	Herring	2	<0.99	<0.22	<0.10	1.4	<0.53	<0.22
Kilkeel	Cod	4	<1.2	<0.24	<0.12	1.4	<0.46	<0.17
Kilkeel	Plaice	4	<0.70	<0.17	<0.07	1.8	<0.41	<0.15
Kilkeel	Spurdog	3	<0.87	<0.21	<0.08	2.0	<0.54	<0.22
Kilkeel	Haddock	4	<0.91	<0.19	<0.09	0.82	<0.37	<0.14
Glenarm	Farmed salmon	1	<2.2	<0.48	<0.20	0.40	<1.1	<0.43
Further afield								
Baltic Sea	Cod	3	<1.6	<0.35	<0.16	7.3	<0.71	<0.28
Baltic Sea	Herring	3	<1.1	<0.24	<0.11	5.2	<0.53	<0.20
Barents Sea	Cod	1	<0.68	<0.15	<0.07	0.23	<0.34	<0.13
Barents Sea	Haddock	1	<0.70	<0.15	<0.07	0.17	<0.34	<0.13
Norwegian Sea	Cod	2	<1.3	<0.28	<0.13	<0.22	<0.51	<0.19
Norwegian Sea	Saithe	2	<0.70	<0.17	<0.08	0.23	<0.46	<0.21
Norwegian processed	Cod	1	<0.58	<0.12	<0.06	0.19	<0.27	<0.10
Iceland area	Cod	1	<0.57	<0.12	<0.06	0.10	<0.24	<0.09
Skagerrak	Cod	3	<1.2	<0.24	<0.12	0.29	<0.44	<0.17
Skagerrak	Herring	3	<0.60	<0.13	<0.06	0.35	<0.33	<0.13
Northern North Sea	Cod	3	<0.55	<0.11	<0.06	0.22	<0.25	<0.09
Northern North Sea	Plaice	2	<1.1	<0.25	<0.11	0.18	<0.57	<0.22
Northern North Sea	Haddock	3	<0.88	<0.19	<0.09	<0.15	<0.49	<0.19
Northern North Sea	Herring	1	<0.70	<0.18	<0.08	0.11	<0.43	<0.23
Northern North Sea	Whiting	1	<0.54	<0.13	<0.05	0.26	<0.35	<0.15
Mid North Sea	Cod	2	<0.41	<0.09	<0.04	0.24	<0.20	<0.08
Mid North Sea	Plaice	3	<1.5	<0.30	<0.14	<0.19	<0.60	<0.22
Mid North Sea	Whiting	1	<0.46	<0.10	<0.04	0.46	<0.23	<0.08
Gt Yarmouth (retail shop)	Cod	3	<0.40	<0.09	<0.04	0.14	<0.21	<0.09
Gt Yarmouth (retail shop)	Plaice	3	<0.52	<0.12	<0.05	<0.06	<0.25	<0.10
Southern North Sea	Cod	3	<0.47	<0.11	<0.05	0.24	<0.28	<0.12
Southern North Sea	Plaice	2	<0.55	<0.12	<0.06	0.17	<0.22	<0.09
Southern North Sea	Sole	1	<1.7	<0.34	<0.17	2.4	<0.55	<0.21
Southern North Sea	Herring	1	<0.72	<0.15	<0.07	0.26	<0.38	<0.12
English Channel-East	Cod	2	<0.51	<0.12	<0.05	0.15	<0.30	<0.12
English Channel-East	Plaice	2	<1.3	<0.26	<0.12	<0.13	<0.49	<0.18
English Channel-East	Whiting	1	<0.51	<0.12	<0.06	0.23	<0.32	<0.15
English Channel-East	Dab	1	<0.73	<0.15	<0.08	<0.07	<0.30	<0.11
English Channel-West	Mackerel	3	<1.1	<0.26	<0.11	<0.29	<0.62	<0.25
English Channel-West	Plaice	3	<1.4	<0.27	<0.13	<0.12	<0.60	<0.24
English Channel-West	Whiting	3	<0.57	<0.13	<0.06	0.25	<0.32	<0.14
Celtic Sea	Cod	2	<0.48	<0.12	<0.05	0.86	<0.28	<0.11
Celtic Sea	Haddock	1	<0.60	<0.14	<0.07	0.12	<0.29	<0.12
Celtic Sea	Whiting	2	<1.7	<0.34	<0.15	0.45	<0.74	<0.28
Northern Irish Sea	Dab	1	<1.9	<0.38	<0.17	2.3	<0.70	<0.24
Northern Irish Sea	Lesser spotted dogfish	1	<1.7	<0.34	<0.15	1.0	<0.61	<0.21
Northern Irish Sea	Skates/rays	1	<2.1	<0.40	<0.20	4.6	<0.74	<0.26

* *Not detected by the method used*

[a] *The concentrations of ^{129}I and ^{147}Pm were <1.5 and <0.038 Bq kg^{-1} respectively*

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2007

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	^{106}Ru
Cumbria											
Silloth	Mussels	4		<25		0.46		<0.35	<0.57		<0.85
Silloth	Shrimps	4				<0.08		<0.32	<0.48		<0.79
Parton	Crabs	4				0.47		<0.40	<0.72		<0.79
Parton	Lobsters	4				0.25		<0.41	<0.82		<0.72
Parton	Winkles	4				1.5		<0.37	<0.55		<1.9
Whitehaven	Nephrops	4			83	<0.16	0.16	<0.91	<1.9	51	<1.7
Whitehaven	Cockles	2				<0.03		<0.22	<0.46		<0.39
Whitehaven	Mussels	2				<0.04	<0.041	<0.32	<0.64		<0.49
Whitehaven outer harbour	Mussels	2				0.77		<0.36	<0.61		<1.2
Saltom Bay	Winkles	4				2.4		<0.39	<0.58		<2.4
St Bees	Winkles[a]	4			170	3.2	2.6	<0.57	<0.88	21	4.7
St Bees	Mussels	4				1.8		<0.37	<0.54		4.8
St Bees	Limpets	4				1.6		<0.35	<0.53		3.1
Nethertown	Winkles	12	<25	<25	190	3.4	4.3	<0.52	<0.88	52	8.3
Nethertown	Mussels	4	<70	<77	220	2.7		<0.32	<0.44	100	6.6
Sellafield coastal area	Crabs[b]	8			230	1.5	0.41	<0.64	<0.88	17	<1.4
Sellafield coastal area	Lobsters	8			320	0.97	0.20	<0.70	<0.86	560	<1.5
Sellafield coastal area	Nephrops	2				<0.22		<1.1	<1.9	84	<2.4
Sellafield coastal area[c]	Winkles	8			100	2.6	1.8	<0.56	<1.0	31	<6.5
Sellafield coastal area[c]	Mussels	4				1.5	0.82	<0.45	<0.74		<5.2
Sellafield coastal area[c]	Limpets	4			90	0.58	2.4	<0.49	<0.88	100	<2.0
Whitriggs	Shrimps	1				<0.20		<1.3	<3.1		<2.3
Drigg	Winkles	4			170	2.9		<0.34	<0.54	87	6.5
Ravenglass	Crabs	4				0.72	0.25	<0.48	<0.76	8.7	<0.74
Ravenglass	Lobsters	6				0.56	0.13	<0.44	<0.72	280	<0.78
Ravenglass	Winkles	2				1.8		<0.33	<0.48		4.0
Ravenglass	Cockles	4			180	6.1	2.0	<0.45	<0.74	12	6.5
Ravenglass	Mussels	4		41		2.1		<0.36	<0.63	230	5.5
Tarn Bay	Winkles	4				2.4		<0.53	<0.91		7.2
Haverigg	Cockles	4				2.7		<0.74	<1.3		<1.9
Millom	Mussels	2				0.48		<0.34	<0.58		<0.73
Barrow	Crabs	4				0.29		<0.46	<0.92		<0.75
Barrow	Lobsters	4				<0.10		<0.41	<0.85	190	<0.68
Roosebeck	Pacific oysters	2				0.08		<0.18	<0.31		<0.40
Morecambe Bay (Flookburgh)	Shrimps	4			66	<0.09		<0.35	<0.56	0.83	<0.81
Morecambe Bay (Flookburgh)	Cockles	4			62	0.34	0.24	<0.30	<0.50	3.7	<0.66
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2				<0.15		<0.85	<1.7		<1.7
Morecambe Bay (Morecambe)	Mussels	4	54	77	67	0.23		<0.30	<0.47	43	<0.71
Red Nab Point	Winkles	4				0.29		<0.40	<0.76		<0.79
Morecambe Bay (Middleton Sands)	Cockles	2				0.79		<0.24	<0.35		<0.54
Knott End	Cockles	2				0.60		<0.48	<0.80		<1.2
Fleetwood	Squid	1				<0.06		<0.40	<0.86		<0.56
Ribble Estuary	Shrimps	2			58	<0.06		<0.28	<0.50	<0.75	<0.54
Ribble Estuary	Mussels	2				<0.06		<0.17	<0.20		<0.50
Ribble Estuary	Cockles	1				0.24		<0.52	<0.81		<1.3
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<25							
Dee Estuary	Cockles	4				<0.17		<0.75	<1.2	5.6	<1.7
Wirral	Shrimps	2		<25		<0.06		<0.25	<0.37	0.59	<0.61

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	<0.16	0.53	<0.08	3.5	<0.45		<0.22	<0.19	
Silloth	Shrimps	4	<0.16	<0.21	<0.08	3.4	<0.42		<0.22	<0.18	
Parton	Crabs	4	<0.17	<0.26	<0.08	1.4	<0.41		<0.23	<0.16	
Parton	Lobsters	4	<0.28	<0.18	<0.07	2.5	<0.40		<0.20	<0.17	
Parton	Winkles	4	<0.33	1.2	<0.10	8.7	<0.61		<0.26	<0.27	
Whitehaven	*Nephrops*	4	<0.32	<0.46	<0.16	3.3	<0.71		<0.48	<0.28	200
Whitehaven	Cockles	2	<0.07	<0.09	<0.04	0.10	<0.26		<0.09	<0.10	
Whitehaven	Mussels	2	<0.10	<0.11	<0.05	<0.05	<0.24		<0.12	<0.09	
Whitehaven outer harbour	Mussels	2	<0.15	1.1	<0.07	1.8	<0.37		<0.20	<0.14	
Saltom Bay	Winkles	4	<0.46	1.6	<0.11	8.2	<0.63		<0.29	<0.29	
St Bees	Winkles[a]	4	1.0	1.6	<0.13	11	<0.64	0.43	<0.38	<0.27	
St Bees	Mussels	4	<0.17	2.1	<0.09	3.4	<0.42		<0.26	<0.17	
St Bees	Limpets	4	0.54	2.5	<0.09	6.1	<0.52		<0.25	<0.22	
Nethertown	Winkles	12	1.4	1.7	<0.12	9.7	<0.66	0.66	<0.34	<0.28	280
Nethertown	Mussels	4	<0.16	3.0	<0.08	2.8	<0.51		<0.23	<0.23	210
Sellafield coastal area	Crabs[b]	8	<0.56	<0.54	<0.11	2.0	<0.54	0.21	<0.29	<0.21	180
Sellafield coastal area	Lobsters	8	1.2	<0.43	<0.09	3.5	<0.52	0.13	<0.26	<0.20	760
Sellafield coastal area	*Nephrops*	2	<0.44	<0.53	<0.22	4.3	<1.1		<0.63	<0.40	
Sellafield coastal area[c]	Winkles	8	<1.1	1.7	<0.12	10	<0.67	<0.28	<0.33	<0.30	
Sellafield coastal area[c]	Mussels	4	<0.18	1.9	<0.10	3.4	<0.59		<0.25	<0.26	
Sellafield coastal area[c]	Limpets	4	<0.32	2.2	<0.11	5.1	<0.53		<0.32	<0.21	
Whitriggs	Shrimps	1	<0.41	<0.44	<0.21	2.9	<0.77		<0.57	<0.28	
Drigg	Winkles	4	1.2	1.6	<0.09	5.7	<0.52	0.37	<0.25	<0.22	270
Ravenglass	Crabs	4	<0.23	<0.28	<0.07	1.6	<0.46		<0.19	<0.17	140
Ravenglass	Lobsters	6	0.59	<0.24	<0.07	2.5	<0.39		<0.21	<0.15	530
Ravenglass	Winkles	2	0.84	1.1	<0.09	8.0	<0.61		<0.25	<0.28	
Ravenglass	Cockles	4	<0.21	1.1	<0.10	5.2	<0.55		<0.31	<0.25	150
Ravenglass	Mussels	4	<0.16	1.9	<0.08	1.7	<0.39		<0.20	<0.16	
Tarn Bay	Winkles	4	0.74	1.4	<0.13	9.6	<0.80		<0.31	<0.35	
Haverigg	Cockles	4	<0.27	<0.80	<0.15	4.0	<0.70		<0.41	<0.31	
Millom	Mussels	2	<0.13	0.51	<0.07	1.2	<0.29		<0.18	<0.12	
Barrow	Crabs	4	<0.16	<0.24	<0.08	1.2	<0.43		<0.21	<0.17	
Barrow	Lobsters	4	<0.16	<0.16	<0.07	1.9	<0.35		<0.20	<0.14	300
Roosebeck	Pacific oysters	2	0.18	<0.15	<0.04	0.96	<0.19		<0.10	<0.07	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.17	<0.23	<0.09	4.1	<0.49		<0.24	<0.22	
Morecambe Bay (Flookburgh)	Cockles	4	<0.13	<0.17	<0.07	3.7	<0.34		<0.19	<0.14	
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2	<0.31	<0.38	<0.16	4.9	<0.85		<0.41	<0.36	
Morecambe Bay (Morecambe)	Mussels	4	<0.13	0.33	<0.07	2.9	<0.37		<0.19	<0.15	
Red Nab Point	Winkles	4	<0.15	0.46	<0.08	4.9	<0.44		<0.21	<0.18	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.11	0.43	<0.06	2.7	<0.32		<0.14	<0.14	
Knott End	Cockles	2	<0.21	<0.29	<0.11	3.0	<0.60		<0.30	<0.26	
Fleetwood	Squid	1	<0.13	<0.12	<0.06	0.91	<0.29		<0.19	<0.11	
Ribble Estuary	Shrimps	2	<0.12	<0.13	<0.06	2.2	<0.26		<0.16	<0.10	
Ribble Estuary	Mussels	2	<0.09	<0.14	<0.05	0.95	<0.28		<0.13	<0.12	
Ribble Estuary	Cockles	1	<0.24	<0.30	<0.14	1.5	<0.70		<0.35	<0.32	
Dee Estuary	Cockles	4	<0.29	<0.37	<0.16	1.6	<0.66		<0.42	<0.25	
Wirral	Shrimps	2	<0.12	<0.16	<0.06	1.9	<0.40		<0.17	<0.18	

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland										
Lewis	Mussels	1			<0.10		<0.12	<0.10		<0.49
Skye	Lobsters	1			<0.11		<0.23	<0.18	37	<0.91
Skye	Mussels	1			<0.10		<0.20	<0.10		<0.75
Islay	Scallops	1			<0.10		<0.16	<0.15		<0.50
Kirkcudbright	Scallops	4[F,S]			<0.08		<0.34	<0.57	0.45	<0.65
Kirkcudbright	Queens	5[F,S]			<0.10		<0.23	<0.37	0.49	<0.43
Kirkcudbright	Limpets	1			0.54		<0.81	<1.1		<1.9
Southerness	Winkles	4	<5.7		0.53	0.24	<0.33	<0.36	62	<0.95
North Solway coast	Crabs	5[F,S]		100	<0.26	0.30	<0.41	<0.50	5.5	<1.0
North Solway coast	Lobsters	5[F,S]		40	<0.12	0.098	<0.44	<0.53	220	<1.1
North Solway coast	*Nephrops*	1		79	<0.06		<0.24	<0.41	59	<0.52
North Solway coast	Winkles	4[F,S]			<0.61	0.69	<0.35	<0.40	79	<0.94
North Solway coast	Cockles	2[F,S]			1.4	0.80	<0.30	<0.39		<0.75
North Solway coast	Mussels	5[F,S]	<5.5	<34	0.33		<0.21	<0.27	61	<0.48
Inner Solway	Shrimps	2	<5.0		<0.10	<0.10	<0.28	<0.33	2.4	<0.78
Isle of Man										
Isle of Man	Lobsters	4			<0.06		<0.38	<0.76	75	<0.62
Isle of Man	Scallops	4			<0.05		<0.28	<0.54		<0.49
Wales										
Conwy	Mussels	2		52	<0.05		<0.20	<0.30		<0.50
North Anglesey	Crabs	2			<0.07		<0.42	<0.87	1.9	<0.74
North Anglesey	Lobsters	2			<0.05		<0.21	<0.32	86	<0.52
Northern Ireland										
Ballycastle	Lobsters	2			<0.17		<1.1	<2.2	83	<2.1
County Down	Scallops	2			<0.17		<0.88	<1.7		<1.8
Ards Peninsula	Winkles	1			<0.16		<0.76	<1.3		<1.7
Kilkeel	Crabs	4			<0.08		<0.54	<1.2		<0.85
Kilkeel	Lobsters	4			<0.11		<0.64	<1.2	62	<1.2
Kilkeel	*Nephrops*	4			<0.14		<0.86	<1.8	21	<1.6
Minerstown	Winkles	4			<0.19		<0.87	<1.4		<1.8
Carlingford Lough	Mussels	2			<0.13		<0.76	<1.4	9.8	<1.5
Further afield										
Northern North Sea	*Nephrops*	3			<0.06		<0.25	<0.39	4.8	<0.61
Cromer	Crabs	1			<0.06		<0.32	<0.58		<0.61
Southern North Sea	Cockles	1			<0.03		<0.18	<0.33		<0.36
Southern North Sea	Mussels	3			<0.10		<0.38	<0.52	1.5	<0.95
Southern North Sea	Cockles[d]	1			0.05		<0.21	<0.42	<0.79	<0.41
Southern North Sea	Mussels[d]	1			<0.03		<0.25	<0.62		<0.38
English Channel-East	Scallops	3		29	<0.07		<0.33	<0.52		<0.71
English Channel-West	Crabs	3		33	<0.13		<0.62	<1.1		<1.3
English Channel-West	Lobsters	3			<0.16		<0.91	<1.6	0.46	<1.8
English Channel-West	Scallops	3		17	<0.11		<0.69	<1.4		<1.3
Northern Irish Sea	Crabs	1			0.48		<0.54	<0.73		<1.5
Northern Irish Sea	Lobsters	1			<0.20		<1.2	<2.6		<2.2

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	<0.14	<0.10	0.24	<0.29	<0.10	<0.14	
Skye	Lobsters	1	<0.10	<0.27	<0.10	0.18	<0.63	<0.15	<0.28	
Skye	Mussels	1	<0.10	<0.21	<0.10	0.16	<0.41	<0.10	<0.15	
Islay	Scallops	1	<0.10	<0.14	<0.10	0.49	<0.34	<0.10	<0.18	
Kirkcudbright	Scallops	4[F,S]	<0.13	<0.17	<0.08	<0.22	<0.42	<0.11	<0.17	
Kirkcudbright	Queens	5[F,S]	<0.11	<0.13	<0.09	0.50	<0.26	<0.12	<0.13	
Kirkcudbright	Limpets	1	<0.30	<0.48	<0.21	2.6	<1.5	<0.32	<0.62	
Southerness	Winkles	4	<0.15	<0.28	<0.11	1.6	<0.56	<0.13	<0.25	
North Solway coast	Crabs	5[F,S]	<0.16	<0.28	<0.13	1.1	<0.63	<0.15	<0.27	
North Solway coast	Lobsters	5[F,S]	<0.17	<0.27	<0.11	1.7	<0.68	<0.16	<0.28	
North Solway coast	*Nephrops*	1	<0.11	<0.13	<0.06	2.6	<0.24	<0.17	<0.10	
North Solway coast	Winkles	4[F,S]	<0.19	<0.46	<0.11	2.1	<0.58	<0.15	<0.25	
North Solway coast	Cockles	2[F,S]	<0.14	<0.43	<0.09	5.1	<0.42	<0.15	<0.18	
North Solway coast	Mussels	5[F,S]	<0.10	<0.31	<0.09	2.7	<0.37	<0.11	<0.16	
Inner Solway	Shrimps	2	<0.13	<0.22	<0.10	4.1	<0.46	<0.11	<0.20	
Isle of Man										
Isle of Man	Lobsters	4	<0.13	<0.14	<0.06	0.47	<0.30	<0.19	<0.12	170
Isle of Man	Scallops	4	<0.10	<0.11	<0.05	0.40	<0.27	<0.15	<0.11	
Wales										
Conwy	Mussels	2	<0.09	<0.13	<0.05	0.21	<0.29	<0.13	<0.13	
North Anglesey	Crabs	2	<0.15	<0.18	<0.07	0.47	<0.41	<0.19	<0.16	
North Anglesey	Lobsters	2	<0.11	<0.13	<0.05	0.72	<0.29	<0.15	<0.13	180
Northern Ireland										
Ballycastle	Lobsters	2	<0.37	<0.45	<0.20	0.26	<1.1	<0.51	<0.44	
County Down	Scallops	2	<0.33	<0.33	<0.17	0.45	<0.59	<0.47	<0.22	
Ards Peninsula	Winkles	1	<0.30	<0.35	<0.16	0.38	<0.60	<0.42	<0.21	
Kilkeel	Crabs	4	<0.17	<0.18	<0.08	0.21	<0.41	<0.23	<0.15	
Kilkeel	Lobsters	4	<0.23	<0.24	<0.12	0.42	<0.45	<0.33	<0.17	
Kilkeel	*Nephrops*	4	<0.28	<0.32	<0.15	0.86	<0.70	<0.41	<0.28	
Minerstown	Winkles	4	<0.33	<0.36	<0.18	<0.35	<0.62	<0.51	<0.24	
Carlingford Lough	Mussels	2	<0.26	<0.31	<0.15	0.61	<0.63	<0.37	<0.24	
Further afield										
Northern North Sea	*Nephrops*	3	<0.12	<0.13	<0.06	<0.08	<0.28	<0.18	<0.12	
Cromer	Crabs	1	<0.12	<0.13	<0.06	0.07	<0.30	<0.18	<0.11	
Southern North Sea	Cockles	1	<0.07	<0.09	<0.03	0.08	<0.24	<0.09	<0.10	
Southern North Sea	Mussels	3	<0.17	<0.21	<0.10	<0.15	<0.40	<0.27	<0.17	
Southern North Sea	Cockles[d]	1	<0.08	<0.11	<0.05	0.09	<0.29	<0.10	<0.13	
Southern North Sea	Mussels[d]	1	<0.08	<0.08	<0.04	<0.03	<0.19	<0.09	<0.07	65
English Channel-East	Scallops	3	<0.13	<0.16	<0.07	<0.06	<0.40	<0.19	<0.17	
English Channel-West	Crabs	3	<0.23	<0.28	<0.13	<0.11	<0.58	<0.34	<0.23	
English Channel-West	Lobsters	3	<0.32	<0.36	<0.18	<0.14	<0.75	<0.46	<0.32	
English Channel-West	Scallops	3	<0.24	<0.27	<0.13	<0.10	<0.66	<0.35	<0.26	
Northern Irish Sea	Crabs	1	<0.25	<0.35	<0.14	1.2	<0.75	<0.38	<0.31	
Northern Irish Sea	Lobsters	1	<0.40	<0.48	<0.20	1.1	<1.2	<0.53	<0.49	

[a] *The concentration of ^{129}I was <2.2 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*
[F,S] *Samples collected on behalf of the Food Standards Agency and SEPA*

Table 2.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2007

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	Mussels	1		0.72	4.0		8.2	*	0.016
Silloth	Shrimps	1		0.0034	0.019	<1.1	0.037	0.000052	0.000045
Maryport	Plaice	4					<0.20		
River Derwent	Sea trout	1					<0.17		
Parton	Cod	4					<0.22		
Parton	Crabs	4					0.93		
Parton	Lobsters	4					1.8		
Parton	Winkles	1		1.5	8.1	63	16	*	0.0091
Whitehaven	Cod	1		0.00090	0.0054		0.0085	*	*
Whitehaven	Plaice	1		0.00080	0.0044		0.0078	*	*
Whitehaven	Skates / rays	1		0.00086	0.0046		0.0084	0.00025	*
Whitehaven	Sole	1		0.00040	0.0019		0.0034	*	*
Whitehaven	Nephrops	1		0.042	0.25		0.62	*	0.00061
Whitehaven	Cockles	1		0.0037	0.013		0.018	*	0.00082
Whitehaven	Mussels	1		0.0034	0.020	<0.70	0.035	0.00012	0.000077
Whitehaven outer harbour	Mussels	2					6.2		
Saltom Bay	Winkles	4					17		
St Bees	Winkles	1	0.020	2.3	13	99	28	*	0.027
St Bees	Mussels	2		1.4	7.2	62	21	*	0.049
St Bees	Limpets	1		1.6	8.9		19	*	0.021
Nethertown	Winkles	4	0.043	3.0	15	120	32	<0.058	0.044
Nethertown	Mussels	4		1.5	7.5		17	<0.029	0.031
River Ehen	Salmon	1					<0.11		
River Ehen	Sea trout	1					<0.10		
Sellafield coastal area	Cod	2		0.0010	0.0051		0.011	<0.000044	<0.000016
Sellafield coastal area	Plaice	1		0.0022	0.012		0.023	0.00011	0.000027
Sellafield coastal area	Bass	1					<0.52		
Sellafield coastal area	Grey mullet	1					<0.20		
Sellafield coastal area	Crabs	2	0.0058	0.090	0.44	6.9	2.1	*	0.0044
Sellafield coastal area	Lobsters	2	0.016	0.12	0.54	5.7	6.4	0.0064	0.011
Sellafield coastal area	Nephrops	1		0.083	0.45		1.9	*	*
Sellafield coastal area[a]	Winkles	2	0.016	2.6	14	120	28	<0.010	0.032
Sellafield coastal area[a]	Mussels	1		1.2	6.1	50	11	0.020	0.016
Sellafield coastal area[a]	Limpets	1		1.0	5.3	44	13	*	0.015
Sellafield offshore area	Cod	1					<0.12		
Sellafield offshore area	Plaice	1	0.00060	0.0081	0.043		0.071	*	0.00015
Sellafield offshore area	Dab	1					<0.15		
Sellafield offshore area	Flounder	1					<0.76		
Sellafield offshore area	Lesser spotted dogfish	2					<0.24		
Sellafield offshore area	Grey mullet	1					<0.45		
Sellafield offshore area	Skates / rays	1		0.0019	0.012		0.020	*	0.000043
River Calder	Sea trout	1					<0.58		
Whitriggs	Shrimps	1					<0.14		
River Esk	Salmon	2					<0.27		
Drigg	Winkles	1	0.019	2.1	11	85	24	*	0.031
Ravenglass	Cod	1		0.00049	0.0020		0.0043	*	*
Ravenglass	Plaice	1		0.0033	0.020		0.033	*	*
Ravenglass	Crabs	1		0.051	0.24	3.7	1.3	*	0.0025
Ravenglass	Lobsters	1		0.071	0.56	3.6	4.6	*	0.0070
Ravenglass	Winkles	2					24		
Ravenglass	Cockles	1		1.8	9.7	81	28	0.10	0.048
Ravenglass	Mussels	1		1.0	5.2	48	12	*	0.024
Tarn Bay	Winkles	1		2.4	13	100	26	0.038	0.030
Haverigg	Cockles	1		1.5	8.1		27	*	0.046
Millom	Mussels	2					4.5		
Barrow	Crabs	1		0.029	0.15		0.60	*	0.00077
Barrow	Lobsters	4					0.63		
Roosebeck	Pacific oysters	1		0.088	0.50		0.46	*	0.0010
Morecambe Bay (Flookburgh)	Flounder	1		0.00039	0.0023		0.0049	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0036	0.022	0.58	0.038	*	*
Morecambe Bay (Flookburgh)	Cockles	1		0.33	1.9	14	5.7	*	0.0074

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					<0.10		
Morecambe Bay (Morecambe)	Bass	2					<0.15		
Morecambe Bay (Morecambe)	Flounder	4					<0.15		
Morecambe Bay (Morecambe)	Shrimps	2					<0.46		
Morecambe Bay (Morecambe)	Mussels	1		0.41	2.4		3.9	*	0.0029
Red Nab Point	Winkles	1		0.28	1.7		3.3	0.0051	0.0032
Morecambe Bay (Middleton Sands)	Cockles	1		0.36	2.0		5.9	*	*
Morecambe Bay (Sunderland Point)	Whitebait	1		0.038	0.23	2.8	0.47	*	*
Fleetwood	Cod	1		0.00016	0.00080		0.0016	0.000060	*
Fleetwood	Plaice	1		0.00066	0.0038		0.0049	*	*
Fleetwood	Squid	1					<0.06		
Knott End	Cockles	1		0.27	1.7		5.0	*	*
Ribble Estuary	Flounder	1					<0.09		
Ribble Estuary	Grey mullet	2					<0.14		
Ribble Estuary	Salmon	1					<0.10		
Ribble Estuary	Sea trout	1					<0.12		
Ribble Estuary	Bass	1					<1.0		
Ribble Estuary	Shrimps	1	0.00035	0.0019	0.012		0.021	*	0.000040
Ribble Estuary	Mussels	2					0.98		
Ribble Estuary	Cockles	1		0.11	0.63		2.1	*	0.0038
Dee Estuary	Cockles	1		0.17	0.95		2.7	*	*
Wirral	Shrimps	2					<0.24		
Scotland									
Shetland	Fish meal	2		0.00033	0.0013		0.0020	*	*
Shetland	Fish oil	3					<0.15		
Minch	Herring	1					<0.10		
Minch	Mackerel	1		0.000076	0.00014		0.00022	*	*
West of Scotland	Mackerel	1					<0.74		
West of Scotland	Farmed salmon	1					<0.08		
Lewis	Mussels	1					<0.10		
Skye	Lobsters	1					<0.14		
Skye	Mussels	1					<0.11		
Islay	Scallops	1					<0.16		
Kirkcudbright	Plaice	1		<0.00055	0.0026		0.0043		
Kirkcudbright	Scallops	1		0.021	0.11		0.050		
Kirkcudbright	Queens	1		0.0062	0.035		0.058		
Kirkcudbright	Limpets	1					5.4		
Southerness	Winkles	1		0.20	1.0	3.0	2.2		
North Solway	Cod	1		0.00023	0.0018		0.0053	*	*
North Solway coast	Crabs	1		0.031	0.16	0.61	0.59		
North Solway coast	Lobsters	1		0.0062	0.031	<0.17	0.23		
North Solway coast	Nephrops	1		0.046	0.26		0.68	*	0.00044
North Solway coast	Winkles	1		0.28	1.5		3.1		
North Solway coast	Cockles	2[F,S]		2.0	11	57	31	0.061	0.025
North Solway coast	Mussels	1		0.44	2.5	34	5.3		
Inner Solway	Flounder	1		0.020	0.097		0.092		
Inner Solway	Salmon	1					<0.31		
Inner Solway	Sea trout	1					<0.29		
Inner Solway	Shrimps	1		0.0049	0.024		0.047		
Isle of Man									
Isle of Man	Cod	1		0.00012	0.00068		0.0012	*	*
Isle of Man	Herring	1		0.0019	0.012		0.024	*	0.000055
Isle of Man	Mackerel	1					<0.30		
Isle of Man	Lobsters	4					<0.12		
Isle of Man	Scallops	1		0.030	0.15		0.038	*	0.000085

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	0.020	0.12	0.20	*	*
North Anglesey	Skates / rays	1	0.00012	0.00099	0.0019	0.000083	*
North Anglesey	Plaice	2			<0.26		
North Anglesey	Bass	1			<0.21		
North Anglesey	Crabs	1	0.0051	0.031	0.080	*	0.00020
North Anglesey	Lobsters	2			<0.19		
Northern Ireland							
North coast	Spurdog	5			<0.21		
Ballycastle	Lobsters	2			<0.53		
County Down	Scallops	2			<0.16		
Ards Peninsula	Winkles	1			0.22		
Ardglass	Herring	2			<0.24		
Kilkeel	Cod	4			<0.10		
Kilkeel	Plaice	4			<0.16		
Kilkeel	Spurdog	3			<0.25		
Kilkeel	Haddock	4			<0.08		
Kilkeel	Crabs	4			<0.10		
Kilkeel	Lobsters	4			<0.10		
Kilkeel	Nephrops	1	0.0039	0.024	0.083	0.00046	*
Minerstown	Winkles	1	0.026	0.14	0.13	*	*
Carlingford Lough	Mussels	2			<0.18		
Glenarm	Farmed salmon	1			<0.38		
Further afield							
Baltic Sea	Cod	3			<0.27		
Baltic Sea	Herring	3			<0.14		
Barents Sea	Cod	1			<0.08		
Barents Sea	Haddock	1			<0.08		
Norwegian Sea	Cod	2			<0.10		
Norwegian Sea	Saithe	2			<0.31		
Norwegian processed	Cod	1	0.000032	0.000079	0.00014	*	*
Iceland area	Cod	1			<0.05		
Skagerrak	Cod	3			<0.09		
Skagerrak	Herring	3			<0.11		
Northern North Sea	Cod	2	0.000065	0.00035	0.00070	<0.000026	*
Northern North Sea	Plaice	2			<0.19		
Northern North Sea	Haddock	2	0.000039	0.00030	0.00045	*	*
Northern North Sea	Herring	1			<0.34		
Northern North Sea	Whiting	1			<0.21		
Northern North Sea	Nephrops	2	0.00015	0.0012	0.0017	*	0.000010
Mid North Sea	Cod	2			<0.05		
Mid North Sea	Plaice	3			<0.14		
Mid North Sea	Whiting	1			<0.05		
Cromer	Crabs	1			<0.06		
Gt Yarmouth (retail shop)	Cod	3			<0.08		
Gt Yarmouth (retail shop)	Plaice	3			<0.10		
Southern North Sea	Cod	3			<0.16		
Southern North Sea	Plaice	2			<0.05		
Southern North Sea	Sole	1			<0.12		
Southern North Sea	Herring	1			<0.06		
Southern North Sea	Cockles	1	0.0011	0.0084	0.0075	*	*
Southern North Sea	Mussels	2	0.0035	0.025	0.010	*	*
Southern North Sea	Cockles[b]	1	0.0014	0.0063	0.0066	*	*
Southern North Sea	Mussels[b]	1	0.00026	0.0028	0.0029	*	*
English Channel-East	Cod	2			<0.15		
English Channel-East	Plaice	2			<0.09		
English Channel-East	Whiting	1			<0.22		
English Channel-East	Dab	1			<0.07		
English Channel-East	Scallops	2	0.00049	0.0020	0.00061	*	0.000031
English Channel-West	Mackerel	3			<0.26		
English Channel-West	Plaice	3			<0.24		
English Channel-West	Whiting	3			<0.14		
English Channel-West	Crabs	2	0.00012	0.00083	0.0019	*	*

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	Lobsters	3			<0.32		
English Channel-West	Scallops	2	0.00025	0.0042	0.00062	*	<0.0000050
Celtic Sea	Cod	2			<0.09		
Celtic Sea	Haddock	1			<0.07		
Celtic Sea	Whiting	2			<0.21		
Northern Irish Sea	Dab	1			<0.12		
Northern Irish Sea	Lesser spotted dogfish	1			<0.11		
Northern Irish Sea	Skates / rays	1			<0.14		
Northern Irish Sea	Crabs	1			1.7		
Northern Irish Sea	Lobsters	1			1.1		

* *Not detected by the method used*
[a] *Samples collected by consumer 12*
[b] *Landed in Holland or Denmark*
[F,S] *Samples collected on behalf of Food Standards Agency and SEPA*

Table 2.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2007

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	<0.56		<1.1	<0.42	<4.0		<4.6	<0.49	150	<2.4
Maryport Outer Harbour	Sediment	2	1.6	<16	<1.3	<0.40	<3.3		<3.6	<0.40	90	<2.1
Workington Harbour	Sediment	2	4.0		<1.0	<0.46	<3.8		<6.4	<0.47	160	<2.4
Harrington Harbour	Sediment	2	1.3		<0.84	<0.39	<3.1		<3.8	<0.38	160	<2.1
Whitehaven Outer Harbour	Sediment	4	<0.86	<2.0	<0.88	<0.38	<2.8		<4.4	<0.36	100	<1.8
St Bees beach	Sediment	4	2.4		<0.69	<0.28	<2.5		<2.9	<0.33	65	<1.5
Sellafield beach, S of former pipeline	Sediment	2	1.8		<0.71	<0.28	<2.5		<2.9	<0.31	84	<1.6
River Calder - downstream	Sediment	2	<0.54		<1.0	<0.40	<3.8		<4.5	<0.46	190	<2.4
River Calder - upstream	Sediment	2	<1.2		<4.6	<1.0	<8.1		<7.1	<1.0	62	<4.5
Seascale beach	Sediment	4	2.0		<0.69	<0.31	<2.4		<2.6	<0.33	38	<1.5
Ravenglass - Carleton Marsh	Sediment	4	14		<1.3	<0.57	38		12	<0.72	400	<3.4
River Mite Estuary	Sediment	4	8.7	100	<3.0	<0.72	<14		<10	<0.95	720	<4.8
Ravenglass - Raven Villa	Sediment	4	6.2		<1.1	<0.50	<5.5		<6.1	<0.54	210	<2.6
Newbiggin (Eskmeals)	Sediment	4	14	120	<2.6	<0.73	<26		14	<1.0	470	<4.6
Haverigg	Sediment	2	0.77		<0.72	<0.29	<2.3		<2.4	<0.31	28	<1.4
Millom	Sediment	2	3.8		<1.0	<0.39	<4.0		<5.0	<0.47	150	<2.2
Low Shaw	Sediment	2	<0.50		<1.1	<0.36	<3.3		<3.7	<0.41	100	<2.0
Walney Channel - N of discharge point	Sediment	2	2.2		<1.0	<0.42	<3.6		<4.0	<0.44	97	<2.1
Walney Channel - S of discharge point	Sediment	2	<1.7		<0.96	<0.34	<3.4		<3.8	<0.43	95	<1.9
Sand Gate Marsh	Sediment	4	<0.91		<0.98	<0.45	<4.0		<4.8	<0.49	160	<2.4
Kents Bank	Sediment	4	<0.85		<1.2	<0.44	<4.4		<5.7	<0.52	230	<2.7
Lancashire												
Morecambe	Sediment	2	<0.99								92	
Half Moon Bay	Sediment	2	<0.64								42	
Heysham pipelines	Sediment	2	<0.59								23	
Potts Corner	Sediment	2	<0.57								30	
Sunderland Point	Sediment	4	<0.94		<1.5	<0.67	<5.3		<5.4	<0.73	68	<3.0
Conder Green	Sediment	4	<0.73		<0.91	<0.47	<3.4		<4.0	<0.46	95	<2.1
Hambleton	Sediment	4	<2.8		<4.5	<1.0	<14		<13	<1.3	380	<5.9
Skippool Creek	Sediment	4	<2.9		<2.3	<0.75	<8.3		<8.7	<1.0	380	<4.2
Fleetwood	Sediment	4	<0.60		<1.2	<0.45	<3.7		<3.4	<0.55	14	<2.1
Blackpool	Sediment	4	<0.50		<1.0	<0.38	<3.2		<2.9	<0.45	4.3	<1.7
Crossens Marsh	Sediment	4	<3.8		<5.3	<1.7	<18		<17	<2.1	300	<9.3
Ainsdale	Sediment	4	<0.30		<0.49	<0.23	<1.8		<1.7	<0.27	5.8	<1.1
Rock Ferry	Sediment	4	<1.1		<2.1	<0.78	<7.4		<8.3	<0.94	150	<4.0
New Brighton	Sediment	4	<0.45		<0.95	<0.35	<2.9		<2.5	<0.40	4.4	<1.7
Scotland												
Campbeltown	Sediment	1	<0.10		<0.20	<0.33	<0.65	<0.11	<0.19	<0.10	8.1	<0.60
Garlieston	Sediment	1	0.28		<0.28	<0.40	<0.61	<0.10	0.74	<0.10	19	<0.58
Innerwell	Mud	1[F]	2.1		<5.1	<11	<8.8	<1.6	<2.7	<1.1	94	<6.2
Innerwell	Sediment	1	1.4		<0.54	<0.71	<1.4	<0.20	1.6	<0.16	91	<1.2
Carsluith	Sediment	1	0.52		<0.39	<0.59	<0.82	<0.13	0.58	<0.10	35	<0.74
Skyreburn	Sediment	1	6.2		<1.4	<2.3	7.0	<0.49	5.8	<0.35	300	<2.3
Cutter's Pool	Sediment	1	1.1		<0.42	<0.85	13	<0.16	6.7	<0.12	280	0.86
Rascarrel Bay	Sediment	1	0.88		<0.56	<0.81	<1.2	<0.19	1.1	<0.13	74	<1.2
Palnackie Harbour	Sediment	1	2.3		<0.53	<1.3	2.2	<0.22	2.2	<0.17	140	<1.4
Gardenburn	Sediment	1	2.2		<0.64	<1.2	2.1	<0.20	2.1	<0.14	150	<1.4
Kippford Slipway	Sediment	1	2.1		<0.30	<0.53	2.1	<0.15	2.0	<0.12	130	<0.98
Kippford Merse	Sediment	1	2.6		<0.29	<0.57	<1.2	<0.15	0.96	<0.13	150	<1.1
Southerness	Sediment	1	0.25		<0.26	<0.31	<0.76	<0.12	<0.18	<0.10	21	<0.73
Kirkconnel Merse	Sediment	1	1.4		<0.92	<2.0	<3.0	<0.32	1.9	<0.24	820	<2.9

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	<3.9	<1.4				66	370	<550
Maryport Outer Harbour	Sediment	2	<3.4	<1.0	13	71	480	88	370	420
Workington Harbour	Sediment	2	<3.8	<1.4				160	800	1000
Harrington Harbour	Sediment	2	<3.1	<1.1				67	370	660
Whitehaven Outer Harbour	Sediment	4	<3.0	<0.95	9.2	43	310	60	400	700
St Bees beach	Sediment	4	<2.9	<0.77				150	350	370
Sellafield beach, S of former pipeline	Sediment	2	<2.7	<0.81				98	340	470
River Calder - downstream	Sediment	2	<3.8	<1.4				35	420	1100
River Calder - upstream	Sediment	2	<8.9	<2.1					530	1200
Seascale beach	Sediment	4	<2.8	<0.88				150	420	360
Ravenglass - Carleton Marsh	Sediment	4	<6.3	<3.2				1100	1800	1300
River Mite Estuary	Sediment	4	<10	<4.1	150	800	6100	1400	2400	1600
Ravenglass - Raven Villa	Sediment	4	<4.5	<2.4				400	1100	1000
Newbiggin (Eskmeals)	Sediment	4	<8.0	<3.6	110	590	4700	890	2300	1400
Haverigg	Sediment	2	<2.7	<0.86				61	210	400
Millom	Sediment	2	<4.1	<1.1				330	730	660
Low Shaw	Sediment	2	<3.4	<0.98				130	340	510
Walney Channel - N of discharge point	Sediment	2	<4.0	<1.1				200	580	880
Walney Channel - S of discharge point	Sediment	2	<3.8	<0.94				180	390	620
Sand Gate Marsh	Sediment	4	<4.0	<1.3				100	410	570
Kents Bank	Sediment	4	<4.1	<1.5				120	390	710
Lancashire										
Morecambe	Sediment	2						77		
Half Moon Bay	Sediment	2						38		
Heysham pipelines	Sediment	2						22		
Potts Corner	Sediment	2						17		
Sunderland Point	Sediment	4	<5.8	<2.7				56	410	570
Conder Green	Sediment	4	<3.7	<1.3				77	340	640
Hambleton	Sediment	4	<9.1	<3.2				300	640	1200
Skippool Creek	Sediment	4	<5.8	<2.8				290	820	1100
Fleetwood	Sediment	4	<4.6	<1.0				15	<150	330
Blackpool	Sediment	4	<3.9	<0.81				3.2	<95	220
Crossens Marsh	Sediment	4	<16	<4.8				230	500	1100
Ainsdale	Sediment	4	<2.3	<0.60				2.9	<100	230
Rock Ferry	Sediment	4	<8.1	<2.1				79	390	740
New Brighton	Sediment	4	<3.5	<0.83				2.9	<98	300
Scotland										
Campbeltown	Sediment	1	<0.14	<0.27						
Garlieston	Sediment	1	<0.13	<0.28	4.6	25		35		
Innerwell	Mud	1[F]	<2.2	<2.5				180		
Innerwell	Sediment	1	<0.21	0.65				110		
Carsluith	Sediment	1	0.41	0.75	5.8	28		56	210	500
Skyreburn	Sediment	1	2.7	1.7				390		
Cutter's Pool	Sediment	1	2.4	1.8				<1.3		
Rascarrel Bay	Sediment	1	<0.24	2.1				<0.33		
Palnackie Harbour	Sediment	1	1.1	<1.3	22	83		180		
Gardenburn	Sediment	1	0.91	1.7	26	140		250		
Kippford Slipway	Sediment	1	0.75	<0.46	17	91		180		
Kippford Merse	Sediment	1	0.72	0.95	23	120		240		
Southerness	Sediment	1	<0.17	0.59	3.6	15		26		
Kirkconnel Merse	Sediment	1	1.9	2.0	46	280		500	320	1100

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	<0.34	<0.53	<0.30	<1.9		<1.8	<0.30	5.7	<1.2
Wales											
Rhyl	Sediment	2	<0.58	<1.3	<0.50	<3.7		<4.0	<0.51	82	<2.4
Llandudno	Sediment	2	<0.30	<0.65	<0.24	<1.9		<1.7	<0.27	3.5	<1.2
Caerhun	Sediment	2	<0.59	<1.3	<0.48	<4.8		<6.3	<0.54	310	<3.0
Llanfairfechan	Sediment	2	<0.53	<1.1	<0.39	<3.6		<3.9	<0.48	75	<2.3
Northern Ireland											
Carrichue	Mud and sand	1^{N}	<0.48	<1.9	<2.4	<4.6	<0.93	<1.1	<0.50	2.1	<2.3
Carrichue	Shell and sand	1^{N}	<0.39	<2.7	<4.6	<4.8	<0.92	<1.4	<0.53	2.1	<3.7
Portrush	Sand	2^{N}	<0.35	<2.8	<6.0	<4.0	<0.76	<0.97	<0.46	0.77	<2.8
Oldmill Bay	Mud	2^{N}	<0.60	<2.8	<3.9	<6.3	<1.2	<1.8	<0.74	30	<4.1
Ballymacormick	Mud	2^{N}	<0.47	<2.4	<3.8	<5.0	<0.96	<1.4	<0.60	11	<3.5
Strangford Lough - Nicky's Point	Mud	2^{N}	<0.50	<2.3	<3.4	<5.5	<1.0	<1.6	<0.67	27	<3.9
Dundrum Bay	Mud	2^{N}	<0.43	<2.0	<2.6	<4.7	<0.90	<1.3	<0.59	4.8	<3.8
Carlingford Lough	Mud	2^{N}	<0.49	<1.9	<2.2	<5.4	<0.97	<1.6	<0.68	44	<3.2

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	<2.5	<0.73			1.3			120	540
Wales											
Rhyl	Sediment	2	<4.1	<1.5			45			350	860
Llandudno	Sediment	2	<2.3	<0.70						<100	260
Caerhun	Sediment	2	<4.3	<1.7			71			380	1000
Llanfairfechan	Sediment	2	<3.9	<1.3			38			310	750
Northern Ireland											
Carrichue	Mud and sand	1^{N}	<1.6	<1.1	0.037	0.26	0.35	*	*		
Carrichue	Shell and sand	1^{N}	<1.2	<1.8			<3.0				
Portrush	Sand	2^{N}	<1.0	<1.1			<1.1				
Oldmill Bay	Mud	2^{N}	<1.9	<1.8			15				
Ballymacormick	Mud	2^{N}	<1.5	<1.6			6.7				
Strangford Lough - Nicky's Point	Mud	2^{N}	<1.6	<1.8			6.9				
Dundrum Bay	Mud	2^{N}	<1.4	<1.8			<2.3				
Carlingford Lough	Mud	2^{N}	<1.5	<1.4	2.3	14	9.0	*	*		

* *Not detected by the method used*

^{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*

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, 2007

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Salt marsh	1	0.079
Rockcliffe Marsh	Grass	1	0.086
Burgh Marsh	Salt marsh	1	0.079
Burgh Marsh	Grass	1	0.077
Port Carlisle 1	Mud and sand	1	0.083
Port Carlisle 1	Mud and salt marsh	1	0.085
Port Carlisle 1	Salt marsh	1	0.087
Port Carlisle 1	Grass	1	0.079
Port Carlisle 2	Grass	4	0.086
Greenend 1	Mud	1	0.093
Greenend 1	Mud and sand	1	0.093
Greenend 1	Mud and pebbles	2	0.094
Greenend 2	Mud and grass	1	0.087
Greenend 2	Mud and pebbles	2	0.092
Greenend 2	Grass	1	0.087
Cardurnock Marsh	Salt marsh	2	0.083
Cardurnock Marsh	Grass	2	0.074
Newton Arlosh	Grass and mud	1	0.10
Newton Arlosh	Salt marsh	2	0.11
Newton Arlosh	Grass	1	0.11
Silloth harbour	Mud and pebbles	1	0.095
Silloth harbour	Pebbles and sand	2	0.090
Silloth harbour	Concrete	1	0.090
Silloth silt pond	Sand	1	0.078
Silloth silt pond	Grass and sand	1	0.075
Silloth silt pond	Grass	2	0.076
Allonby	Sand	1	0.086
Allonby	Pebbles and sand	1	0.11
Allonby	Pebbles	2	0.097
Maryport harbour	Sand	2	0.091
Workington harbour	Mud and pebbles	2	0.099
Harrington harbour	Sand	2	0.10
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	3	0.10
Whitehaven - outer harbour	Pebbles and sand	1	0.10
St Bees	Sand	3	0.089
St Bees	Pebbles and sand	1	0.072
Nethertown beach	Sand	1	0.087
Nethertown beach	Pebbles and rock	1	0.13
Braystones	Pebbles	2	0.11
Sellafield dunes	Sand	1	0.097
Sellafield dunes	Grass	1	0.094
North of former pipeline on foreshore	Sand	1	0.084
North of former pipeline on foreshore	Pebbles and sand	1	0.11
South of former pipeline on foreshore	Sand	1	0.081
South of former pipeline on foreshore	Pebbles and sand	1	0.11
River Calder downstream of factory sewer	Pebbles	1	0.10
River Calder downstream of factory sewer	Pebbles and stones	1	0.10
River Calder upstream of factory sewer	Grass and mud	1	0.098
River Calder upstream of factory sewer	Grass	1	0.096
Seascale beach	Sand	3	0.075
Seascale beach	Pebbles and sand	1	0.073
Seascale	Grass and mud	1	0.080
Seascale	Grass	3	0.078

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	Salt marsh and mud	1	0.16
Ravenglass - Carleton Marsh	Grass and mud	1	0.16
Ravenglass - Carleton Marsh	Salt marsh	2	0.15
Ravenglass - River Mite estuary	Grass and mud	1	0.18
Ravenglass - River Mite estuary	Salt marsh	3	0.18
Ravenglass - Raven Villa	Grass and mud	1	0.15
Ravenglass - Raven Villa	Salt marsh	3	0.15
Ravenglass - boat area	Sand	1	0.11
Ravenglass - boat area	Pebbles and sand	3	0.10
Ravenglass - ford	Mud and pebbles	1	0.11
Ravenglass - ford	Sand	3	0.11
Muncaster Bridge	Grass and mud	2	0.12
Muncaster Bridge	Grass	2	0.12
Ravenglass - salmon garth	Mud and pebbles	1	0.11
Ravenglass - salmon garth	Mussel bed	1	0.10
Ravenglass - salmon garth	Pebbles and sand	1	0.10
Ravenglass - salmon garth	Pebbles and stones	1	0.10
Ravenglass - Eskmeals Nature Reserve	Mud	1	0.11
Ravenglass - Eskmeals Nature Reserve	Salt marsh and mud	1	0.14
Ravenglass - Eskmeals Nature Reserve	Salt marsh	2	0.13
Newbiggin/Eskmeals viaduct	Salt marsh and mud	1	0.16
Newbiggin/Eskmeals viaduct	Salt marsh	3	0.15
Newbiggin/Eskmeals bridge	Salt marsh	4	0.16
Tarn Bay	Sand	1	0.078
Tarn Bay	Pebbles and sand	1	0.070
Silecroft	Pebbles and sand	1	0.094
Silecroft	Pebbles	1	0.11
Haverigg	Sand	2	0.074
Millom	Mud and sand	1	0.095
Millom	Salt marsh	1	0.10
Low Shaw	Grass and mud	2	0.084
Askam	Sand	1	0.076
Askam	Pebbles and sand	1	0.084
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud and pebbles	2	0.092
Walney Channel, S of discharge point	Mud	1	0.092
Walney Channel, S of discharge point	Mud and sand	1	0.091
Tummer Hill Marsh	Salt marsh	1	0.12
Tummer Hill Marsh	Grass and salt marsh	1	0.12
Roa Island	Mud and sand	2	0.090
Greenodd Salt Marsh	Grass and mud	2	0.077
Sand Gate Marsh	Salt marsh	2	0.091
Sand Gate Marsh	Grass	2	0.087
Kents Bank 2	Salt marsh	3	0.088
Kents Bank 2	Grass and salt marsh	1	0.083
High Foulshaw	Grass and mud	2	0.076
High Foulshaw	Grass	2	0.077
Arnside 1	Mud	1	0.084
Arnside 1	Mud and salt marsh	1	0.083
Arnside 1	Mud and sand	2	0.074
Arnside 2	Salt marsh	3	0.095
Arnside 2	Grass	1	0.092
Lancashire and Merseyside			
Morecambe Central Pier	Mud and sand	1	0.074
Morecambe Central Pier	Pebbles and sand	1	0.073
Heysham pipelines	Mud and rock	1	0.077
Heysham pipelines	Sand	1	0.078
Half Moon Bay	Mud and rock	1	0.076
Half Moon Bay	Sand	1	0.071
Middleton Sands	Sand	1	0.075
Sunderland Point	Mud	3	0.083
Sunderland Point	Mud and sand	1	0.089
Sunderland	Salt marsh	4	0.091
Colloway Marsh	Salt marsh	3	0.12
Lancaster	Grass and mud	2	0.079
Lancaster	Grass	2	0.079

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	0.13
Aldcliffe Marsh	Salt marsh	3	0.10
Conder Green	Grass and mud	1	0.086
Conder Green	Salt marsh	3	0.088
Pilling Marsh	Salt marsh	4	0.096
Knott End	Sand	1	0.069
Knott End	Concrete	1	0.074
Heads - River Wyre	Salt marsh and mud	1	0.090
Heads - River Wyre	Salt marsh	3	0.10
Height o' th' hill - River Wyre	Salt marsh and mud	1	0.10
Height o' th' hill - River Wyre	Salt marsh	3	0.11
Hambleton	Grass and mud	2	0.11
Hambleton	Salt marsh	2	0.11
Skippool Creek 1	Grass and mud	2	0.11
Skippool Creek 1	Salt marsh	2	0.11
Skippool Creek 2	Mud	2	0.093
Skippool Creek 2	Salt marsh	2	0.11
Skippool Creek 3	Salt marsh	1	0.093
Skippool Creek 3	Wood	3	0.093
Skippool Creek boat 2	Wood	4	0.094
Skippool Creek boat 2 - in vicinity of boats	Mud	1	0.089
Skippool Creek boat 2 - in vicinity of boats	Grass and mud	1	0.087
Skippool Creek boat 2 - in vicinity of boats	Salt marsh	2	0.090
Fleetwood Marsh Nature Park	Salt marsh	1	0.12
Fleetwood Marsh Nature Park	Grass	1	0.084
Fleetwood shore 1	Sand	4	0.075
Fleetwood shore 2	Salt marsh	2	0.13
Blackpool	Sand	4	0.061
Crossens Marsh	Salt marsh	4	0.085
Ainsdale	Sand	4	0.061
Rock Ferry	Mud	1	0.083
Rock Ferry	Mud and sand	2	0.087
Rock Ferry	Sand	1	0.085
New Brighton	Sand	4	0.061
West Kirby	Mud	1	0.064
West Kirby	Sand	2	0.070
West Kirby	Tarmac	1	0.059
Little Neston Marsh 1	Grass and mud	1	0.086
Little Neston Marsh 1	Salt marsh	1	0.085
Little Neston Marsh 2	Salt marsh	1	0.080
Little Neston Marsh 2	Grass	1	0.088
Flint 1	Mud	1	0.079
Flint 1	Mud and salt marsh	1	0.087
Flint 2	Salt marsh	2	0.094
Scotland			
Piltanton Burn	Salt marsh	4	0.062
Garlieston	Mud	4	0.075
Innerwell	Mud	4	0.080
Bladnoch	Mud	4	0.086
Carsluith	Mud	4	0.082
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.083
Kirkcudbright	Salt marsh	4	0.075
Cutters Pool	Winkle bed	4	0.088
Rascarrel Bay	Winkle bed	4	0.10
Gardenburn	Salt marsh	1	0.093
Palnackie Harbour	Mud	1	0.087
Kippford - Slipway	Mud	4	0.10
Kippford - Merse	Salt marsh	1	0.095
Southerness	Winkle bed	4	0.066
Kirkconnell Marsh	Salt marsh	1	0.12
Isle of Man			
Ramsey	Pebbles and sand	1	0.080

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	0.062
Rhyl	Mud	1	0.070
Rhyl	Salt marsh	1	0.080
Llandudno	Pebbles and sand	2	0.082
Caerhun	Salt marsh and mud	1	0.090
Caerhun	Salt marsh	1	0.082
Llanfairfechan	Mud and sand	1	0.075
Llanfairfechan	Salt marsh	1	0.086
Northern Ireland			
Lishally	Mud	1	0.067
Eglington	Shingle	1	0.056
Carrichue	Mud	1	0.066
Bellerena	Mud	1	0.060
Benone	Sand	1	0.062
Castlerock	Sand	1	0.060
Portstewart	Sand	1	0.058
Portrush, Blue Pool	Sand	1	0.059
Portrush, White Rocks	Sand	1	0.060
Portballintrae	Sand	1	0.058
Giant's Causeway	Sand	1	0.063
Ballycastle	Sand	1	0.057
Cushendun	Sand	1	0.063
Cushendall	Sand and stones	1	0.063
Red Bay	Sand	1	0.066
Carnlough	Sand	1	0.059
Glenarm	Sand	1	0.057
Half Way House	Sand	1	0.058
Ballygally	Sand	1	0.058
Drains Bay	Sand	1	0.060
Larne	Sand	1	0.064
Whitehead	Sand	1	0.072
Carrickfergus	Sand	1	0.065
Jordanstown	Sand	1	0.067
Helen's Bay	Sand	1	0.058
Groomsport	Sand	1	0.067
Millisle	Sand	1	0.063
Ballywalter	Sand	1	0.068
Ballyhalbert	Sand	1	0.065
Cloghy	Sand	1	0.074
Portaferry	Shingle and stones	1	0.091
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.074
Ards Maltings	Mud	1	0.088
Island Hill	Mud	1	0.080
Nicky's Point	Mud	1	0.078
Strangford	Shingle and stones	1	0.096
Kilclief	Sand	1	0.073
Ardglass	Mud	1	0.087
Killough	Mud	1	0.086
Rocky Beach	Sand	1	0.074
Tyrella	Sand	1	0.081
Dundrum	Mud	1	0.092
Newcastle	Sand	1	0.11
Annalong	Sand	1	0.10
Cranfield Bay	Sand	1	0.083
Mill Bay	Mud	1	0.11
Greencastle	Sand	1	0.086
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.094

Table 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2007

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
M	Nets	4	0.10
	Rope	4	<0.041
S	Nets	4	<0.011
	Pots	4	<0.058
T	Gill nets	4	<0.037
	Pots	4	<0.069
W	Gill nets	2	<0.025
	Pots	2	<0.028
X	Gill nets	4	<0.040
	Pots	4	<0.066
Z	Nets	4	<0.065

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2007

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, μSv h^{-1}
Whitehaven - outer harbour	Sand	1	0.10
Whitehaven - outer harbour	Pebbles and sand	1	0.10
St Bees	Sand	2	0.10
St Bees	Pebbles and sand	1	0.10
Sellafield pipeline	Sand	1	*
Ravenglass - Raven Villa	Salt marsh	3	*
Tarn Bay	Sand	1	0.10

* *Not detected by the method used*

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2007

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria									
Silloth	Seaweed	2		<0.87		<1.2	<0.61	410	<5.2
Harrington Harbour	Seaweed	2		<0.68		<0.90	<0.44	500	<3.8
St Bees	*Porphyra*	4[F]	24	0.31	0.043	<0.40	<0.65	0.58	<1.9
St Bees	Seaweed	2		<1.6	<1.0	<1.3	<0.69	970	<5.9
Braystones South	*Porphyra*	4[F]		0.29		<0.36	<0.58		4.7
Sellafield	*Rhodymenia* spp.	2		<0.14		<0.61	<1.0		<1.3
Sellafield	Seaweed	1		3.5	<2.0	<1.6	<0.81	4200	<6.8
Seascale	*Porphyra*[a]	53[F]		<0.36		<0.50	<0.29		<5.4
Ravenglass	Samphire	1[F]		<0.08		<0.28	<0.37	0.46	<0.85
Ravenglass	Seaweed	2		2.2		<1.0	<0.49	260	<4.3
Lancashire									
Half Moon Bay	Seaweed	2		<1.1		<1.4	<0.75	320	<6.2
Marshside Sands	Samphire	1[F]		<0.04		<0.24	<0.43		<0.44
Cockerham Marsh	Samphire	1[F]		<0.08		<0.32	<0.43		<0.86
Scotland									
Aberdeen	*Fucus vesiculosus*	1		<0.10		<0.30	<0.38	70	<0.68
Lerwick	*Fucus vesiculosus*	1		<0.10		<0.26	<0.28	150	<0.72
Lewis	*Fucus vesiculosus*	1		<0.10		<0.41	<0.53	200	<0.91
Islay	*Fucus vesiculosus*	1		<0.10		<0.36	<0.54	90	<0.70
Campbeltown	*Fucus vesiculosus*	1		<0.10		<0.18	<0.26	360	<0.35
Knock Bay	*Porphyra*	1[F]		<0.06		<0.31	<0.62		<0.51
Port William	*Fucus vesiculosus*	1[F]		<0.11		<0.30	<0.35		<0.76
Port William	*Fucus vesiculosus*	4		<0.14		<0.43	<0.93	440	<0.61
Garlieston	*Fucus vesiculosus*	1[F]		0.53		<0.29	<0.34		<0.79
Garlieston	*Fucus vesiculosus*	4		<0.25		<0.48	<0.79	300	<0.94
Auchencairn	*Fucus vesiculosus*	1[F]		0.68		<0.31	<0.35		<0.83
Auchencairn	*Fucus vesiculosus*	3		0.45		<0.24	<0.38	1100	<0.45
Auchencairn	*Ascophyllum nodosum*	1		0.97		<0.25	<0.35	1100	<0.49
Isle of Man	*Fucus vesiculosus*	1		<2.0		<2.9	<1.5	110	<13
Wales									
Cemaes Bay	Seaweed	2		<1.6		<2.2	<1.1	500	<9.7
Porthmadog	Seaweed	2		<1.4		<2.0	<1.1	30	<8.7
Lavernock Point	Seaweed	3		<0.99		<1.5	<0.69	9.3	<6.2
Fishguard	Seaweed	2		<1.2		<1.4	<0.75	17	<6.2
South Wales, manufacturer A	Laverbread	4[F]		<0.09		<0.37	<0.54		<0.96
South Wales, manufacturer C	Laverbread	4[F]		<0.07		<0.30	<0.44		<0.76
South Wales, manufacturer D	Laverbread	4[F]		<0.07		<0.30	<0.45		<0.72
South Wales, manufacturer E	Laverbread	1[F]		<0.08		<0.31	<0.38		<0.84
Northern Ireland									
Portrush	*Fucus* spp.	3		<0.06		<0.29	<0.44		<0.59
Strangford Lough	*Rhodymenia* spp.	4		<0.11		<0.65	<1.4	9.3	<1.1
Ardglass	*Ascophyllum nodosum*	2		<0.11		<0.60	<1.1		<1.0
Ardglass	*Fucus vesiculosus*	1		<0.12		<0.71	<1.3	650	<1.4
Carlingford Lough	*Ascophyllum nodosum*	1		<0.10		<0.70	<0.48		<0.89
Carlingford Lough	*Fucus* spp.	3		<0.17		<1.0	<2.1	360	<1.8
Isles of Scilly	*Fucus vesiculosus*	1		<1.1		<1.5	<0.75	3.2	<6.5

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	<0.89	<4.4	<0.72	6.6	<2.5		
Harrington Harbour	Seaweed	2	<0.64	<3.2	<0.53	4.4	<1.9		
St Bees	*Porphyra*	4[F]	<0.17	<0.45	<0.08	1.7	<0.46	<0.24	<0.22
St Bees	Seaweed	2	<1.0	<4.7	<0.82	4.5	<2.8		
Braystones South	*Porphyra*	4[F]	<0.17	<0.99	<0.08	1.5	<0.46	<0.24	<0.21
Sellafield	*Rhodymenia* spp.	2	<0.25	<0.27	<0.13	5.2	<0.49	<0.39	<0.19
Sellafield	Seaweed	1	<1.2	<5.8	<0.96	5.0	<3.3		
Seascale	*Porphyra*[a]	53[F]	<0.52	<1.3	<0.31	1.2	<1.4	<0.93	<0.69
Ravenglass	Samphire	1[F]	<0.13	<0.19	<0.08	2.5	<0.41	<0.21	<0.17
Ravenglass	Seaweed	2	<0.73	<3.8	<0.60	8.0	<1.9		
Lancashire									
Half Moon Bay	Seaweed	2	<1.2	<5.2	<0.86	6.0	<2.8		
Marshside Sands	Samphire	1[F]	<0.09	<0.11	<0.04	0.77	<0.22	<0.13	<0.08
Cockerham Marsh	Samphire	1[F]	<0.15	<0.19	<0.08	2.3	<0.43	<0.22	<0.18
Scotland									
Aberdeen	*Fucus vesiculosus*	1	<0.10	<0.18	<0.10	<0.10	<0.41	<0.10	<0.18
Lerwick	*Fucus vesiculosus*	1	<0.10	<0.19	<0.10	0.22	<0.41	<0.10	<0.19
Lewis	*Fucus vesiculosus*	1	<0.12	<0.25	<0.10	0.41	<0.58	<0.13	<0.25
Islay	*Fucus vesiculosus*	1	<0.10	<0.19	<0.10	0.36	<0.45	<0.10	<0.19
Campbeltown	*Fucus vesiculosus*	1	<0.10	0.18	<0.10	0.53	<0.28	<0.10	<0.11
Knock Bay	*Porphyra*	1[F]	<0.12	<0.10	<0.05	0.49	<0.21	<0.19	<0.08
Port William	*Fucus vesiculosus*	1[F]	<0.17	0.25	<0.09	1.4	<0.37	<0.31	<0.17
Port William	*Fucus vesiculosus*	4	<0.12	<0.25	<0.10	1.2	<0.37	<0.11	<0.13
Garlieston	*Fucus vesiculosus*	1[F]	<0.16	0.42	<0.09	3.5	<0.39	<0.30	<0.18
Garlieston	*Fucus vesiculosus*	4	<0.15	<0.41	<0.12	3.2	<0.63	<0.14	<0.26
Auchencairn	*Fucus vesiculosus*	1[F]	<0.16	0.98	<0.10	5.0	<0.53	<0.27	<0.26
Auchencairn	*Fucus vesiculosus*	3	<0.11	0.61	<0.10	3.4	<0.30	<0.10	<0.15
Auchencairn	*Ascophyllum nodosum*	1	<0.10	0.96	<0.10	5.4	<0.34	<0.10	<0.13
Isle of Man	*Fucus vesiculosus*	1	<2.2	<11	<1.7	<1.6	<5.6	<16	<2.7
Wales									
Cemaes Bay	Seaweed	2	<1.7	<7.9	<1.4	<1.4	<3.9		
Porthmadog	Seaweed	2	<1.7	<7.5	<1.3	<1.8	<3.6		
Lavernock Point	Seaweed	3	<1.1	<4.9	<0.84	<0.77	<2.9	<7.7	<1.4
Fishguard	Seaweed	2	<1.2	<5.1	<0.87	<0.78	<2.7		
South Wales, manufacturer A	Laverbread	4[F]	<0.17	<0.20	<0.09	0.41	<0.39	<0.26	<0.15
South Wales, manufacturer C	Laverbread	4[F]	<0.14	<0.17	<0.07	<0.15	<0.34	<0.22	<0.14
South Wales, manufacturer D	Laverbread	4[F]	<0.13	<0.16	<0.07	0.30	<0.32	<0.20	<0.12
South Wales, manufacturer E	Laverbread	1[F]	<0.15	<0.20	<0.08	0.24	<0.42	<0.23	<0.18
Northern Ireland									
Portrush	*Fucus* spp.	3	<0.13	<0.14	<0.07	<0.13	<0.31	<0.21	<0.14
Strangford Lough	*Rhodymenia* spp.	4	<0.22	<0.23	<0.11	0.71	<0.46	<0.33	<0.17
Ardglass	*Ascophyllum nodosum*	2	<0.22	<0.31	<0.12	0.62	<0.61	<0.34	<0.27
Ardglass	*Fucus vesiculosus*	1	<0.25	<0.31	<0.14	0.75	<0.72	<0.36	<0.29
Carlingford Lough	*Ascophyllum nodosum*	1	<0.19	<0.22	<0.11	0.46	<0.41	<0.31	<0.19
Carlingford Lough	*Fucus* spp.	3	<0.33	<0.37	<0.17	0.64	<0.78	<0.51	<0.31
Isles of Scilly	*Fucus vesiculosus*	1	<1.1	<5.0	<0.92	<0.80	<2.8	<8.4	<1.5

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				4.1			
Harrington Harbour	Seaweed	2				1.8			
St Bees	*Porphyra*	4^{F}	0.23	1.3	11	2.7	*	0.0026	170
St Bees	Seaweed	2	1.7	7.7		5.9			
Braystones South	*Porphyra*	4^{F}	0.30	1.6	13	3.2	*	0.0049	
Sellafield	*Rhodymenia* spp.	2	0.41	1.9		4.0	*	*	
Sellafield	Seaweed	1	3.1	14		3.3			
Seascale	*Porphyra*[a]	53^{F}				4.0			
Ravenglass	Samphire	1^{F}				6.0			
Ravenglass	Seaweed	2				22			
Lancashire									
Half Moon Bay	Seaweed	2				<1.4			
Marshside Sands	Samphire	1^{F}				0.46			
Cockerham Marsh	Samphire	1^{F}				1.3			47
Scotland									
Aberdeen	*Fucus vesiculosus*	1				<0.11			
Lerwick	*Fucus vesiculosus*	1				<0.11			
Lewis	*Fucus vesiculosus*	1				<0.15			
Islay	*Fucus vesiculosus*	1				<0.12			
Campbeltown	*Fucus vesiculosus*	1							
Knock Bay	*Porphyra*	1^{F}				0.55			
Port William	*Fucus vesiculosus*	1^{F}				0.61			
Port William	*Fucus vesiculosus*	4				0.64			
Garlieston	*Fucus vesiculosus*	1^{F}				3.8			
Garlieston	*Fucus vesiculosus*	4				3.3			
Auchencairn	*Fucus vesiculosus*	1^{F}				3.8			
Auchencairn	*Fucus vesiculosus*	3				2.0			
Auchencairn	*Ascophyllum nodosum*	1				5.5			
Isle of Man	*Fucus vesiculosus*	1				<1.7			
Wales									
Cemaes Bay	Seaweed	2				<1.5			
Porthmadog	Seaweed	2				<1.4			
Lavernock Point	Seaweed	3				<0.93			
Fishguard	Seaweed	2				<0.94			
South Wales, manufacturer A	Laverbread	4^{F}				0.29			
South Wales, manufacturer C	Laverbread	4^{F}				<0.19			
South Wales, manufacturer D	Laverbread	4^{F}				<0.46			82
South Wales, manufacturer E	Laverbread	1^{F}				<0.17			
Northern Ireland									
Portrush	*Fucus* spp.	3				<0.14			
Strangford Lough	*Rhodymenia* spp.	4	0.058	0.34		0.46	*	0.00041	
Ardglass	*Ascophyllum nodosum*	2				<0.41			
Ardglass	*Fucus vesiculosus*	1				0.44			
Carlingford Lough	*Ascophyllum nodosum*	1				<0.11			
Carlingford Lough	*Fucus* spp.	3				<0.33			
Isles of Scilly	*Fucus vesiculosus*	1				<0.93			

* *Not detected by the method used*

[a] *Counted fresh*

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

Table 2.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2007

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]	Onions	1		<0.05	<0.20	<0.30	3.1	<0.50	<0.09
Sellafield 14[b]	Potatoes	1		<0.04	<0.43	*		<0.44	<0.09
Sellafield 14[b]	Runner Beans	1		<0.05	<0.20	<0.27	34	<0.52	<0.11
Sellafield 14[b]	Shallots	1		<0.04	<0.18	<0.23	2.3	<0.46	<0.10
Sellafield 14[b]	Soil	1		25	<10	*	6700	<13	11
Sellafield 1602[b]	Potatoes	1		<0.04	<0.23	<0.40	1.0	<0.43	<0.10
Sellafield 1602[b]	Soil	1		<0.19	<1.2	<1.9		<2.4	<0.61
Sellafield 1603[b]	Cabbage	1		<0.03	<0.12	<0.18	<0.16	<0.29	<0.06
Sellafield 1603[b]	Onions	1		<0.05	<0.22	<0.34	<0.29	<0.55	<0.13
Sellafield 1603[b]	Potatoes	1		<0.12	<0.40	<0.45	<0.58	<1.1	<0.24
Sellafield 1603[b]	Runner Beans	1		<0.06	<0.19	<0.25	<0.28	<0.58	<0.13
Sellafield 1710[b]	Onions	1		<0.09	<0.41	<0.63	1.7	<0.92	<0.18
Sellafield 1710[b]	Potatoes	1		<0.09	<0.38	<0.57	11	<0.94	<0.19
Sellafield 1710[b]	Shallots	1		<0.08	<0.34	<0.51	2.3	<0.85	<0.18
Sellafield 1710[b]	Soil	1		2.2	<4.5	<12	650	<6.2	<1.7
Hinkley	Beetroot	1	9.5	<0.07	<0.35	<0.64		<0.67	<0.13
Hinkley	Parsnips	1	22	<0.05	<0.22	<0.35		<0.42	<0.09
Hinkley	Soil	1	10	<0.23	<0.90	<1.0		<2.5	<0.69

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]	Onions	1	<0.05	<0.04	<0.17	<0.15	<0.07	<0.03
Sellafield 14[b]	Potatoes	1	<0.04	0.15	<0.22	<0.14	<0.08	<0.05
Sellafield 14[b]	Runner Beans	1	<0.05	0.06	<0.19	<0.16	<0.07	<0.04
Sellafield 14[b]	Shallots	1	<0.05	<0.04	<0.23	<0.13	<0.10	<0.09
Sellafield 14[b]	Soil	1	<1.2	64	<5.9	<2.9	<2.1	89
Sellafield 1602[b]	Potatoes	1	<0.05	0.11	<0.27	<0.14	<0.12	<0.19
Sellafield 1602[b]	Soil	1	<0.24	<0.19	<1.8	<0.53	<0.73	<0.62
Sellafield 1603[b]	Cabbage	1	<0.03	<0.03	<0.11	<0.10	<0.04	<0.02
Sellafield 1603[b]	Onions	1	<0.06	<0.05	<0.29	<0.17	<0.14	<0.19
Sellafield 1603[b]	Potatoes	1	<0.12	<0.10	<0.42	<0.37	<0.16	<0.08
Sellafield 1603[b]	Runner Beans	1	<0.06	<0.05	<0.30	<0.18	<0.15	<0.20
Sellafield 1710[b]	Onions	1	<0.09	<0.08	<0.32	<0.28	<0.13	<0.07
Sellafield 1710[b]	Potatoes	1	<0.09	0.17	<0.35	<0.29	<0.14	<0.07
Sellafield 1710[b]	Shallots	1	<0.08	<0.07	<0.41	<0.22	<0.19	<0.27
Sellafield 1710[b]	Soil	1	<0.76	54	<5.0	<1.5	<2.0	6.4
Hinkley	Beetroot	1	<0.06	<0.05	<0.25	<0.22	<0.09	<0.05
Hinkley	Parsnips	1	<0.05	<0.04	<0.20	<0.17	<0.08	<0.05
Hinkley	Soil	1	<0.34	6.8	<2.0	<0.71	<0.94	<0.97

* *Not detected by the method used*
[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, 2007

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]		3	<4.7	15	<0.19	0.039	<0.33	<0.29	<0.0035	<1.3	<0.41	<0.0085
Milk	max		<4.8		<0.23	0.057	<0.35	<0.31		<1.4	<0.43	<0.0090
Apples		1	<4.0	14	<0.20	0.041	<0.20	<0.30	<0.010	<1.3	<0.40	<0.027
Barley		1	<8.0	86	<0.20	0.23	<0.30	<0.30	<0.020	<1.2	<0.50	<0.064
Beef kidney[e]		1	<9.0	22	<0.20	0.17	<0.40	<0.30	<0.024	<1.9	<0.60	<0.033
Beef liver		1	<8.0	27	<0.20	0.033	<0.30	<0.20	<0.020	<1.3	<0.30	<0.029
Beef muscle		1	<6.0	20	<0.20	<0.0080	<0.40	<0.20	<0.021	<1.7	<0.50	<0.037
Blackberries		1	<5.0	16	<0.20	0.39	<0.40	<0.30	<0.010	<1.3	<0.50	<0.046
Broad beans		1							<0.012			
Cabbage		1	5.0	<3.0	<0.20	0.51	<0.30	<0.30	16	<1.8	<0.40	<0.029
Carrots		1	<4.0	8.0	<0.30	0.13	<0.60	<0.40	<0.015	<1.7	<0.60	<0.023
Honey		1	<8.0	74	<0.10	0.032	<0.30	<0.20	<0.014	<1.0	<0.50	<0.027
Onions		1							0.050			
Pheasants		1	<6.0	19	<0.30	0.030	<0.30	<0.20	<0.026	<1.3	<0.20	<0.044
Potatoes		1	<5.0	18	<0.20	0.11	<0.40	<0.30	0.054	<1.0	<0.60	<0.026
Runner beans		1	<4.0	15	<0.30	0.18	<0.50	<0.40	<0.012	<2.5	<0.50	<0.026
Sheep muscle		2	<7.0	21	<0.20	<0.0085	<0.35	<0.20	<0.017	<1.5	<0.35	<0.035
Sheep muscle	max		8.0	23		<0.0090	<0.40		<0.022	<1.6	<0.40	<0.036
Sheep offal		2	<10	13	<0.25	0.30	<0.25	<0.25	<0.020	<1.6	<0.50	<0.037
Sheep offal	max		11	15	<0.30	0.40	<0.30	<0.30		<1.7		<0.040
Grass[f]		2							<9.9			
Grass	max								20			

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			Total Cs	^{144}Ce	Total U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	
Milk[d]		3		<0.86		<0.00017	<0.00018	<0.033	<0.00013	
Milk	max			<0.89		<0.00018	<0.00020	<0.034	<0.00015	
Apples		1	0.10	<1.1		<0.00030	0.00040	<0.039	0.00060	
Barley		1	0.27	<0.90		<0.00030	<0.00030	<0.058	0.0013	
Beef kidney[e]		1	0.30	<1.8		0.00020	0.0013	0.083	0.0097	
Beef liver		1	0.26	<0.60		0.0019	0.0096	<0.10	0.0093	
Beef muscle		1	0.53	<1.0		0.00020	<0.00050	<0.083	0.0012	
Blackberries		1	0.11	<1.0		<0.00020	0.00040	<0.043	0.00090	
Broad beans		1			<0.031					
Cabbage		1	0.16	<0.90		<0.00020	0.00090	<0.034	0.0011	
Carrots		1	0.18	<1.5		<0.00020	<0.00020	<0.032	<0.00020	
Honey		1	0.55	<1.4		<0.00010	0.0010	<0.082	0.0017	
Onions		1			<0.031					
Pheasants		1	1.1	<0.60		<0.00040	0.00030	<0.15	0.0013	
Potatoes		1	0.26	<1.1		<0.00010	0.00020	0.058	0.00020	
Runner beans		1	0.034	<1.3		<0.00020	0.00090	<0.062	0.00040	
Sheep muscle		2	0.91	<0.90		0.00045	0.0026	<0.079	0.0051	
Sheep muscle	max		0.95			0.00050		<0.085	0.0054	
Sheep offal		2	0.31	<0.65		0.026	0.13	0.69	0.18	
Sheep offal	max		0.32	<0.70		0.034	0.17	0.84	0.21	
Grass[f]		2							1.9	
Soil[g]		1								

[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 <0.20 and <0.23 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.026, <0.0010 and 0.022 Bq kg^{-1} respectively*

[f] *The concentration of ^{137}Cs was 1.0 Bq kg^{-1}*

[g] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 14, 0.59 and 12 Bq kg^{-1} respectively*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2007

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	710	<0.30	<0.098	<0.27	<0.44	<0.011	<0.010	<2.8	14
River Ehen (100m downstream of sewer outfall)	4	11	<0.29	<0.14	<0.27	<0.25	<0.014	<0.0055	<0.080	0.66
River Calder (downstream)	4	<5.3	<0.30	<0.060	<0.28	<0.26	<0.014	<0.0050	<0.028	<0.11
River Calder (upstream)	4	<6.4	<0.33	<0.060	<0.30	<0.27	<0.011	<0.0055	<0.043	<0.10
Wast Water	1	<5.0	<0.30			<0.26			<0.020	<0.10
Ennerdale Water	1	<4.0	<0.14		<0.12	<0.10			<0.020	<0.10
Devoke Water	1	<6.0	<0.10		<0.10	<0.09			<0.020	<0.10
Thirlmere	1	<4.0	<0.27			<0.26			<0.040	<0.10

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2007

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	<0.61	<3.0	<0.72	770	4.4	34	49
Seascale SS 233	1	<0.47	11	<0.44	330	2.6	26	24
Seascale SS 209	1	<0.41	<3.0	<0.36	41	1.5	8.1	13
Seascale SS 232	1	<0.41	<5.0	<0.38	110	3.2	15	32
Seascale SS 231	1	<0.75	<3.0	<0.81	57	4.8	24	50
Whitehaven SS 201	1	<1.7	<2.0	<1.5	27	<0.60	1.4	2.9

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2003-2007

Group	Exposure, mSv per year				
	2003	2004	2005	2006	2007
Isle of Man	0.006	0.007	0.008	0.007	0.006
Northern Ireland	0.013	0.010	0.020	0.018	0.015
Dumfries and Galloway	0.036	0.038	0.031	0.037	0.060
Whitehaven	0.031	0.013	0.008	0.011	0.009
Sellafield (consumption 2003-7)	0.21	0.22	0.22	0.23	0.24
Morecambe Bay	0.075	0.068	0.063	0.038	0.037
Fleetwood	0.018	0.018	0.019	0.018	0.013
North Wales	0.012	0.012	0.015	0.016	0.014

Table 2.18. Individual radiation exposures, Sellafield, 2007

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 2003-07)	0.52[d]	0.21	0.28	-	0.031	-	-
Local seafood consumers (habits for 2007)	0.46[e]	0.18	0.25	-	0.032	-	-
Whitehaven seafood consumers	0.009	0.009	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.060	0.044	-	-	0.016	-	-
Morecambe Bay seafood consumers	0.037	0.014	-	-	0.024	-	-
Fleetwood seafood consumers	0.013	0.013	-	-	-	-	-
Isle of Man seafood consumers	0.006	0.006	-	-	-	-	-
Northern Ireland seafood consumers	0.015	0.011	-	-	<0.005	-	-
North Wales seafood consumers	0.014	0.010	-	-	<0.005	-	-
Other groups							
Ravenglass Estuary, nature warden	0.027	-	-	-	0.024	<0.005	-
Fishermen handling nets or pots[c]	0.036	-	-	-	0.036	-	-
Bait diggers and shellfish[c] collectors	0.083	-	-	-	0.083	-	-
Ribble Estuary houseboats	0.073	-	-	-	0.073	-	-
Local consumers at Ravenglass[b]	0.014	-	-	0.014	-	-	-
Local consumers of vegetables grown on land with seaweed added	0.012	-	-	0.012	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.023	-	-	0.023	-	-	<0.005
Dumfries and Galloway wildfowlers	0.008	<0.005	-	-	0.007	-	-
Groups with average consumption or exposure							
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Average consumer of locally grown food	0.007	-	-	0.007	-	-	-
Typical visitor to Cumbria	<0.005	<0.005	<0.005	-	<0.005	-	-
Recreational user of beaches							
North Cumbria	0.010	-	-	-	0.010	-	-
Sellafield	0.010	-	-	-	0.010	-	-
Lancashire	0.006	-	-	-	0.006	-	-
North Wales	0.006	-	-	-	0.006	-	-
Isle of Man	0.008	-	-	-	0.008	-	-
Recreational user of mud/saltmarsh areas							
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-
North Cumbria	0.007	-	-	-	0.007	-	-
Sellafield	0.019	-	-	-	0.019	-	-
Lancashire	0.007	-	-	-	0.007	-	-
North Wales	<0.005	-	-	-	<0.005	-	-
All sources[f]	0.37	-	-	-	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1 yr*
[c] *Exposure to skin for comparison with the 50mSv dose limit*
[d] *The* total dose *due to nuclear industry discharges was 0.24mSv*
[e] *The* total dose *due to nuclear industry discharges was 0.21mSv*
[f] *The* total dose *due to discharges and direct radiation. See Appendix 4*

3. Research establishments

Key points

- Generally, concentrations and dose rates similar to 2006 for all establishments (including Harwell and other minor sites)
- At Culham, tritium concentration in grass collected near the site perimeter returned to below the LoD and food consumption dose reduced.
- A new authorisation for Winfrith came into force in January 2008 for the UKAEA site
- Windscale is now operated by Sellafield Limited
- Imperial College are considering the decommissioning of their reactor centre

Dounreay, Highland

- UKAEA and Dounreay Site Restoration Limited (DSRL) jointly applied to transfer authorisations (as an enabler for NDA's competition process)
- UKAEA notified SEPA of radioactive contamination in a surface drain.
- The Dounreay Cementation Plant remained shut down during 2007
- The sodium disposal plant re-started in early 2007
- Construction of the Breeder Fuel Removal Plant progressed
- Inactive commissioning of the Sodium/Potassium destruction plant took place
- Hydraulic isolation of the Dounreay Shaft continued with this being completed in Spring 2008
- Dounreay Particles Advisory Group's (DPAG) Fourth Report, expected in 2008
- Discharges, concentrations and dose rates similar to 2006. Some gamma dose rates slightly higher in 2007
- Terrestrial food consumption assessment now includes atmospheric plume related pathways
- Dose to terrestrial consumers (Table 3.1) was less than 5 per cent of the dose limit
- The *total dose* increased from 3 per cent in 2006 to 6 per cent in 2007

Winfrith, Dorset, Harwell, Oxfordshire and Windscale, Cumbria

- Discharges similar to 2006 at all sites
- New survey of local diet and occupancy rates undertaken at Harwell
- Terrestrial food consumption assessment now includes atmospheric plume related pathways at Harwell and Winfrith
- Concentrations and dose rates similar to 2006
- Radiation doses (Table 3.1) were less than 1 per cent of the dose limit
- In 2007, new *total dose* was estimated for Harwell
- The *total dose* from all sources was less than 3 per cent of the dose limit

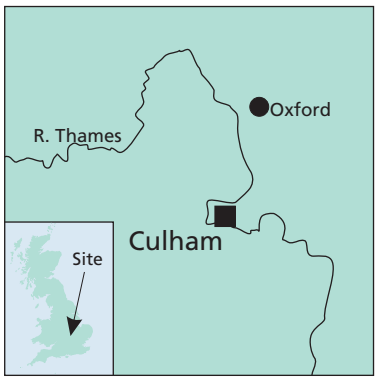
This section considers the effects of discharges from research establishments that hold nuclear site licences.

The UKAEA operated the majority of such sites, with licensed nuclear sites at Harwell and Winfrith in England, and, until recently, at Dounreay in Scotland. Ownership of the sites at Dounreay, Harwell, Winfrith and Windscale were transferred from UKAEA to the Nuclear Decommissioning Authority (NDA) in April 2005 and the non-nuclear site at Culham will transfer to the NDA when operations are expected to cease. UKAEA currently operates Culham on behalf of the European Fusion Development Agreement, and 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.

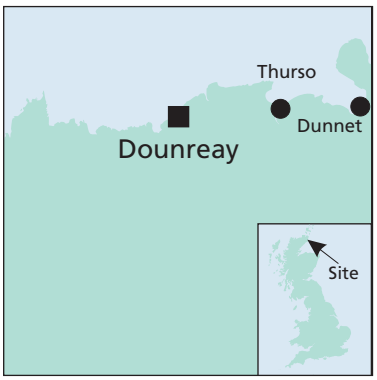
3.1 Culham, Oxfordshire



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 2007. 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 2007, measurements of tritium were less than the LoD. The Environment Agency will continue to monitor the situation in 2008. Overall, no effects due to site operation were detected. 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 (Table 3.1). This dose is 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 measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but are due to discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986. The annual dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2007 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 April 2005, the NDA was formed which became responsible for the UK's civil nuclear liabilities that included those at UKAEA Dounreay. Following the formation of the NDA, UKAEA became a contractor to the NDA.

In common with other NDA sites, UKAEA has prepared a long term decommissioning plan known as the Lifetime Plan. The NDA's ministerially agreed strategy includes 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 the current site license company (UKAEA)

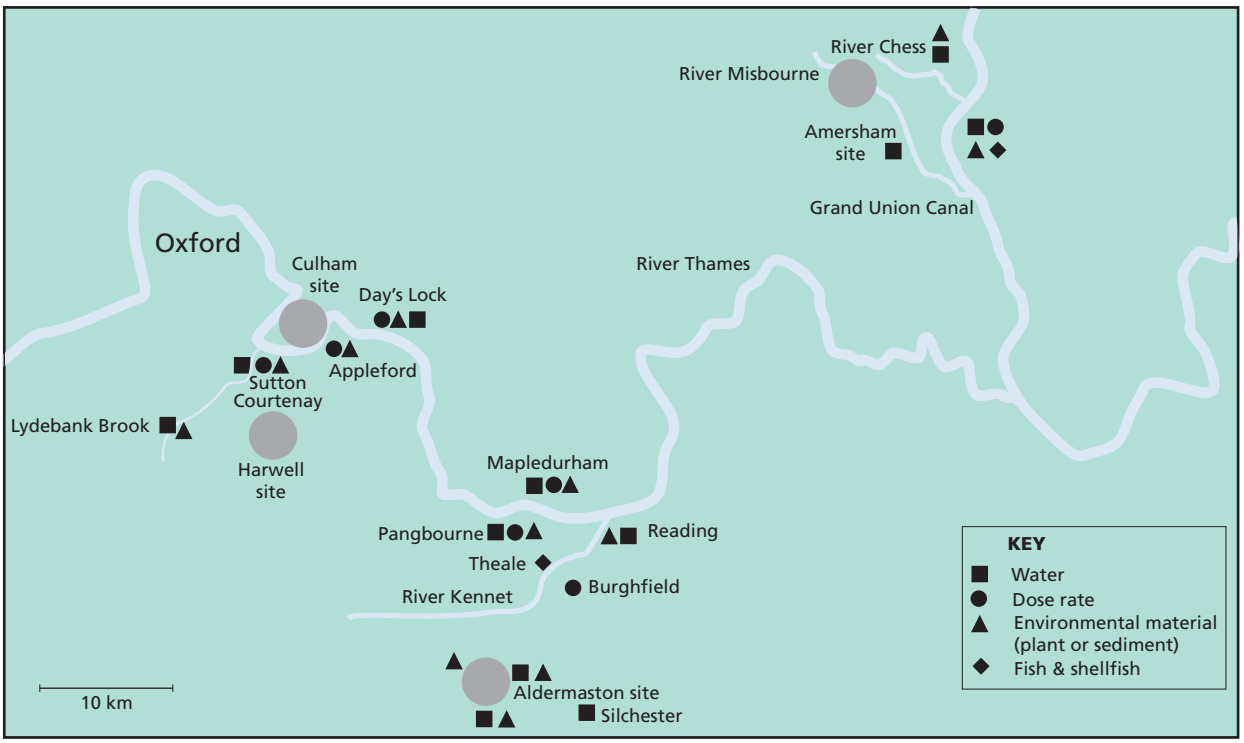


Figure 3.1. Monitoring locations at Thames sites (not including farms)

to a new site license company (Dounreay Site Restoration Limited, DSRL), before DSRL took over the site management contract. UKAEA and DSRL jointly applied on 30 July 2007 to transfer the RSA authorisations.

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. SEPA has 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.

In 2006 UKAEA applied to The Highland Council for planning permission for a Low Level Radioactive Waste Disposal facility adjacent to the site. SEPA is a statutory consultee to this application and during 2007 SEPA undertook assessment work to underpin the planning response. Significant new information from site characterisation work has resulted in UKAEA changing both the design and location from those in the original planning application. SEPA's Project Board established an External Advisory Group to provide independent comment and peer review of the project approach and processes used.

An inspection of UKAEA's decommissioning progress within various facilities across the Dounreay site was conducted in April 2007. No major obstacles to the decommissioning work or its progress were raised during the inspection.

In June 2007 SEPA was notified by UKAEA of the detection of radioactive contamination (including plutonium) in a surface water drain near to the Dounreay foreshore. UKAEA devised a programme of work to intercept the contaminated liquor and divert it to an authorised route and then to identify options to remediate the contaminated land that was believed to be the source of the contamination. The European Commission requested information about this event under the terms of Euratom Treaty Article 35 which requires each Member State to establish facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with the EU Basic Safety Standards Directive. SEPA provided its regulatory overview of this incident to the Scottish Government, which substantially formed the basis of the response sent to the EC.

SEPA conducted an inspection of UKAEA's system for the production of the facility level documents, which support and underpin the identification, segregation and consignment of solid radioactive waste. As a result of issues identified by SEPA, improvements to be made were issued in a Final Warning Letter to UKAEA in August 2007.

Work on grouting around the Dounreay Shaft, to isolate the 65 metre deep facility from the surrounding groundwater prior to being emptied, was carried out during 2007. The hydraulic restoration work was completed in Spring 2008.

The Dounreay Cementation Plant remained shut down during 2007 whilst the clean up continued for the spillage of raffinate which occurred in 2005. This has involved the use of remote handling techniques due to the high radiation levels.

Active commissioning of the bulk sodium/potassium (NaK) coolant disposal plant, including plant optimisation and in particular that of the ion exchange process, at the Dounreay Fast Reactor progressed during 2007.

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.

The sodium disposal plant, which closed for maintenance midway through 2006, re-started in early 2007, and continued to treat sodium removed from the Prototype Fast Reactor during 2007. The removal of the bulk primary sodium was completed in early 2008. SEPA had a quantity of sodium waste that had been declared non radioactive by UKAEA, sampled and analysed. This was undertaken as part of an investigation into the segregation and disposal of sodium waste at the Dounreay site. The results were below the limit of detection. Notwithstanding this, improvements to the management of solid waste were required by SEPA.

As previously reported in RIFE 12, in February 2007 UKAEA was found guilty at Wick Sheriff Court of allowing radioactive fuel fragments from Dounreay to enter the environment and for illegally dumping radioactive waste at a landfill on the site (Scottish Environment Protection Agency, 2007b).

In 2007, radioactive waste discharges from Dounreay were made by UKAEA under authorisations granted by SEPA. The quantities of both gaseous and liquid discharges in 2007 were generally similar to those in 2006 (Appendix 2). Sampling locations for the terrestrial and marine monitoring programme are shown in Figure 3.2.

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 2007 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 2007. The results for terrestrial samples and radioactivity in air are given in Table 3.3(a) and (c) and generally show low concentrations of radioactivity. Low concentrations of zinc-65, strontium-90, caesium-137, europium-155, uranium, plutonium and americium-241 were reported in samples. In 2007, slightly elevated concentrations of caesium-137 were found in lamb muscle, mushrooms and venison in comparison to recent years. The largest activity of caesium-137 was in venison (86 Bq kg^{-1}), samples of which had not been obtained in recent years.

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 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 (Table 3.3(a) and (b)) generally show low concentrations of radioactivity in 2007 and are generally similar to those for 2006. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield. Gamma dose rates measured over intertidal areas (see Table 3.3(b)) were similar to those measured in previous years, although slightly higher rates (including Sandside winkle bed, Melvich and Strathy) were measured in 2007 in comparison to values reported in 2006. Beta dose measurements were less than the LoD (Table 3.3(b)).

During 2007, UKAEA continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. At one of the beaches, monitoring for radioactive fragments is undertaken via an agreement between UKAEA Dounreay and the landowner. In 2007, access was periodically withdrawn and as a result monitoring was interrupted during the year.

Figure 3.2. Monitoring locations at Dounreay (not including farms)

* *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.*

In 2007, 27 fragments were recovered from Sandside Bay and 9 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 5.2 kBq and 500 kBq (similar to ranges observed in 2006).

In April 2007, during additional monitoring performed by UKAEA, one fragment was recovered from Murkle beach. The caesium-137 activity measured in this fragment was 13 kBq.

Following UKAEA's detection and removal of a buoyant radioactively contaminated plastic item on Sandside Beach (December 2006), SEPA undertook reassurance monitoring for the presence of radioactivity of the most recent strandline at Dunnet Bay on 20 February 2007 and the most recent strandline at Sandside Bay on 16 April 2007. No radioactivity was detected during this monitoring.

In 2005, UKAEA deployed a remotely operated survey vehicle to assist with demarcation of the extent of contamination of the marine environment. In 2007 (and 2006), further monitoring has taken place to provide more information on the extent of the contamination of the environment. Surveys undertaken by a remotely operated vehicle during 2007 identified 78 fragments on the offshore seabed, 5 of which were recovered.

The offshore work provided data on repopulation rates of particles to areas of the seabed previously cleared of particles. This work has improved the understanding of particle movements in the marine environment. The current state of knowledge is described in the DPAG's† Third Interim Report, published in November 2006, and is available on SEPA's website (Dounreay Particles Advisory Group, 2006). A Fourth Report is currently being drafted and it is anticipated that the report will be published after July 2008.

In 2007, the Food Standards Agency reviewed the risk associated with the particles, assessed as low, with a view to reviewing the FEPA order. The report, which has been peer-reviewed by HPA, has been passed to Food Standards Agency Scotland who are in the process of considering the broader policy aspects.

Doses to the public

The estimated dose from the consumption of local terrestrial foodstuffs, including a contribution due to weapon test fallout, was less than 0.047 mSv, which was less than 5 per cent of the annual dose limit of members of the public of 1 mSv. This includes a new assessment of the effects for non-food pathways from discharges to air. As in 2006, the critical age group was 1-year-old infants, as opposed to 10-year-old children in 2005. The apparent increase in dose to the critical group (less than 0.039 mSv in 2006) was attributable to increased LoDs for americium-241 and iodine-129 in goats' milk and potato samples, respectively. 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 four potential exposure pathways at Dounreay. Details are given in Appendix 1.

The first potential pathway involves the internal exposure of consumers of locally collected fish and shellfish. The estimated dose from consumption of fish and shellfish by high-rate consumers was 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 3.1).

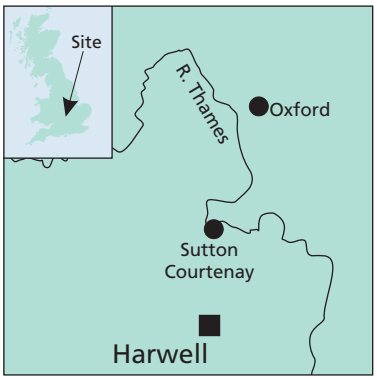
The second potential pathway relates to external exposure over local beaches. The radiation dose due to occupancy in such areas was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv. The increase from < 0.005 mSv in 2006 is most likely due to normal variability in the environment.

The third potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore. 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 fourth potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a 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 measurements was of no radiological significance.

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.059 mSv or approximately 6 per cent of the dose limit. This is an increase from 0.029 mSv in 2006, and was largely attributable to the inclusion of concentrations of caesium-137 in venison.

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. GE Healthcare occupies buildings in two small areas embedded

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

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. Discharges of radioactive wastes from Harwell continued in 2007 under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere.

The monitoring programme sampled milk, other terrestrial foodstuffs, freshwater fish, water and indicator materials together with measurements of gamma dose rates close to the liquid discharge point. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.1.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 3.4(a) and (b). Concentrations of caesium-137 were enhanced close to the outfall from liquid discharges at Sutton Courtenay but the levels were small in terms of any radiological effect. The concentrations of most radionuclides in flounder from the lower reaches of the Thames were below the LoD; only caesium-137 was positively detected. Concentrations of transuranic elements were similar to those in 2006.

A new habits survey was undertaken in September 2007. The predominant aquatic species consumed by critical groups were perch and signal crayfish. The occupancy by anglers of the riverbank was assessed to estimate their external exposures, which had decreased since the last survey in 1991. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1. Neither perch nor crayfish were sampled in 2007 and estimates of activity concentrations have been used from previous data for pike, taking recent variations in sediment concentrations into account. On this basis, and excluding a background dose rate of 0.06 μGy h^{-1}, the radiation dose to anglers in 2007 was 0.006 mSv, which was approximately 0.6 per cent of the dose limit for members of the public of 1 mSv (Table 3.1). The decrease in dose from 0.008 mSv in 2006 is attributed to the reduced occupancy rate on the riverbank. Thames river water is used as a source of drinking water. The annual dose from drinking River Thames water downstream of the discharge point was much less than 0.005 mSv.

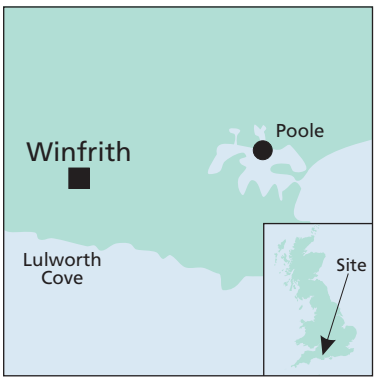
The results of tritium and gamma-ray spectrometry analyses of terrestrial food samples were all below detection limits. The estimated annual dose to the critical group for terrestrial food consumers was less than 0.005 mSv. In 2007, the maximum dose from non-food pathways arising from discharges to air was also assessed. After allowing for these pathways, using the methods and data given in Appendix 1, the critical group dose in 2007 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). In 2007, 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.

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. A new authorisation for Windscale came into force on 1st January 2006, which is more stringent but allows flexibility for decommissioning activities. 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. The 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



Discharges of radioactive wastes from this site continued in 2007, at the low rates typical of recent years. Liquid wastes are disposed of under authorisation to deep water in Weymouth Bay. Gaseous wastes are disposed of from various stacks on site.

The Environment Agency decided to grant revised variations to UKAEA and Waste Management Technology Limited (WMTL) and these came into effect on 23 March 2006 (Environment Agency, 2006e,f). UKAEA have applied to vary their existing authorisation to dispose of radioactive waste, to increase their tritium discharges, from the Winfrith site. The Environment Agency issued a decision document in December 2007 and issued a new certificate of authorisation with effect from January 2008.

The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and environmental materials. Sampling locations at Winfrith are shown in Figure 3.3. 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. The estimated annual dose to the critical group for terrestrial food consumers was less than 0.005 mSv. In 2007, the maximum dose from non-food pathways arising from discharges to air was also assessed. After allowing for radionuclides in air, using the methods and data given in Appendix 1, the critical group dose in 2007 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 2007 at much less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members 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 2007 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 is currently looking at the future of the Centre at Silwood Park, with a final decision whether to decommission the facility expected to be made in 2008 (Imperial College London, 2008).

In 2007, gaseous discharges were very low (similar to 2006) 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 2007 were either close to or less than the limits of detection.

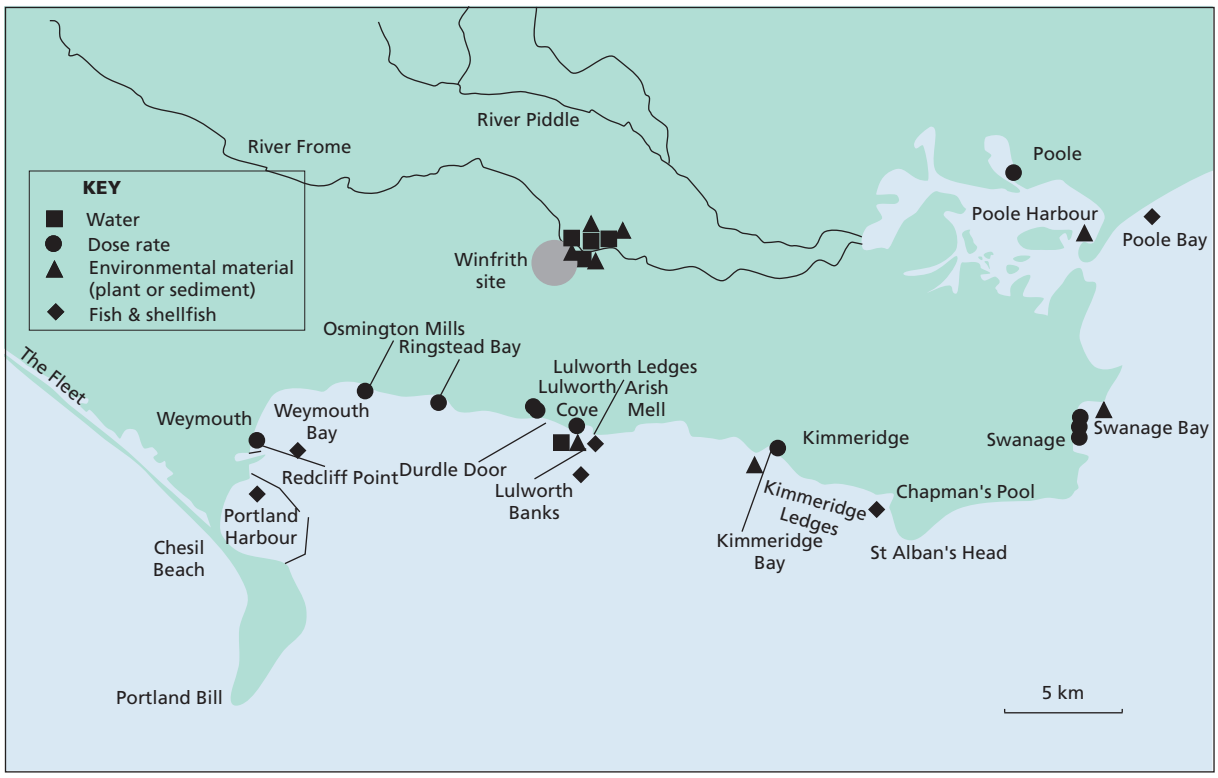


Figure 3.3. Monitoring locations at Winfrith (not including farms)

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 2007. In 2007, 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, 2007

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	<0.005	<0.005	-	-	-	-
	Beach occupants	0.006	-	-	0.006	-	-
	Geo occupants	<0.005	-	-	<0.005	-	-
	Inhabitants and consumers of locally grown food[b]	0.047	-	0.047	-	-	<0.005
	All sources[c]	0.059	-	-	-	-	-
Harwell	Anglers	0.006	<0.005	-	0.006	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	-	<0.005
	All sources[c]	0.026	-	-	-	-	-
Winfrith	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Inhabitants and 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*

Table 3.2. Concentrations of radionuclides in the environment near Culham, 2007

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				<0.24	<0.050	0.25
Freshwater	River Thames (downstream)	2	<4.0				<0.25	<0.055	0.23
Grass	1 km west of site perimeter	1	<25	45	4.7	<2.0	<1.4		95
Sediment	River Thames (upstream)	2					18		
Sediment	River Thames (downstream)	2					37		
Soil	1 km west of site perimeter	1	<25	<25	8.0	<1.0	4.5		300

[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, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb	^{99}Tc	^{125}Sb	^{137}Cs
Marine samples										
Crabs	Pipeline inner zone	4		<0.15	<0.71		<18	2.1	<0.38	<0.13
Crabs	Pipeline	4		<0.15	<0.61		<18		<0.36	<0.11
Crabs	Strathy	4		<0.11	<0.31		<0.79		<0.25	<0.14
Crabs	Kinlochbervie	4		<0.12	<0.27		<0.63	0.34	<0.22	<0.12
Crabs	Melvich Bay	4		<0.14	<0.35		<0.86	0.65	<0.29	<0.14
Winkles	Brims Ness	4		<0.13	<0.32	<0.10	<0.79		<0.27	<0.12
Winkles	Sandside Bay	4		<0.12	<0.30	<0.10	<0.56	5.0	<0.26	<0.15
Mussels	Echnaloch Bay	4		<0.10	<0.30		<0.47	14	<0.27	<0.11
Mussels	Thurso East Mains	4		<0.12	<0.28		<0.30		<0.26	0.35
Fucus vesiculosus	Kinlochbervie	4		<0.10	<0.19		<0.32	95	<0.15	0.33
Fucus vesiculosus	Brims Ness	4		<0.11	<0.27		<0.60		<0.19	0.19
Fucus vesiculosus	Sandside Bay	4		<0.12	<0.30		<0.52	140	<0.24	0.21
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.21		<0.51	35	<0.15	<0.12
Sediment	Oigins Geo	2		<0.12	<0.46		<0.47		<0.28	4.5
Sediment	Brims Ness	1		<0.10	<0.31		<0.41		<0.19	1.5
Sediment	Sandside Bay	1		<0.10	<0.23		<0.28		<0.16	2.8
Sediment	Rennibister	1		<0.10	<0.33		<0.26		<0.22	10
Seawater	Brims Ness	4	<1.0	<0.10	<0.14		<0.16		<0.15	<0.10
Seawater	Sandside Bay	4	<1.0	<0.10	<0.12		<0.11		<0.11	<0.10
Spume	Oigins Geo	2		1.1	<0.98		<1.4		<1.5	36

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	<0.18	<0.35	0.0029	0.016	0.020	3.6	78
Crabs	Pipeline	4	<0.16	<0.31			<0.15		
Crabs	Strathy	4	<0.13	<0.24	<0.00099	0.0030	0.053		
Crabs	Kinlochbervie	4	<0.12	<0.21	0.012	0.031	0.15		
Crabs	Melvich Bay	4	<0.15	<0.29	0.0025	0.0058	0.0076		
Winkles	Brims Ness	4	<0.21	<0.25	0.019	0.084	<0.18		
Winkles	Sandside Bay	4	<0.13	<0.24	0.030	0.12	0.19		
Mussels	Echnaloch Bay	4	<0.13	<0.24	0.043	0.21	0.019		
Mussels	Thurso East Mains	4	<0.13	<0.25	0.019	0.078	0.061		
Fucus vesiculosus	Kinlochbervie	4	<0.10	<0.15			<0.11		
Fucus vesiculosus	Brims Ness	4	<0.11	<0.19			<0.13	4.0	290
Fucus vesiculosus	Sandside Bay	4	<0.14	<0.26			0.27	<4.8	430
Fucus vesiculosus	Burwick Pier	4	<0.10	<0.16			<0.11		
Sediment	Oigins Geo	2	<0.21	1.3	3.0	13	6.8		
Sediment	Brims Ness	1	<0.10	0.42	1.5	4.8	6.2		
Sediment	Sandside Bay	1	0.33	<0.27	3.0	12	13		
Sediment	Rennibister	1	<0.15	1.3	0.71	0.67	0.78		
Seawater	Brims Ness	4	<0.10	<0.14			<0.11		
Seawater	Sandside Bay	4	<0.10	<0.11			<0.10		
Spume	Oigins Geo	2	<0.93	<1.4	11	48	44		

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	^{65}Zn	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{131}I	^{134}Cs
Terrestrial samples											
Beef muscle		1	<5.0	<0.05		<0.10	<0.13	<0.29			<0.04
Beef offal		1	<5.0	<0.05		<0.10	<0.18	<0.32	<0.77		<0.05
Blackberries		1	<5.0	<0.09		0.39	<0.53	<0.84		<0.10	<0.09
Cabbage		1	<5.0	<0.05		0.14	<0.22	<0.34		<0.08	<0.05
Goats' milk		1	<5.0	<0.06		<0.10	<1.8	<0.62		<0.05	<0.06
Lamb muscle		1	<5.0	<0.05		<0.10	<0.09	<0.24			<0.05
Mushrooms		1	<5.0	<0.08		<0.10	<0.32	<0.71	<2.3		<0.07
Oats		1	<5.0	<0.05		0.37	<0.16	<0.43		<0.07	<0.05
Potatoes		1	<5.0	<0.05		0.13	<0.12	<0.27	<0.55		<0.05
Red berries		1	<5.0	<0.05		1.0	<0.05	<0.22		<0.10	<0.05
Rosehips		1	<5.0	<0.05		0.84	<0.07	<0.33		<0.10	<0.05
Turnips		1	<5.0	<0.05		0.30	<0.19	<0.44	<0.33		<0.05
Venison		1	<5.0	<0.05		<0.10	<0.16	<0.43		<0.10	<0.05
Grass		6	<5.0	<0.05		0.55	<0.23	<0.35	<0.25	<0.07	<0.05
Grass	max					1.2	<0.40	<0.44	<0.32		
Soil		6	<5.1	<0.09	0.15	1.1	<0.33	<0.80	<2.7	<0.09	<0.10
Soil	max		<5.3	<0.14		1.6	<0.67	<1.3			<0.16

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{137}Cs	^{144}Ce	^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples											
Beef muscle		1	0.30	<0.20		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Beef offal		1	0.25	<0.20		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Blackberries		1	<0.09	<0.53							<0.050
Cabbage		1	<0.05	<0.24					<0.050	<0.050	<0.050
Goats' milk		1	0.05	<0.48							<0.10
Lamb muscle		1	12	<0.17		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Mushrooms		1	31	<0.50					<0.050	<0.050	<0.050
Oats		1	0.07	<0.31					<0.050	<0.050	<0.050
Potatoes		1	0.23	<0.18					<0.050	<0.050	<0.050
Red berries		1	0.13	<0.14					<0.050	<0.050	<0.050
Rosehips		1	0.39	<0.22					<0.050	<0.050	<0.050
Turnips		1	0.08	<0.30					<0.050	<0.050	<0.050
Venison		1	86	<0.33		<0.050	<0.050	<0.050	<0.050	<0.050	<0.13
Grass		6	<0.23	<0.24	0.14	0.27	<0.049	0.24	<0.050	<0.050	<0.054
Grass	max		0.59	<0.29		0.84	<0.050	0.81			0.071
Soil		6	28	<0.74	1.4	32	1.6	28	<0.055	0.43	0.29
Soil	max		46	<1.2	1.9	48	2.5	43	0.087	0.59	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, 2007

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	0.054
Sandside Bay	Winkle bed	2	0.11
Oigin's Geo	Spume/sludge	4	0.15
Brims Ness	Shingle and stones	2	0.11
Melvich	Salt Marsh	2	0.081
Melvich	Sand	2	0.061
Strathy	Sand	2	0.053
Thurso	Riverbank	2	0.067
Achreregan Hill	Soil	2	<0.045
Thurso Park	Soil	2	0.070
Borrowston Mains	Soil	2	0.077
East of Dounreay	Soil	2	0.078
Castletown Harbour	Sand	2	0.069
Dunnet	Sand	2	<0.048
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, 2007

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	12	<0.010	<0.0058	0.085
Reay	12	<0.010	<0.0059	0.068
Balmore	12	<0.010	<0.0066	0.10

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2007

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	<0.05	0.11	
Sediment	Appleford	4[E]		<0.37	12	<0.30
Sediment	Outfall (Sutton Courtenay)	4[E]		<1.5	18	<0.30
Sediment	Day's Lock	4[E]		<0.87	6.5	<0.50
Sediment	Lydebank Brook	4[E]		<0.64	7.3	<0.60
Freshwater	Day's Lock	4[E]	<4.0	<0.38	<0.31	
Freshwater	Lydebank Brook	4[E]	<4.5	<0.37	<0.30	
Freshwater	R Thames (above discharge point)	4[E]	<4.5	<0.31	<0.26	
Freshwater	R Thames (below discharge point)	4[E]	<4.0	<0.29	<0.24	

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		<0.05		
Sediment	Appleford	4[E]	0.41	1.5	190	360
Sediment	Outfall (Sutton Courtenay)	4[E]	0.83	3.1	240	360
Sediment	Day's Lock	4[E]	<0.30	2.3	<150	310
Sediment	Lydebank Brook	4[E]	1.6	1.3	160	350
Freshwater	Day's Lock	4[E]			<0.060	0.21
Freshwater	Lydebank Brook	4[E]			<0.048	0.14
Freshwater	R Thames (above discharge point)	4[E]			<0.055	0.16
Freshwater	R Thames (below discharge point)	4[E]			<0.055	0.23

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		3	<4.8	<5.0	<0.20
Milk	max		<5.0		
Apples		1	<4.0	<4.0	<0.20
Blackberries		1	4.0	6.0	<0.20
Cabbage		1	<4.0	<4.0	<0.20
Chard		1	<4.0	<4.0	<0.20
Honey		1		<7.0	<0.20
Potatoes		1	<5.0	<5.0	<0.30

[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 3.4(b). Monitoring of radiation dose rates near Harwell, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Mud and sand	1	0.069
Appleford	Mud and grass	1	0.057
Sutton Courtenay	Grass and mud	2	0.077
Day's Lock	Mud	1	0.069
Day's Lock	Grass and mud	1	0.059

Table 3.5 (a). Concentrations of radionuclides in food and the environment near Winfrith, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{14}C	^{60}Co	^{65}Zn	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples								
Plaice	Weymouth Bay	2		<0.06	<0.18		<0.06	
Bass	Weymouth Bay	2		<0.05	<0.16		0.18	
Crabs	Chapman's Pool	1		<0.09	<0.20		<0.06	0.00015
Crabs	Lulworth Banks	1	31	<0.05	<0.12		<0.04	0.000098
Pacific Oysters	Poole	1		<0.17	<0.49		<0.14	
Cockles	Poole	1		<0.13	<0.40		<0.10	
Whelks	Poole Bay	1		<0.07	<0.19		<0.05	0.00049
Whelks	Lyme Regis	1		<0.06	<0.19		<0.05	0.00021
Scallops	Lulworth Ledges	1		<0.04	<0.12		<0.04	0.00036
Clams	Portland Harbour	1		<0.13	<0.30		<0.10	
Seaweed	Lulworth Cove	1[E]		<1.2		<5.0	<0.82	
Seaweed	Bognor Rock	1[E]		<0.80		2.3	<0.60	
Sediment	Poole Harbour	1[E]		<0.18			<0.17	
Sediment	Weymouth	1[E]		<0.28			<0.22	
Sediment	Ringstead Bay	1[E]		<0.20			<0.19	
Sediment	Lulworth Cove	1[E]		<0.24			<0.22	
Sediment	Swanage Beach 1	1[E]		<0.25			<0.22	
Sediment	Swanage Beach 2	1[E]		<0.26			<0.21	
Sediment	Swanage Beach 3	1[E]		<0.27			<0.21	
Seawater	Lulworth Cove	1[E]		<0.47			<0.38	

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		<0.14				
Bass	Weymouth Bay	2		<0.05				
Crabs	Chapman's Pool	1	0.00078	0.0016	*	*		
Crabs	Lulworth Banks	1	0.00056	0.0010	*	0.000020		
Pacific Oysters	Poole	1		<0.12				
Cockles	Poole	1		<0.08				
Whelks	Poole Bay	1	0.0026	0.0035	*	0.000018		
Whelks	Lyme Regis	1	0.0016	0.0032	*	*		
Scallops	Lulworth Ledges	1	0.0023	0.0013	*	*		
Clams	Portland Harbour	1		<0.08				
Seaweed	Lulworth Cove	1[E]		<1.4				
Seaweed	Bognor Rock	1[E]		<0.84				
Sediment	Poole Harbour	1[E]					<100	<100
Sediment	Weymouth	1[E]					240	150
Sediment	Ringstead Bay	1[E]					100	120
Sediment	Lulworth Cove	1[E]					140	110
Sediment	Swanage Beach 1	1[E]					<100	<100
Sediment	Swanage Beach 2	1[E]					260	200
Sediment	Swanage Beach 3	1[E]					<100	130
Seawater	Lulworth Cove	1[E]		<0.50			<3.0	15

Table 3.5 (a). continued

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	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		4	<5.1	<5.1	16	<0.21		
Milk	max		<5.8	<5.8	17	<0.23		
Apples		1	<4.0	<4.0	13	<0.20		
Blackberries		1	<5.0	5.0	15	<0.20		
Chard		1	<6.0	6.0	11	<0.20		
Honey		1		<8.0	79	0.30		
Potatoes		1	<5.0	<5.0	15	<0.20		
Swede		1	<5.0	<5.0	5.0	<0.30		
Grass		2	<6.0	<6.0	19	<0.35		
Grass	max				22	0.50		
Sediment	North of site (Stream A)	1[E]				15	360	450
Sediment	R Frome (upstream)	1[E]				0.83	<100	280
Sediment	R Frome (downstream)	1[E]				2.5	190	170
Sediment	R Win, East of site	1[E]				<0.39	<100	110
Freshwater	North of site (Stream A)	2[E]		20		<0.32	<0.21	0.27
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.23	<0.12	<0.10
Freshwater	R Frome (downstream)	2[E]		<4.5		<0.26	<0.040	<0.11
Freshwater	R Win, East of site	2[E]		<4.5		<0.20	<0.15	0.20

* *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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand	1	0.052
Weymouth Bay	Sand and shingle	1	0.057
Red Cliffe Point to Black Head	Shingle	1	0.052
Osmington Mills	Stones	1	0.059
Ringstead Bay	Sand and shingle	2	0.052
Durdle Door	Shingle	1	0.049
St Oswald's Head	Shingle	1	0.051
Lulworth Cove	Sand and shingle	1	0.062
Lulworth Cove	Sand and stones	1	0.056
Kimmeridge Bay	Rock	1	0.079
Swanage Bay 1	Sand	2	0.052
Swanage Bay 2	Sand	2	0.052
Swanage Bay 3	Sand	2	0.052
Poole Harbour	Sand	1	0.048

4. Nuclear power stations

Key points

- Electricity production continued in 2007 at two Magnox stations – Oldbury and Wylfa and all the BE power stations. The remaining Magnox power stations were either decommissioning or defuelling
- Dungeness A and Sizewell A permanently shut down at the end of 2006
- Additional analysis conducted at Sizewell B due to failure of tritium and carbon-14 stack sampler
- 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

England

- The Environment Agency has completed a review of the authorisations for British Energy to dispose of radioactive wastes from their six nuclear power stations in England
- New authorisations in England were issued in April 2007 (at Dungeness B, Hartlepool, Heysham 1 & 2, Hinkley Point B, and Sizewell B)
- Discharges were similar to 2006 except at; Dungeness 'A', where carbon-14 and sulphur-35 gaseous discharges were reduced (argon-41 was zero), at Hinkley Point B, where sulphur-35 gaseous discharges were reduced and at Sizewell A, where tritium discharges increased slightly, but others were reduced (argon-41 was zero)
- Most recent surveys (2007) of local diet and occupancy habits at Berkeley, Oldbury and Bradwell included new data in assessments
- Concentrations and dose rates were generally similar to those in 2006
- Concentrations of carbon-14 were enhanced at Hartlepool due to factors other than power station operation (probably including non-nuclear industry discharges), concentrations of polonium-210 and lead-210 were lower in 2007
- Terrestrial food consumption assessment included other gaseous discharge pathways at all sites
- At Hinkley, dose from use of seaweeds as fertilisers and soil conditioners was assessed
- At Bradwell, seafood dose increased due to new habits occupancy information
- At Dungeness, dose from gaseous discharges decreased to less than 1 per cent of the dose limit due to reduced argon-41 releases
- At Hartlepool and Dungeness, seafood dose decreased to less than 4 per cent of the dose limit due to reduced natural concentrations
- At Hinkley Point, local fishermen dose decreased due to lower dose rates (but same dose rate as 2005)
- Doses from discharges (Table 4.1) were generally less than 1 per cent of dose limit and similar to 2006
- In 2007, new *total dose*s were estimated for Berkeley and Oldbury combined, and Bradwell
- At Dungeness and Sizewell, the *total dose* decreased due to cessation of Magnox power generation
- At most sites, *total dose*s from all sources were less than 6 per cent of the dose limit (Dungeness 28 per cent)

Scotland

- At Torness and Hunterston B, new authorisations came into force in 2007
- At Chapelcross and Hunterston A, applications to vary existing authorisation received
- At Chapelcross, 4 cooling towers successfully demolished as part of decommissioning
- At Chapelcross, fewer contaminated items of scale particulate (1) detected at the end of the liquid discharge pipe in 2007
- At Chapelcross, de-scaling of the pipeline commenced in 2007
- New survey of local diet and occupancy rates undertaken at Hunterston
- Discharges, concentrations and dose rates were generally similar to 2006
- Terrestrial food consumption assessment included other gaseous discharge pathways at all sites
- Doses from discharges (Table 4.1) were less than 3 per cent of dose limit and similar to 2006
- The *total dose*s from all sources were generally less than 2 per cent of the dose limit (Hunterston 9 per cent)

Wales

- Discharges, concentrations and dose rates were generally similar to 2006
- Terrestrial food consumption assessment included other gaseous discharge at both Trawsfynydd and Wylfa in 2007
- Doses from discharges (Table 4.1) were less than 1 per cent of dose limit and similar to 2006
- The *total dose*s from all sources were generally less than 2 per cent of the dose limit

This section considers the effects of discharges from nuclear power stations during 2007. There are a total of 19 nuclear power stations at 14 locations, nine in England (Berkeley, Oldbury, Bradwell, Calder Hall, Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell), two in Wales (Trawsfynydd and Wylfa) and three in Scotland (Chapelcross, Hunterston and Torness). Eleven of the 19 are older Magnox power stations now owned by the NDA. They are operated by Magnox Electric Limited on behalf of the owner, the NDA. Day-to-day operations (across two regions of UK reactor sites) are operated by Magnox North and Magnox South. From April 2005, the NDA was formed which 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 April 2007, the NDA published their Annual Plan, which summarizes the programme of work that they intend to deliver both within the NDA and at each of their sites during 2007/8 (Nuclear Decommissioning Authority, 2007).

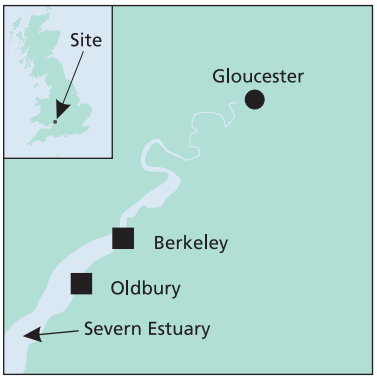
In 2007, only two of these Magnox stations (Oldbury and Wylfa) continued to generate electricity (others are in the process of decommissioning). Discharges from one of the Magnox stations (Calder Hall) are considered in Section 2 because it is located at Sellafield. British Energy Generation Limited and British Energy Generation (UK) Limited operated a fleet of seven advanced gas-cooled reactor (AGR) power stations and one pressurised water reactor (PWR) power station. All of these were generating electricity during 2007.

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 2007, 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 summarized 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. In 2007, new *total doses* were estimated for Berkeley and Oldbury combined, and Bradwell. 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 is the first commercial power station in the UK to be decommissioned, when it ceased electricity generation in March 1989. Decommissioning is still in progress and radioactive wastes are still generated by decommissioning operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples. The Oldbury Power Station, located on the south bank of the close to the village of , 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 power station is currently scheduled for closure in 2008. The potential for extended generation is being explored.

A habits survey was undertaken at the Berkeley and Oldbury sites in August/November 2007. The two potentially critical pathways for public radiation exposure in the aquatic environment were confirmed. Variations in consumption rates (fish and crustacean) and an increase in occupancy rates have been observed. The critical group remained as fish and shellfish consumers. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. The main focus for terrestrial sampling was on the tritium, carbon-14 and sulphur-35 content of milk, crops and fruit. Local surface freshwater samples were also analysed. Data for 2007 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.

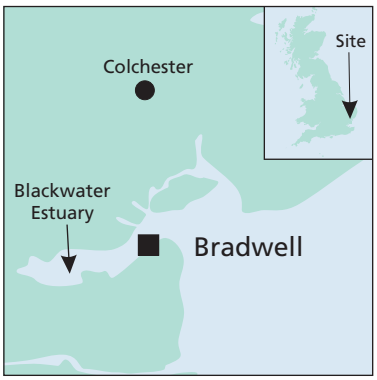
Liquid waste discharges and aquatic monitoring

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 2007 are presented in Tables 4.2(a) and (b). Where comparisons can be drawn, gamma dose rates and concentrations in the aquatic environment were generally similar to those in recent years. Most of the artificial radioactivity detected was due to tritium and radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have remained reasonably consistent for the last decade (Figure 4.1). Relatively high concentrations of tritium were detected in fish and shellfish and these were likely to be mainly due to discharges from GE Healthcare, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance.

Doses to the public

The estimated dose from consumption of terrestrial foodstuffs was less than 0.005 mSv. In 2007, the dose from non-food pathways arising from discharges to air was also assessed for Berkeley and Oldbury sites as less than 0.005 mSv. Taking both the pathways into account, the critical group dose in 2007 was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit. The total dose to the critical group of fish and shellfish consumers was estimated to be 0.018 mSv, which was less than 2 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). Recent trends in doses in the area of the Severn Estuary are shown in Figure 6.4. In 2007, the *total dose* (Berkeley and Oldbury combined) from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.061 mSv or approximately 6 per cent of the dose limit.

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. A habits survey was undertaken in June 2007. Significant decreases in the fish, crustacean and mollusc consumption rates have been observed in comparison with those of the previous survey in 1999. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1.

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 2007 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 was in excess of the WHO screening level of 1 Bq l^{-1} for drinking water. In 2007, more results of tritium concentrations in coastal ditches were available, and these were lower than the 2006 value and were 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 drinking water source.

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 2006, discharges were reduced, particularly for caesium-137 and other radionuclides. Measurements for

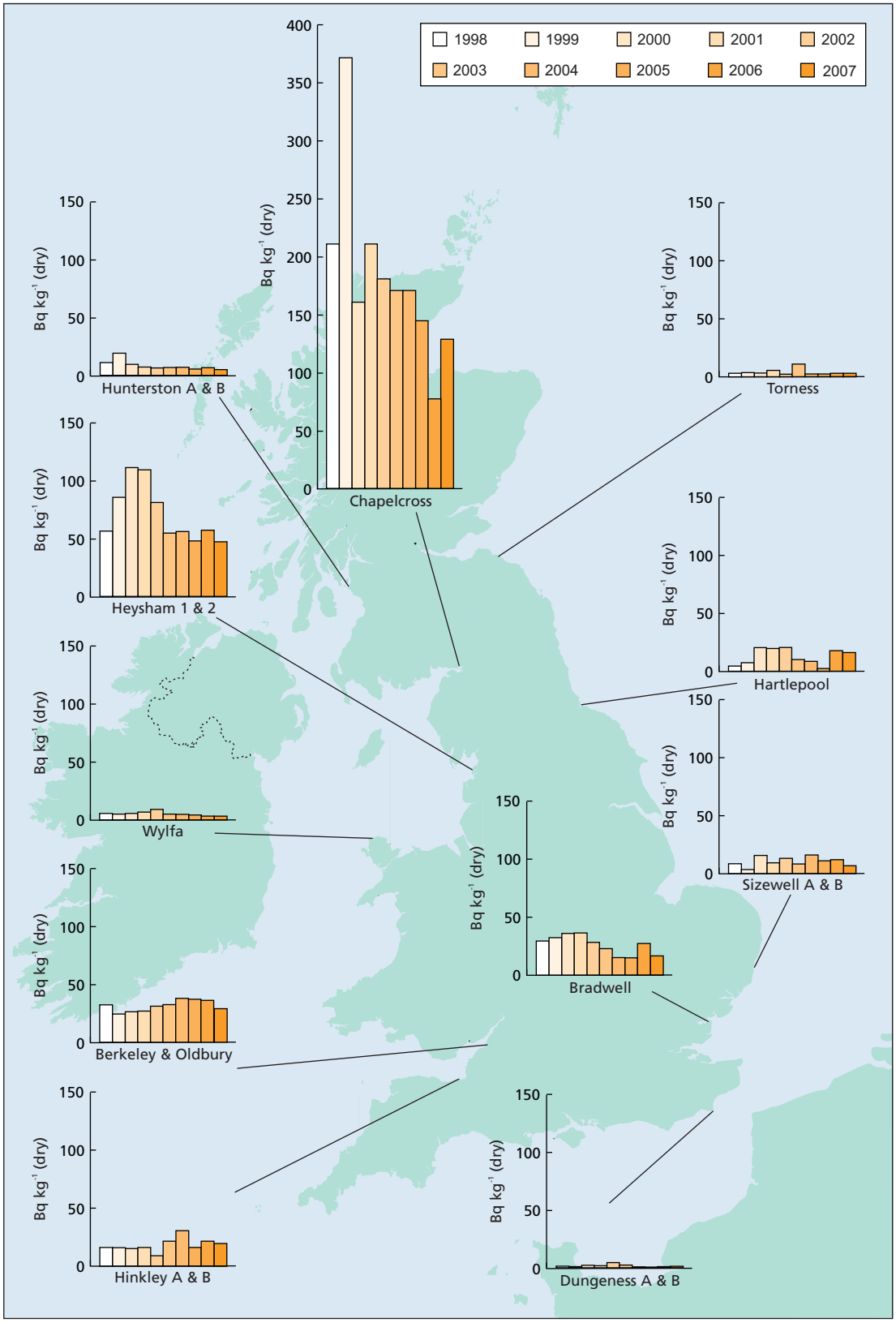


Figure 4.1. Caesium-137 concentration in marine sediments near nuclear power stations

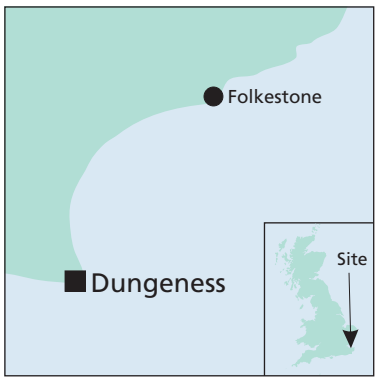
2007 are summarized in Tables 4.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were generally similar to those for 2006, however, there is evidence for a small decline in caesium-137 concentrations in biota from reduced discharges in 2007 (Table 4.3(a)), and overall decline in sediments in recent years (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 group of seafood consumers received 0.017 mSv, mostly due to the effects of external exposure, which was less than 2 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose was less in 2006, at 0.010 mSv. The increase in dose was attributed to the inclusion of the new habits information arising in an increase in external exposure from occupancy over mud. Occupancy at West Mersea was used in the assessment, being most active as the main mooring location for the commercial fishing boats and private yachts. The trend in marine doses at Bradwell and in the South East generally is shown in Figure 4.2. Prior to 2007, the variability in dose seen 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 2007, 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.

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. The Environment Agency has completed their review of the authorisations that allow British Energy to dispose of radioactive wastes from Dungeness B. New authorisation limits were effective from 1 April 2007 (Appendix 2). The most recent habits survey was conducted during 2005.

Gaseous discharges and terrestrial monitoring

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. Discharges of carbon-14 and sulphur-35 were reduced from Dungeness A, in comparison to releases in 2006. Concentrations of carbon-14 were generally within the range of observed background activity concentrations, but some enhancement was observed in peas. Low concentrations of tritium and sulphur-35 were detected in some samples. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. In January 2007, the site operators at Dungeness A reported that the weekly advisory levels had been exceeded for carbon-14. The Food Standards Agency did not carry out additional analyses as, at that time, the wind direction was out to sea.

Liquid waste discharges and aquatic monitoring

Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2007 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

The infant age group received the maximum dose due to gaseous disposals. Their dose in 2007 was estimated to be 0.006 mSv, which was less than 1 per cent of the dose limit for members of the public. This represents a large decrease in the dose in comparison to the value obtained in 2006 (13 per cent), in which the age group was adult. The decrease in dose is consistent with a reduction in gaseous argon-41 discharges from 1280 TBq (2006) to zero (2007) from Dungeness A. As in 2006, the contribution from the food consumption pathway was less than 0.005 mSv. For seafood consumers, local bait diggers who also eat fish and shellfish represented the critical group. Their radiation dose was 0.007 mSv, which was less than 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). The decrease in dose from 0.013 mSv (in 2006) was attributed to no gamma dose rate being measured at Rye Harbour in 2007 and the assessment using a lower dose rate at Rye Bay. The trend in

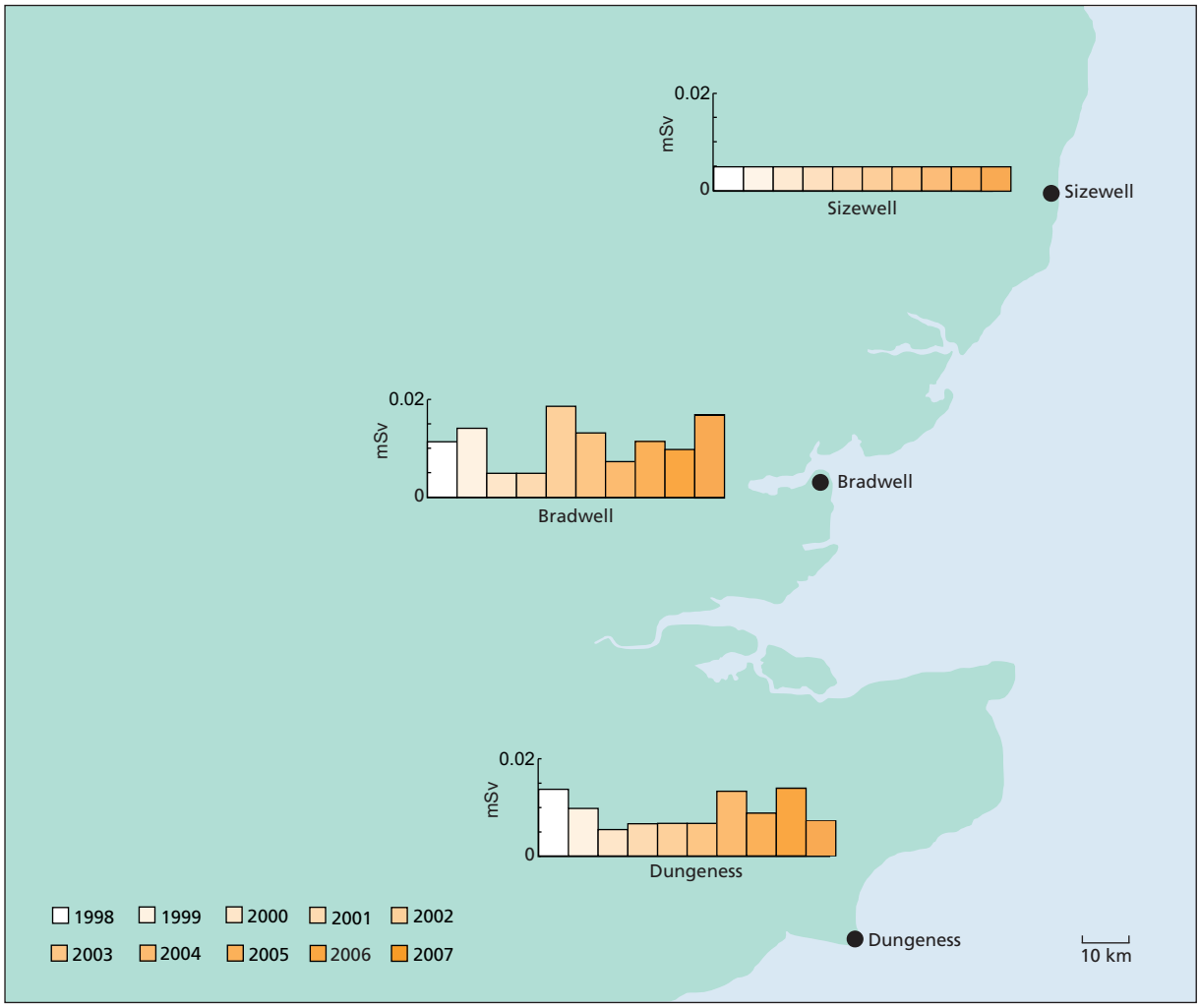


Figure 4.2. Individual radiation exposures from marine pathways for artificial radionuclides in South-east England, 1998-2007. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

marine doses at Dungeness and in the South East 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 2007, the external radiation dose for local houseboat occupants was estimated to be 0.007 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.28 mSv, or 28 per cent of the dose limit. The majority of the *total dose* was due to direct radiation from Dungeness A power station. This reduced significantly due to cessation of power generation (0.55 mSv in 2006)

4.4 Hartlepool, Cleveland

Hartlepool Power Station is situated on the mouth of the Tees estuary and is powered by twin AGRs. The Environment Agency has completed their review of the authorisations that allow British Energy Limited to dispose of radioactive wastes from Hartlepool. New authorisation limits were effective from 1 April 2007 (Appendix 2).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. 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 2007 are presented in Table 4.5(a). The effects of gaseous disposals from the site were 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 and the River Tees. The most recent habits survey (2002) established that exposures could be represented by consumption of local fish and shellfish and external irradiation whilst digging for bait. This will be reassessed during a habits survey in 2008. Technetium-99 analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield. As in 2006, a further assessment of polonium-210 was conducted to consider the possibility of local enhancement of naturally-occurring radionuclides from waste slag historically disposed of from the local iron and steel industries along parts of the River Tees.

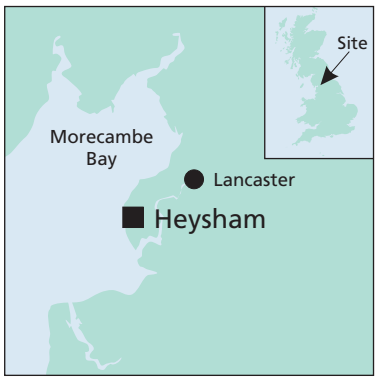
Results of the aquatic monitoring programme conducted in 2007 are shown in Tables 4.5(a) and (b). Tritium activity in seawater was slightly elevated in comparison to results in recent years and appears to have been due to water sampling being conducted following a discharge to sea. Concentrations of carbon-14 were enhanced above a background of approximately 25 Bq kg^{-1} expected for seafood (see Appendix 1). This is 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 2006 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 detected in seaweed around the bottom of the River Tees Estuary and this 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 2007, the levels of polonium-210 were lower than in 2006, and lead-210 in winkles were slightly lower and could not be distinguished from background levels (Table A4.1). The concentration of polonium-210 found in winkles from Paddy's Hole was 20 Bq kg^{-1} (23 Bq kg^{-1} in 2006) and was above that expected due to natural sources. These results are consistent with values for winkles from Paddy's Hole obtained from sampling and analysis undertaken in recent years. The dose rates at Paddy's Hole are also consistent with values measured in recent years. The enhanced levels at Paddy's Hole are believed to be due to a combination of waste slag from local iron and steel industries, used along the River Tees as sea defences, and/or the build up of naturally-occurring radionuclides in sediments at this location as the result of degradation of the sea defence materials over time. The critical occupancy group does not spend time at Paddy's Hole.

Doses to the public

As a result of the new authorisation, there is a now a gaseous discharge limit for cobalt-60, and data for this nuclide have been included in dose assessments. The dose from consumption of locally grown foodstuffs was estimated to be 0.006 mSv. In 2007, the dose from non-food pathways arising from discharges to air was also assessed. After allowing for discharges to air, using the methods and data given in Appendix 1, the critical group dose in 2007 was 0.006 mSv which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The apparent increase to the critical group (less than 0.005 mSv in 2006, from food consumption only) was largely attributable to increased LoDs for sulphur-35 in milk samples, and the inclusion of the LoD for cobalt-60 analysis in the assessments.

The radiation dose to local fish and shellfish consumers, including external radiation but excluding naturally-occurring radionuclides in seafood, was low, at less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). Paddy's Hole is unlikely to sustain a high rate consumption of winkles as it is a very localised area which contains oil and other wastes. In addition, the most recent habits survey undertaken (in 2002) did not identify any consumption of molluscs from Paddy's Hole. This pathway is being assessed in the 2008 habits survey, for future assessments. However, in the unlikely event that some of these molluscs did enter the diet of the critical group of fish and shellfish consumers, it is estimated that an additional dose from naturally-occurring radionuclides of 0.036 mSv would be received by this group in addition to that from artificial radionuclides. This estimate assumes that the median concentrations for naturally-occurring radionuclides at background (Appendix 1) should be subtracted from the total concentrations as measured in 2007. This represents a large decrease in the dose from naturally-occurring radionuclides, in comparison to the value obtained in 2006 (0.060 mSv), which is attributable to the decrease in polonium-210 and lead-210 concentrations in molluscs in 2007. There has been no significant trend in doses from marine pathways in recent years (Figure 4.3). 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.

4.5 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. Disposals of radioactive waste from both stations are made under authorisation via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. The Environment Agency has completed a review of the authorisations that allow British Energy to dispose of radioactive wastes from Heysham 1 and 2. New authorisation limits were effective from 1 April 2007 (Appendix 2). The most recent habits survey was undertaken in September 2006.

Gaseous discharges and terrestrial monitoring

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

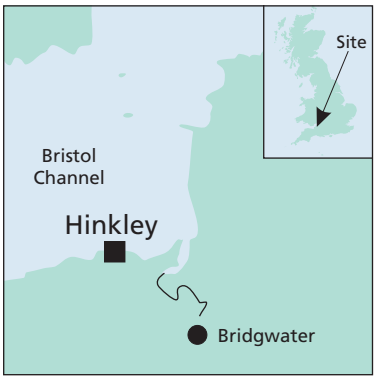
Liquid waste discharges and aquatic monitoring

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 2007 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2006 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in plaice and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at the higher levels typical of recent years, 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).

Doses to the public

As a result of the new authorisation, there now exists a gaseous discharge limit for cobalt-60, and data for this nuclide have been included in dose assessments. The estimated dose for terrestrial food consumers was 0.006 mSv. In 2007, the dose from non-food pathways arising from discharges to air was included. The dose was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The apparent increase to the critical group (less than 0.005 mSv in 2006, from food consumption only) was largely attributable to the inclusion of the LoD for cobalt-60 analysis in the assessments. The radiation dose in 2007 to the critical group of fishermen, including a component due to external radiation, was 0.037 mSv, which is less than 4 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This is a similar value to 2006, and a decrease compared with 0.063 mSv in 2005. The decrease in dose from 2005 was due to a reduction in mollusc consumption rate, and hence the contribution from americium-241. Trends in aquatic doses in the area of Northern England (and Wales and Southern Scotland) are shown in Figure 4.3. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.038 mSv or less than 4 per cent of the dose limit.

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 and the station began defuelling in 2002. Defuelling was complete in 2004. Environmental monitoring covers the effects of the two power stations together. The Environment Agency has completed their review of the authorisations that allow British Energy to dispose of radioactive wastes from Hinkley Point B. New authorisation limits were effective from 1 April 2007 (Appendix 2). The most recent habits survey was undertaken in 2006.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Discharges of sulphur-35 were reduced in comparison to releases in 2006. Analyses of milk,

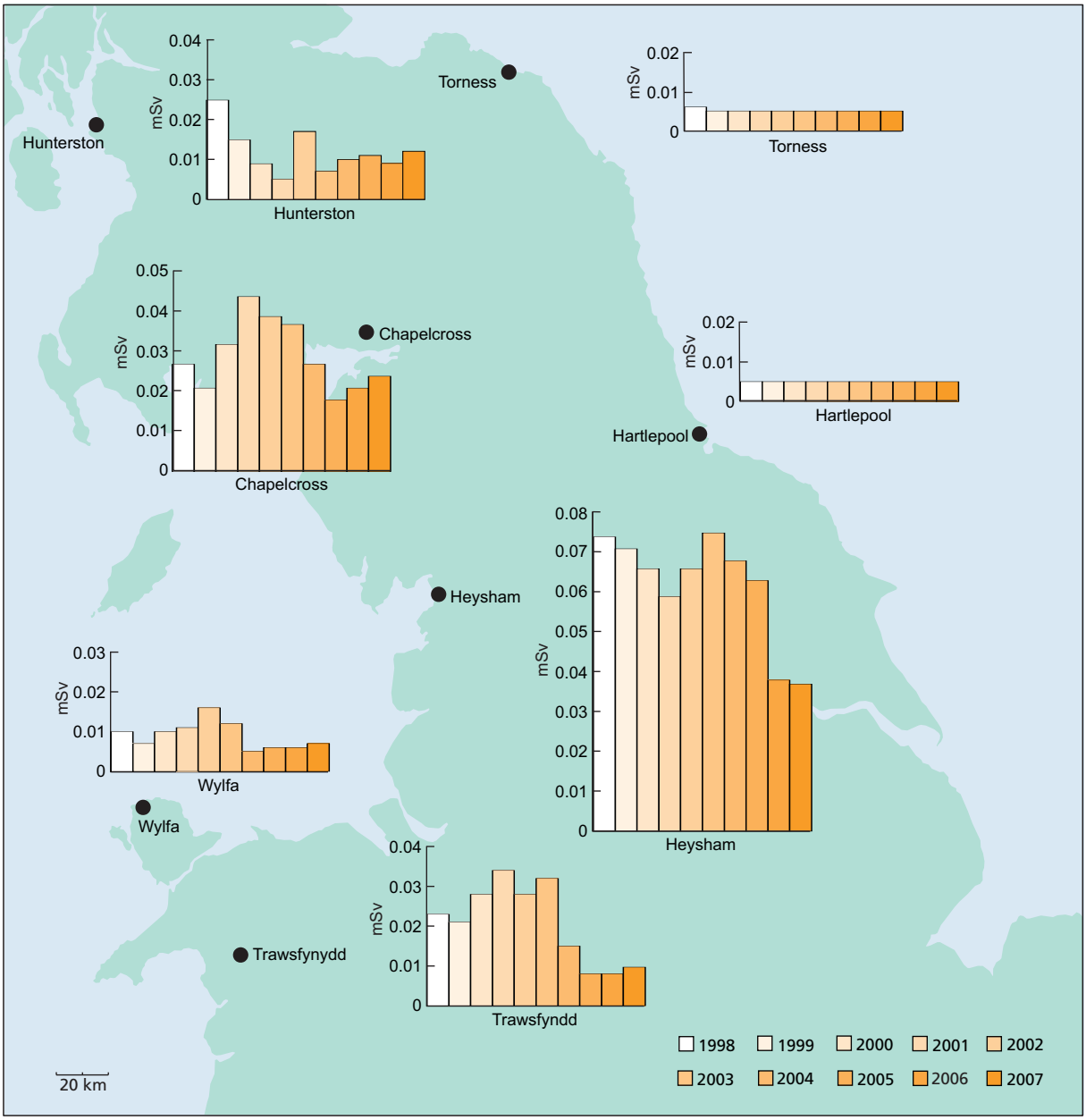


Figure 4.3. Individual radiation exposures at nuclear power stations from aquatic pathways for artificial radionuclides in Northern England and Wales, and Southern Scotland, 1998-2007. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

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. Data for 2007 are presented in Table 4.7(a). 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 reduced, in comparison to 2006, due to the lower 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. In 2007, the use of seaweeds as fertilisers and soil conditioners was assessed, to investigate transfer of radionuclides from sea to land. The results from vegetable and soil samples, to which seaweed or its compost, had been added, are shown in Table 2.13.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent from both power stations are made via a common cooling water outlet to 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 2007 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 2006 (see also Figure 4.1). Concentrations of tritium and carbon-14 in cod and shrimps were similar to their levels in 2006. Further information on tritium concentrations in seawater from the Bristol Channel

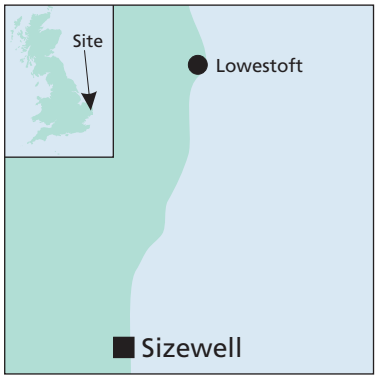
is given in Section 8. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl 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 2006. The rates at one location (Stolford) in 2006 were marginally decreased.

Doses to the public

The estimated dose for terrestrial food consumers was less than 0.005 mSv, including a component due to non-food pathways. This was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). In 2007, the use of seaweeds as fertilisers and soil conditioners was assessed. Assuming that high-rate vegetable consumers obtain all of their supplies from monitored plots near Hinkley, the dose in 2007 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 0.029 mSv, which was less than 3 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This 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 decrease in dose, from 0.040 mSv (in 2006), was due to a decrease in the slightly enhanced gamma dose rates 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**.** The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.035 mSv or less than 4 per cent of the dose limit. 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.

4.7 Sizewell, Suffolk



Sizewell power station is located on the Suffolk coast, near Leiston. At this location there are two stations. The 'A' station has two Magnox reactors whilst the 'B' station has a PWR. The 'B' station began operation in 1995. Sizewell A power station ceased to be an electricity generator on 31 December 2006 and is due to be decommissioned. The Environment Agency has completed their review of the authorisations that allow British Energy to dispose of radioactive wastes from Sizewell B. New authorisation limits were effective from 1 April 2007 (Appendix 2).

In July 2007, the site operators reported a tritium and carbon-14 sampler failure on one of the discharge stacks at Sizewell B. The Food Standards Agency undertook extra analyses of tritium and carbon-14 in samples of local milk but found no elevated concentrations of this radionuclide.

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. The results of the terrestrial monitoring in 2007 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 2007. Concentrations of activity in local freshwater were all low. In January 2007, the site operators at Sizewell A reported that the weekly advisory levels for carbon-14 had been exceeded. The Food Standards Agency did not carry out additional analyses as, at that time, the wind direction was out to sea.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent are made via outfalls to the North Sea. In the aquatic programme, analysis of seafood, sediment, sand and seawater, and measurements of gamma dose rates in intertidal areas were undertaken. Data for 2007 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 station is known to have had a local effect in recent years.

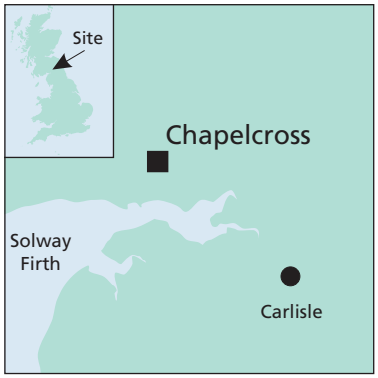
Doses to the public

The estimated dose from consumption of locally grown foodstuffs was less than 0.005 mSv. After making an allowance for non-food pathways using the methods and data in Appendix 1, the critical group dose for discharges to air in 2007 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. This represents a large decrease in the dose in comparison to the value obtained in 2006 (6 per cent of the dose limit). The decrease in dose is consistent with a reduction in gaseous argon-41 discharges from 2130 TBq (2006) to zero (2007) from Sizewell A. In 2007, 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 trend 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 less than 0.005 mSv or less than 0.5 per cent of the dose limit. This reduced due to cessation of power generation (0.091 mSv in 2006).

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 is expected to begin in the middle of 2008.

In October 2007, SEPA received an application from Magnox Electric Limited requesting variation of two existing authorisations. The variations are required in order to reflect the change of operator at Sellafield and the low level waste repository near Drigg in Cumbria and storage of authorisation records. SEPA has completed the consultation process and variation notices have been issued.

As part of the site's decommissioning programme, the station's four cooling towers were successfully demolished by controlled explosion in May 2007. The site collected a large number of samples from the cooling towers, before the towers were demolished, and analysis demonstrated that the resultant waste was not "radioactive waste" as defined by RSA 93. Samples were also taken by SEPA to assess tritium concentrations and provide a check on operator monitoring. Steel reinforcement bars were removed for recycling and the concrete was crushed and used to infill the cooling tower basements. A new Flask Handling Building has been constructed to allow the reactor cores to be safely defuelled.

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2005. This survey confirmed the existence of local fishermen who eat large quantities of local seafood and are also exposed to external radiation whilst tending stake nets. A further group was identified consisting of wildfowlers who were exposed to external radiation whilst on salt marshes. In 2007, a habits survey of consumption and occupancy, by members of the public, was completed on the Dumfries and Galloway coast. 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. The end of power generation at Chapelcross also brought an end to the discharge of the radioactive gas, argon-41, which was not discharged during 2007. Terrestrial monitoring was expanded in 2004 and a greater number of samples are now collected and analysed. A variety of foods, including milk, fruit and crops, as well as grass and soil samples, were measured for a range of radionuclides. Monitoring of air at three locations was added to the programme in 2001.

The results of terrestrial food and cooling tower samples, and air monitoring, in 2007 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 2006. The maximum concentration of tritium in milk decreased from 38 Bq l^{-1} in 2006 to 20 Bq l^{-1} in 2007, and is consistent with reported discharge values. The results for terrestrial foods show that the effects of discharges from Chapelcross can be seen in the concentrations of tritium and sulphur-35 in a range of foods. Measured concentrations of radioactivity in air samples, at locations near to the site, were very low.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent are discharged to the Solway Firth. Samples of seawater and *Fucus vesiculosus*, as useful environmental indicators, were collected in addition to seafood, sediments and dose rates. Data for 2007 are presented in Tables 4.9(a) and (b). 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. Slight reductions in concentrations of technetium-99 in biota were observed. In comparison to 2006 data, gamma dose rates slightly increased in some intertidal areas. Measurements of the contact beta dose-rate on fishing 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 Electric Limited monitor this area frequently. In 2007, a single particle with activity above background was detected during routine monitoring. However, it is suspected that this single particle was due to an earlier event (i.e. not associated with

2007 discharges). In comparison, 3 particles with activity above background were detected in 2006, with a total of 126 particles during the period 2000 to 2006. 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 Electric Limited and taken back to Chapelcross for analysis and appropriate disposal. SEPA conducted additional monitoring in the vicinity of the pipeline during 2005 and again in November 2006 and did not find any particles above background levels. During 2007 attempts were made to de-scale the inside the effluent pipeline. Approximately 4 tonnes of solid waste was removed from a section of the pipeline, but due to operational difficulties and a sustained period of very heavy rainfall, the adopted de-scaling technique was judged to be only partially successful. This has prevented returning the pipeline to full routine operation and as a consequence there has been a limited discharge of aqueous radioactive waste, together with increased accumulation of these wastes on site. Alternative methods that will prevent the discharge of contaminated particles from the pipeline are currently under review.

Doses to the public

The annual dose from terrestrial food consumption was estimated to be 0.021 mSv in 2007. The dose in 2006 was larger at 0.028 mSv. The decrease in dose was largely attributed to a lower LoD for sulphur-35 in milk, together with a reduced value for the maximum carbon-14 activity in milk. In 2007, the dose from non-food pathways arising from discharges to air was also assessed. Combining this with the food dose, the critical group dose from gaseous discharges in 2007 was 0.021 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 2007, this dose was mostly attributed to the consumption of local foodstuffs. The doses from consumption of terrestrial foods include contributions due to weapons testing and Chernobyl fallout. The dose to the critical group of fishermen who consume seafood and are exposed to external radiation over intertidal areas was 0.024 mSv in 2007, which was approximately 2 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from 0.021 mSv in 2006 was due to slight increases 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.

As in 2006, samples of wildfowl were monitored and an assessment has been undertaken to estimate the dose for consumers of wildfowl and their occupancy over salt marsh. The total exposure to wildfowlers including external dose was 0.008 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase from 0.006 mSv (in 2006) was due to slightly increased gamma dose rates in some intertidal areas. The dose from consumption of wildfowl was less than 0.005 mSv. The annual dose from inhaling air containing caesium-137 was estimated to be much less than 0.005 mSv. Trends in aquatic doses in the area of Southern Scotland (and Northern England and Wales) are shown in Figure 4.3. The reduction of the dose in 2004 was due to lower gamma dose rates reported from the re-calibration instruments. 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 0.019 mSv or, less than 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 and operated by British Energy, while Hunterston A is operated by Magnox Electric 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 the estimated decommissioning date of Hunterston B is 2016. Environmental monitoring in the area considers the effects of both sites together.

SEPA granted a new certificate of authorisation to British Energy for operations at Hunterston B in June 2007. In October 2007, SEPA received an application from Magnox Electric Limited requesting variation of an existing authorisation, for Hunterston A, to reflect the change of operator at the low level waste repository near Drigg in Cumbria. SEPA will vary the authorisation, as it considers appropriate, through notice served on the authorisation holder.

Two potential pathways have been identified in the recent habits survey: seafood consumers and terrestrial food consumers. The habits survey was undertaken in June/July 2007. Since the previous survey in 2001, consumption rates of fish, mollusc and crustacean rates increased, together with an increase in occupancy rates. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. 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 2007 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.

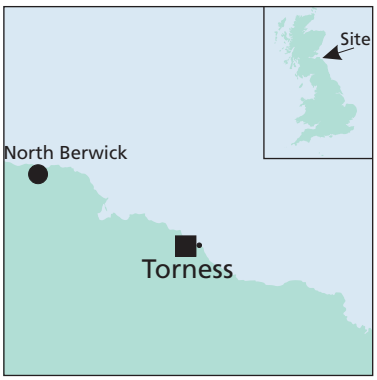
The results of aquatic monitoring in 2007 are shown in Tables 4.10(a) and (b). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs around Hunterston were similar to those in 2006. Technetium-99 concentrations in the common lobster continued to decrease in 2007. Small concentrations of activation products such as manganese-54 that are likely to have originated from the site were also detected but were of negligible radiological significance. Slight enhancements in gamma dose rates were observed at some monitoring sites in comparison to 2006.

Doses to the public

As in 2006, the estimated dose for consumption of terrestrial food, including a contribution due to weapon testing and Chernobyl fallout, was 0.023 mSv. This assessment included a relatively high LoD for strontium-90 in milk, compared to 2006, but excluded a contribution for americium-241 analysis (that was detectable in 2006, but not 2007). In 2007, the dose from non-food pathways arising from discharges to air was also assessed. Taking the food and non-food pathways together, the critical group dose in 2007 was 0.024 mSv which was less than 3 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. In 2007, the dose to the critical group from 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 4.1). This includes a contribution from the Sellafield-derived technetium-99 in shellfish and inclusion of the new habits data.

Trends in aquatic doses in the area of Southern Scotland (and Northern England and Wales) are shown in Figure 4.3. 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 0.090 mSv, or 9 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, came into operation at the end of 1987.

SEPA granted a new certificate of authorisation to British Energy for operations at Torness in June 2007. Unlike previous authorisations the new authorisation covers the discharge and disposal, as appropriate, of all types of radioactive waste.

The most recent habits survey was 2006. 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, fruit and crops, as well as grass and soil samples, were measured for a range of radionuclides. Air sampling was introduced in 2001 to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2007 are presented in Tables 4.11(a) and (c). The effects of discharges from the power station were observed in low concentrations of tritium and 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 2007 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges

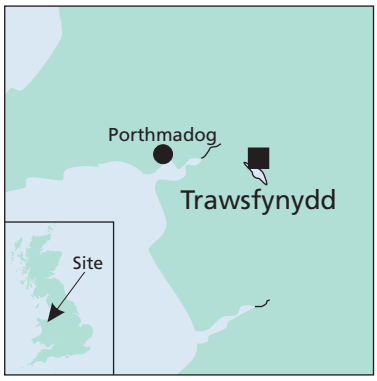
and to weapon testing and Chernobyl fallout. As in recent years, very low concentrations of activation products were detected which were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2006. Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates on beaches were generally indistinguishable from natural background and remained at similar levels to those detected in recent years.

Doses to the public

As a result of the new authorisation, there is a now a gaseous discharge limit for iodine-131, and data for this nuclide have been included in dose assessments. The estimated dose from terrestrial food consumption, including a contribution due to weapon testing and Chernobyl fallout, was 0.008 mSv. This represents a large decrease in the dose in comparison to the value obtained in 2006 (0.016 mSv). The decrease in dose was attributable to the exclusion of the LoD for americium-241 activity in food in the 2007 assessment. In line with the rules on use of results for dose calculations, americium-241 was not included because no detectable activity was observed in other samples from the terrestrial environment. In 2007, the dose from non-food pathways arising from discharges to air was also assessed. After allowing for the non-food pathways, using the methods and data given in Appendix 1, the critical group dose in 2007 was 0.008 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. The dose to fish and shellfish consumers (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). There has been no significant trend in doses from marine pathways in recent years (Figure 4.3). 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 2007 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.

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, including those for local milk, crops and animal samples, are shown in Tables 4.12 (a). Concentrations of activity in all terrestrial foods were low. Caesium-137 was detected in some of the terrestrial foods (apples, blackberries, eggs 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. The maximum concentration of total caesium in sheep muscle decreased from 10 Bq kg^{-1} in 2006 to 1.2 Bq kg^{-1} in 2007. 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 2007.

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 is directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. It is also directed at freshwater and sediment analysis. Habits surveys have established that species of fish regularly consumed are brown 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.

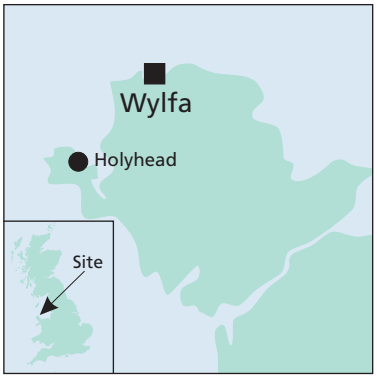
Data for 2007 are presented in Tables 4.12(a) and (b). Concentrations of radiocaesium in fish in 2007 were similar to those in 2006. The activity concentrations in sediments, and in the fish, that result from discharges from earlier years (and maintained in the water column by processes such as remobilisation) predominate at this stage. Low concentrations of other radionuclides including actinides are also detected, particularly in lake sediments (which increase with depth beneath the sediment surface). However, the actinide 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 2006. The predominant radionuclide is caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.4. A substantial decline in levels was observed in the late 1990s in line with reducing discharges (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007). Over the last decade, the observed levels now are mainly affected by sample variability.

Doses to the public

The critical group for terrestrial foods at Trawsfynydd in 2007 received doses of less than 0.005 mSv. The infant age group received the maximum dose from milk consumption. This represents a slight decrease in the dose in comparison to the value obtained in 2006 (0.007 mSv), in which the age group was adult, and was attributable to a reduction in the activity of total caesium in sheep muscle. The estimate includes consideration of the dose from non-food pathways arising from discharges to air. The dose 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 0.010 mSv in 2007, which was 1 per cent of the dose limit for members of the public of 1 mSv. The increase from the estimate of 0.008 mSv in 2006 was due to a slight increase in the observed concentrations in lake sediments. It is these that 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. Trends in doses in the area of Wales (and Northern England and Southern Scotland) are shown in Figure 4.3. The reduction of the dose in 2004 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 0.018 mSv or approximately 2 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.

Gaseous discharges and terrestrial monitoring

The main focus for terrestrial sampling was on the tritium, carbon-14 and sulphur-35 content of milk, crops and fruit. Local surface water samples were also taken and analysed.

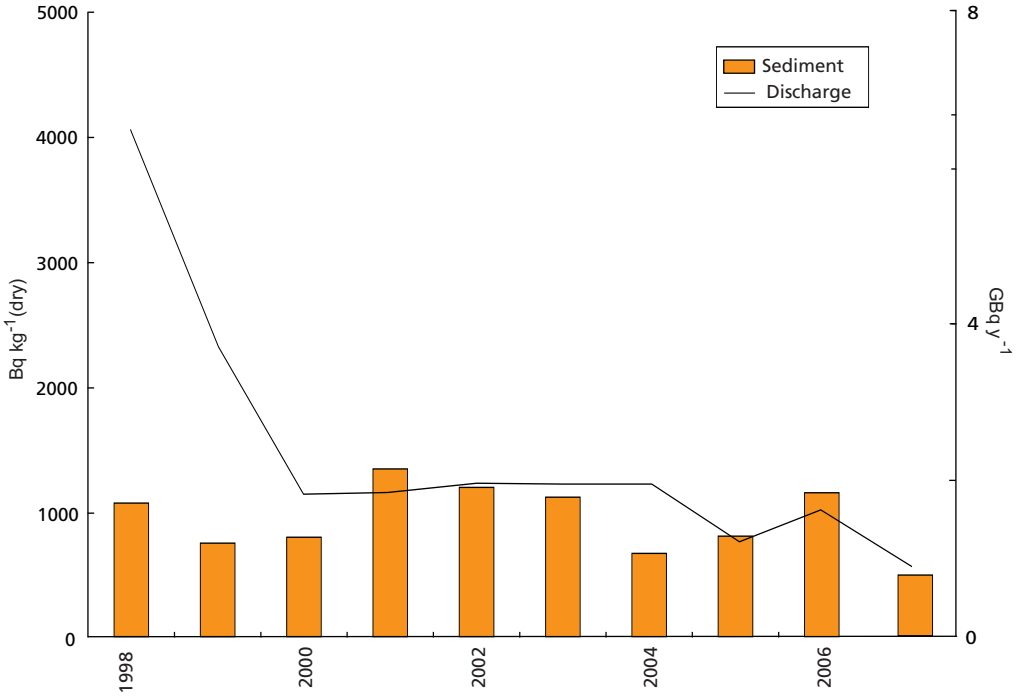


Figure 4.4. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

Data for 2007 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, but mostly at concentrations expected for background. 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.

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. The results of the programme in 2007 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 2006, and continued to show the effects of technetium-99 from Sellafield. Gamma dose rates, measured using portable instruments, were similar to those found in 2006.

Doses to the public

The dose received by terrestrial food consumption was less than 0.005 mSv. After allowing for radionuclide discharges to air, using the methods and data given in Appendix 1, the critical group dose in 2007 was also 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 high-rate fish and shellfish consumers 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). Trends in doses in the area of Wales (and Northern England and Southern Scotland) are shown in Figure 4.3. The reduction of the dose in 2004 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, 2007

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	0.018	<0.005	-	0.017	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[d]	0.061	-	-	-	-
Bradwell	Seafood consumers	0.017	<0.005	-	0.016	-
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005
	All sources[d]	0.070	-	-	-	-
Dungeness	Seafood consumers	0.007	<0.005	-	0.005	-
	Houseboat occupants	0.007	-	-	0.007	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	<0.005	-	<0.005
	All sources[d]	0.28	-	-	-	-
Hartlepool	Seafood consumers[c]	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	0.006	-	<0.005
	All sources[d]	0.021	-	-	-	-
Heysham	Seafood consumers	0.037	0.014	-	0.024	-
	Inhabitants and consumers of locally grown food[b]	0.006	-	<0.005	-	<0.005
	All sources[d]	0.038	-	-	-	-
Hinkley Point	Seafood consumers	0.029	<0.005	-	0.028	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[d]	0.035	-	-	-	-
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]	<0.005	-	-	-	-
Scotland						
Chapelcross	Seafood consumers	0.024	<0.005	-	0.022	-
	Wildfowlers	0.008	-	<0.005	0.007	-
	Inhabitants and consumers of locally grown food[b]	0.021	-	0.021	-	<0.005
	All sources[d]	0.019	-	-	-	-
Hunterston	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.024	-	0.023	-	<0.005
	All sources[d]	0.090	-	-	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.008	-	0.008	-	<0.005
	All sources[d]	0.022	-	-	-	-
Wales						
Trawsfynydd	Anglers	0.010	0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
	All sources[d]	0.018	-	-	-	-
Wylfa	Seafood consumers	0.007	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<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*

Table 4.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2007

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	<29			<0.07	0.18	
Bass	River Severn	1	510			0.25	2.7	
Grey mullet	River Severn	1	32			<0.06	0.79	
Elvers	River Severn	1	<25			<0.11	<0.09	
Shrimps	Guscar	2	300	35		0.10	0.51	0.00049
Seaweed	Pipeline	2[E]			<5.8	<1.0	<2.0	
Sediment	Hills Flats	2[E]				1.5	25	
Sediment	1 km south of Oldbury	2[E]				1.6	30	
Sediment	2 km south west of Berkeley	2[E]				1.9	41	
Sediment	Sharpness	2[E]				1.1	16	
Seawater	Local beach	2[E]				<0.32	<0.30	

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		<0.06				
Bass	River Severn	1		<0.10				
Grey mullet	River Severn	1		<0.05				
Elvers	River Severn	1		<0.08				
Shrimps	Guscar	2	0.0025	0.0027	0.000021	0.000028		
Seaweed	Pipeline	2[E]		<1.2				
Sediment	Hills Flats	2[E]		<1.6				
Sediment	1 km south of Oldbury	2[E]		<0.88				
Sediment	2 km south west of Berkeley	2[E]		<1.3				
Sediment	Sharpness	2[E]		<0.77				
Seawater	Local beach	2[E]		<0.37			<1.1	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	<5.2	16	<0.27	<0.20	<0.21		
Milk	max		<6.5	17	<0.38		<0.23		
Apples		1	<4.0	15	<0.20	<0.20	<0.30		
Blackberries		1	<4.0	18	<0.20	<0.20	<0.20		
Honey		1	<7.0	99	0.40	<0.20	<0.20		
Lettuce		1	<4.0	7.0	0.20	<0.20	<0.30		
Onions		1	<5.0	10	<0.20	<0.20	<0.20		
Potatoes		1	<4.0	18	0.60	<0.20	<0.20		
Runner beans		1	<4.0	10	<0.20	<0.30	<0.30		
Wheat		1	<6.0	88	1.4	<0.20	<0.20		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<1.0	<0.28	<0.25	<0.045	0.18
Freshwater	Public supply	2[E]	<4.5		<1.5	<0.27	<0.26	<0.050	<0.15

[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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Salt marsh and mud	2	0.092
2 km south west of Berkeley	Mud and rock	2	0.072
Guscar Rocks	Mud and salt marsh	1	0.077
Guscar Rocks	Mud and stones	1	0.082
Lydney Rocks	Mud and salt marsh	2	0.093
Sharpness	Salt marsh and mud	2	0.077
Hills Flats	Salt marsh and mud	2	0.087

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2007

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			<0.13	0.30		
Bass	Pipeline	1			<0.07	1.4		
Mullet	Pipeline	1			<0.07	0.36		
Lobsters	West Mersea	1			<0.07	0.24		
Native oysters	Tollesbury N. Channel	1			<0.07	0.11	0.00016	0.0011
Pacific oysters	Goldhanger Creek	2			<0.07	0.11		
Winkles	Pipeline	2			<0.19	<0.20		
Winkles	Heybridge Basin	2			<0.18	0.26		
Seaweed	Bradwell	2[E]		5.8	<0.76	<0.72		
Leaf beet	Tollesbury	1			<0.08	<0.06		
Samphire	Tollesbury	1			<0.06	0.19		
Sediment	Pipeline	2[E]	<2.5			6.1		
Sediment	Waterside	2[E]	<1.5			14		
Sediment	West Mersea Beach Huts	2[E]	<2.5			1.6		
Sediment	West Mersea 2	2[E]	<2.0			6.2		
Sediment	Maldon	2[E]	<2.0			51		
Sediment	N side Blackwater Estuary	2[E]	<2.5			23		
Seawater	Bradwell	2[E]			<0.31	<0.28		

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	<0.36				
Bass	Pipeline	1	<0.06				
Mullet	Pipeline	1	<0.26				
Lobsters	West Mersea	1	<0.27				
Native oysters	Tollesbury N. Channel	1	0.0020	0.00018	0.00012		
Pacific oysters	Goldhanger Creek	2	<0.05				
Winkles	Pipeline	2	<0.13				
Winkles	Heybridge Basin	2	<0.62				
Seaweed	Bradwell	2[E]	<0.78				
Leaf beet	Tollesbury	1	<0.05				
Samphire	Tollesbury	1	<0.11				
Sediment	Pipeline	2[E]	<0.82				
Sediment	Waterside	2[E]	<1.3				
Sediment	West Mersea Beach Huts	2[E]	<0.41				
Sediment	West Mersea 2	2[E]	<0.94				
Sediment	Maldon	2[E]	<2.5				
Sediment	N side Blackwater Estuary	2[E]	<0.62				
Seawater	Bradwell	2[E]	<0.36			<3.5	15

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			5	<4.6	16		<0.21		
Milk		max		<4.8	18		<0.23		
Apples			1	<4.0	15		<0.20		
Blackberries			1	<4.0	17		<0.20		
Cabbage			1	5.0	12		<0.20		
Carrots			1	<4.0	12		<0.20		
Lucerne			1	<4.0	7.0		<0.20		
Potatoes			1	<4.0	22		<0.20		
Rabbit			1	11	19		<0.20		
Wheat			1	<7.0	64		<0.20		
Freshwater	Public supply		2[E]	<4.0		<1.0	<0.29	<0.065	0.28
Freshwater	Coastal ditch 1		1[E]	<4.0		<2.0	<0.30	<0.90	4.4
Freshwater	Coastal ditch 2		1[E]	<4.0		<2.0	<0.21	<0.50	2.5
Freshwater	Coastal ditch 3		1[E]	15		<1.0	<0.21	<0.30	7.0
Freshwater	Coastal ditch 4		1[E]	19		<1.0	<0.32	<0.50	12

** Not detected by the method used*

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

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

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

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

Table 4.3(b). Monitoring of radiation dose rates near Bradwell, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and sand	1	0.074
Bradwell Beach	Sand and shingle	1	0.085
Beach opposite power station, N side of estuary	Mud	1	0.076
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.071
Waterside	Mud	1	0.068
Waterside	Mud and stones	1	0.068
Maldon	Mud	2	0.069
West Mersea Beach Huts	Sand	1	0.050
West Mersea Beach Huts	Sand and shingle	1	0.075
West Mersea	Sand	1	0.049
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, 2007

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									
Plaice	Pipeline	1	<25	<25		<0.05			0.11
Cod	Pipeline	2		<25		<0.05			0.20
Bass	Pipeline	1		<25		<0.06			0.43
Sole	Pipeline	1	<25	<25		<0.12			0.17
Crabs	Eastbourne / Folkestone landed	1				<0.06			<0.05
Shrimps	Pipeline	2	<25	<25	35	<0.17			<0.15
Scallops	Pipeline	2				<0.05	<0.030		<0.05
Sea kale	Dungeness Beach	1				<0.05			0.07
Seaweed	Copt Point	2[E]				<0.85		2.2	<0.64
Sediment	Rye Harbour 1	2[E]				<0.60			1.2
Sediment	Camber Sands	2[E]				<0.31			<0.38
Sediment	Pilot Sands	2[E]				<0.39			<0.40
Seawater	Dungeness South	2[E]		<5.0		<0.36			<0.28

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									
Plaice	Pipeline	1			<0.23				
Cod	Pipeline	2			<0.14				
Bass	Pipeline	1			<0.06				
Sole	Pipeline	1			<0.09				
Crabs	Eastbourne / Folkestone landed	1			<0.26				
Shrimps	Pipeline	2			<0.23				
Scallops	Pipeline	2	0.00043	0.0022	0.00065	0.00017	0.000023		
Sea kale	Dungeness Beach	1			<0.04				
Seaweed	Copt Point	2[E]			<0.81				
Sediment	Rye Harbour 1	2[E]			<0.78				660
Sediment	Camber Sands	2[E]			<0.36				
Sediment	Pilot Sands	2[E]			<0.42				
Seawater	Dungeness South	2[E]			<0.41			<3.5	13

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	<4.8	14	<0.20	<0.16	<0.21		
Milk		max		15		<0.20	<0.23		
Blackberries		1	<5.0	17	0.10	<0.20	<0.20		
Cabbage		1	<4.0	9.0	0.60	<0.20	<0.20		
Dried peas		1	21	82	3.0	<0.10	<0.30		
Potatoes		1	<5.0	19	<0.10	<0.20	<0.30		
Sea kale		1	<4.0	12	0.90	<0.20	<0.20		
Wheat		1	<8.0	86	1.4	<0.20	<0.20		
Grass		1				<0.40	0.30		
Freshwater	Long Pits	2[E]	<4.5		<1.5	<0.27	<0.23	<0.065	0.15
Freshwater	Pumping station Well number 1	1[E]	10		<1.0	<0.26	<0.21	<0.020	<0.087
Freshwater	Pumping station Well number 2	1[E]	<5.0		1.1	<0.40	<0.30	<0.040	0.11
Freshwater	Reservoir	2[E]	<4.5		<1.0	<0.35	<0.30	<0.050	<0.14

[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, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	1	0.066
Littlestone-on-Sea	Shingle	1	0.056
Greatstone-on-Sea	Sand	1	0.053
Greatstone-on-Sea	Sand and shingle	1	0.058
Dungeness East	Mud and shingle	1	0.064
Dungeness East	Sand and shingle	1	0.075
Dungeness South	Shingle	2	0.051
Jury's Gap	Shingle	2	0.052
Rye Bay	Sand and shingle	2	0.054

Table 4.5 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2007

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	31	<0.09		*
Cod	Pipeline	2				<0.05		*
Crabs	Pipeline	2			36	<0.05		*
Winkles	Paddy's Hole	1						
Winkles	South Gare	2	<25	<25		<0.05		*
Mussels	Seal Sands	2			190	<0.08		*
Seaweed	Pilot Station	2[E]				<1.3	42	55
Sediment	Old Town Basin	2[E]				<0.40		
Sediment	Seaton Carew	2[E]				<0.31		
Sediment	Paddy's Hole	2[E]				<0.66		
Sediment	North Gare	2[E]				<0.43		
Sediment	Greatham Creek	2[E]				<0.65		
Sea coal	Old Town Basin	2[E]				<0.47		
Sea coal	Carr House Sands	2[E]				<0.53		
Seawater	North Gare	2[E]		59		<0.29		

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	0.22				
Cod	Pipeline	2	0.28				
Crabs	Pipeline	2	0.09			0.00031	0.0021
Winkles	Paddy's Hole	1			20		
Winkles	South Gare	2	0.11	11	0.46	0.0042	0.026
Mussels	Seal Sands	2	<0.08				
Seaweed	Pilot Station	2[E]	<0.99				
Sediment	Old Town Basin	2[E]	2.5				
Sediment	Seaton Carew	2[E]	<0.25				
Sediment	Paddy's Hole	2[E]	15				
Sediment	North Gare	2[E]	<0.66				
Sediment	Greatham Creek	2[E]	3.5				
Sea coal	Old Town Basin	2[E]	<0.42				
Sea coal	Carr House Sands	2[E]	<2.0				
Seawater	North Gare	2[E]	<0.22				

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	<0.15				
Cod	Pipeline	2	<0.15				
Crabs	Pipeline	2	0.0017	*	*		
Winkles	Paddy's Hole	1					
Winkles	South Gare	2	0.018	*	0.000050		
Mussels	Seal Sands	2	<0.07				
Seaweed	Pilot Station	2[E]	<1.4				
Sediment	Old Town Basin	2[E]	<0.61				
Sediment	Seaton Carew	2[E]	<0.41				
Sediment	Paddy's Hole	2[E]	<1.0				
Sediment	North Gare	2[E]	<0.58				
Sediment	Greatham Creek	2[E]	<0.94				
Sea coal	Old Town Basin	2[E]	<0.64				
Sea coal	Carr House Sands	2[E]	<0.74				
Seawater	North Gare	2[E]	<0.29			<3.5	19

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	<0.89	<0.20	<0.20		
Milk	max		<6.3	17	<1.4	<0.23			
Apples		1	<4.0	11	<0.10	<0.20	0.20		
Beetroot		1	<5.0	11	<0.10	<0.30	<0.30		
Blackberries		1	<4.0	13	0.30	<0.20	<0.20		
Cabbage		1	<5.0	6.0	0.30	<0.20	<0.30		
Honey		1	<7.0	73	<0.10	<0.20	<0.20		
Potatoes		1	<5.0	19	0.20	<0.20	<0.30		
Runner beans		1	<4.0	6.0	<0.10	<0.10	<0.20		
Wheat		1	<8.0	96	0.80	<0.20	<0.30		
Freshwater	Public supply	1[E]	<4.0		<1.0	<0.25	<0.20	<0.020	<0.10
Freshwater	Borehole, Dalton Piercy	2[E]	<4.5		<1.0	<0.30	<0.27	<0.20	0.19

* *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, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.062
Fish Sands	Sand and sea coal	1	0.068
Old Town Basin	Mud and sand	2	0.066
Carr House	Sand	1	0.059
Carr House	Sea coal	1	0.060
Seaton Carew	Sand	1	0.065
Seaton Carew	Sand and pebbles	1	0.058
Seaton Sands	Sand	1	0.059
Seaton Sands	Sand and pebbles	1	0.062
North Gare	Sand	1	0.054
North Gare	Sand and pebbles	1	0.062
Paddy's Hole	Mud and pebbles	2	0.18
Greatham Creek Bird Hide	Salt marsh and mud	2	0.086

Table 4.6 (a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2007

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			64	<0.09			<1.1
Flounder	Morecambe	4	<32	35		<0.10	0.032	1.8	<1.1
Whiting	Morecambe	4				<0.09			<0.98
Bass	Morecambe	2				<0.09			<0.94
Whitebait	Sunderland Point	1				<0.08	0.069		<0.73
Shrimps	Flookburgh	4			66	<0.09		0.83	<0.81
Shrimps	Morecambe	2				<0.15			<1.7
Cockles	Middleton Sands	2				0.79			<0.54
Cockles[b]	Flookburgh	4			62	0.34	0.24	3.7	<0.66
Winkles	Red Nab Point	4				0.29			<0.79
Mussels	Morecambe	4	54	77	67	0.23		43	<0.71
Wild fowl	Morecambe	1				<0.08			<0.82
Samphire	Cockerham Marsh	1				<0.08			<0.86
Seaweed	Half Moon Bay	2[E]				<1.1		320	<6.2
Sediment	Half Moon Bay	2[E]				<0.65			
Sediment	Pott's Corner	2[E]				<0.57			
Sediment	Heysham pipelines	2[E]				<0.59			
Sediment	Morecambe Central Pier	2[E]				<0.99			
Sediment	Sunderland Point	4[E]				<0.94			<5.3
Sediment	Conder Green	4[E]				<0.73			<3.4
Sediment	Sand Gate Marsh	4[E]				<0.91			<4.0
Seawater	Heysham Harbour	1[E]		12		<0.39			<2.6

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	<0.30	<0.10	15	<0.29	0.00039	0.0023	
Flounder	Morecambe	4	<0.26	<0.11	7.6	<0.21			
Whiting	Morecambe	4	<0.22	<0.09	7.4	<0.16			
Bass	Morecambe	2	<0.24	<0.09	8.5	<0.20			
Whitebait	Sunderland Point	1	<0.20	<0.08	5.3	<0.20	0.038	0.28	2.8
Shrimps	Flookburgh	4	<0.23	<0.09	4.1	<0.22	0.0036	0.022	0.58
Shrimps	Morecambe	2	<0.38	<0.16	4.9	<0.36			
Cockles	Middleton Sands	2	0.43	<0.06	2.7	<0.14	0.33	1.9	
Cockles[b]	Flookburgh	4	<0.17	<0.07	3.7	<0.14	0.33	1.9	14
Winkles	Red Nab Point	4	0.46	<0.08	4.9	<0.18	0.28	1.7	
Mussels	Morecambe	4	0.33	<0.07	2.9	<0.15	0.41	2.4	
Wild fowl	Morecambe	1	<0.20	<0.09	1.2	<0.16			
Samphire	Cockerham Marsh	1	<0.19	<0.08	2.3	<0.18			
Seaweed	Half Moon Bay	2[E]	<5.2	<0.86	6.0				
Sediment	Half Moon Bay	2[E]			42				
Sediment	Pott's Corner	2[E]			30				
Sediment	Heysham pipelines	2[E]			23				
Sediment	Morecambe Central Pier	2[E]			92				
Sediment	Sunderland Point	4[E]	<5.4	<0.73	68	<2.7			
Sediment	Conder Green	4[E]	<4.0	<0.46	95	<1.3			
Sediment	Sand Gate Marsh	4[E]	<4.8	<0.49	160	<1.3			
Seawater	Half Moon Bay	1		*	0.14				
Seawater	Heysham Harbour	1[E]		<0.35	<0.33				

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	0.0049	*	*		
Flounder	Morecambe	4	<0.15				
Whiting	Morecambe	4	<0.10				
Bass	Morecambe	2	<0.15				
Whitebait	Sunderland Point	1	0.47	*	*		
Shrimps	Flookburgh	4	0.038	*	*		
Shrimps	Morecambe	2	<0.46				
Cockles	Middleton Sands	2	5.9	*	*		
Cockles[b]	Flookburgh	4	5.7	*	0.0074		
Winkles	Red Nab Point	4	3.3	0.0051	0.0032		
Mussels	Morecambe	4	3.9	*	0.0029		
Wild fowl	Morecambe	1	<0.09				
Samphire	Cockerham Marsh	1	1.3				47
Seaweed	Half Moon Bay	2[E]	<1.4				
Sediment	Half Moon Bay	2[E]	38				
Sediment	Pott's Corner	2[E]	17				
Sediment	Heysham pipelines	2[E]	22				
Sediment	Morecambe Central Pier	2[E]	77				
Sediment	Sunderland Point	4[E]	56			410	570
Sediment	Conder Green	4[E]	77			340	640
Sediment	Sand Gate Marsh	4[E]	100			410	570
Seawater	Half Moon Bay	1					
Seawater	Heysham Harbour	1[E]	<0.37			<0.020	13

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		6	<5.3	15	<0.43	<0.18	<0.22		
Milk	max		<5.8	18	<0.75	<0.20	<0.25		
Apples		1	<5.0	10	<0.10	<0.20	<0.30		
Barley		1	<7.0	65	1.3	<0.20	<0.20		
Blackberries		1	6.0	16	0.20	<0.20	<0.20		
Cabbage		1	<4.0	11	0.50	<0.30	<0.20		
Honey		1	<7.0	66	<0.10	<0.10	0.20		
Onions		1	<5.0	11	0.20	<0.20	<0.20		
Potatoes		1	<5.0	18	0.20	<0.20	<0.20		
Sprouts		1	<5.0	13	1.3	<0.30	<0.30		
Freshwater	Lancaster	2[E]	<4.0		<1.0	<0.31	<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 19 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, 2007

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	2	0.077
Sand Gate Marsh	Salt marsh	2	0.091
Sand Gate Marsh	Grass	2	0.087
High Foulshaw	Grass and mud	2	0.076
High Foulshaw	Grass	2	0.077
Arnside 1	Mud	1	0.084
Arnside 1	Mud and salt marsh	1	0.083
Arnside 1	Mud and sand	2	0.074
Arnside 2	Salt marsh	3	0.095
Arnside 2	Grass	1	0.092
Morecambe Central Pier	Mud and sand	1	0.074
Morecambe Central Pier	Pebbles and sand	1	0.073
Half Moon Bay	Mud and rock	1	0.076
Half Moon Bay	Sand	1	0.071
Heysham pipelines	Mud and rock	1	0.077
Heysham pipelines	Sand	1	0.078
Middleton Sands	Sand	1	0.075
Sunderland	Salt marsh	4	0.091
Sunderland Point	Mud	3	0.083
Sunderland Point	Mud and sand	1	0.089
Colloway Marsh	Salt marsh	3	0.12
Lancaster	Grass and mud	2	0.079
Lancaster	Grass	2	0.079
Aldcliffe Marsh	Mud	1	0.13
Aldcliffe Marsh	Salt marsh	3	0.10
Conder Green	Grass and mud	1	0.086
Conder Green	Salt marsh	3	0.088

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2007

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	77	110	29	<0.06	<0.07			<0.07
Bass	Stolford	1	61	86	33	<0.05	<0.05			0.06
Shrimps	Stolford	2	95	100	36	<0.11	<0.10			<0.10
Limpets	Stolford	1		52	22	<0.04	<0.04			<0.04
Sea lettuce	Stolford	1				<0.04	<0.03			<0.04
Fucus vesiculosus	Stolford	1				<0.05	<0.06			<0.06
Porphyra	Stolford	1				<0.07	<0.06			<0.07
Seaweed	Pipeline	2[E]					<1.1		15	<0.84
Beetroot	Stolford	1			9.5	<0.07	<0.07			<0.06
Parsnips	Stolford	1			22	<0.05	<0.05			<0.05
Soil	Stolford	1			10	<0.29	<0.23			<0.34
Mud	Watchet Harbour	2[E]					<0.52	<1.5		
Sediment	Pipeline	2[E]					<0.51	<3.0		
Sediment	Stolford	2[E]					<0.53	<2.0		
Sediment	Steart Flats	2[E]					<0.68	<1.5		1.1
Sediment	River Parrett	2[E]					<0.65	<2.0		1.2
Sediment	Weston-Super-Mare	2[E]					<0.37	<1.5		
Sediment	Burnham-On-Sea	2[E]					<0.36	<1.5		
Sediment	Kilve	2[E]					<0.56	<2.0		
Sediment	Blue Anchor Bay	2[E]					<0.38	<1.0		
Seawater	Pipeline	2[E]					<0.36	<0.050		<0.31

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	0.74			<0.07				
Bass	Stolford	1	1.8			<0.05				
Shrimps	Stolford	2	0.32	0.000063	0.00048	0.0016	*	*		
Limpets	Stolford	1	0.53			<0.05				
Sea lettuce	Stolford	1	1.1			<0.11				
Fucus vesiculosus	Stolford	1	0.66			<0.16				
Porphyra	Stolford	1	0.93			<0.30				
Seaweed	Pipeline	2[E]	<1.1			<1.0				
Beetroot	Stolford	1	<0.05			<0.05				
Parsnips	Stolford	1	<0.04			<0.05				
Soil	Stolford	1	6.8			<0.97				
Mud	Watchet Harbour	2[E]	7.8			<0.76				
Sediment	Pipeline	2[E]	10			<0.66				
Sediment	Stolford	2[E]	20			<1.1				
Sediment	Steart Flats	2[E]	17			<2.7				
Sediment	River Parrett	2[E]	31			<0.93				
Sediment	Weston-Super-Mare	2[E]	2.4			<0.49				
Sediment	Burnham-On-Sea	2[E]	2.1			<0.47				
Sediment	Kilve	2[E]	6.8			<1.2				
Sediment	Blue Anchor Bay	2[E]	2.4			<0.57				
Seawater	Pipeline	2[E]	<0.29			<0.36			<2.5	13

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	^{134}Cs	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<5.1	17	<0.30	<0.18	<0.20		
Milk	max		<5.8	19	<0.33	<0.20			
Apples		1	<5.0	12	<0.20	<0.20	<0.30		
Barley		1	10	90	<0.30	<0.20	<0.30		
Blackberries		1	<5.0	12	0.20	<0.20	<0.20		
Cabbage		1	<5.0	5.0	1.0	<0.20	<0.20		
Honey		1	<8.0	66	<0.20	<0.20	<0.20		
Onions		1	<5.0	15	0.30	<0.20	<0.20		
Potatoes		1	<5.0	10	<0.20	<0.20	<0.20		
Rhubarb		1	<4.0	13	<0.20	<0.20	<0.20		
Freshwater	Durleigh Reservoir	2[E]	<4.5		<1.0	<0.23	<0.22	<0.055	0.20
Freshwater	Ashford Reservoir	2[E]	<4.0		<1.0	<0.28	<0.26	<0.025	<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] *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 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Sand	4	0.064
Burnham	Sand	4	0.062
River Parrett	Mud and rock	4	0.081
Steart Flats	Mud	2	0.078
Steart Flats	Mud and sand	2	0.073
Stolford	Mud	1	0.095
Stolford	Mud and rock	3	0.085
Hinkley Point	Mud and rock	1	0.10
Hinkley Point	Pebbles and sand	3	0.095
Kilve	Rock and mud	3	0.091
Kilve	Pebbles and rock	1	0.070
Watchet Harbour	Rock and mud	1	0.11
Watchet Harbour	Pebbles and sand	1	0.098
Watchet Harbour	Rock and sand	2	0.10
Blue Anchor Bay	Mud and sand	2	0.076
Blue Anchor Bay	Pebbles and sand	2	0.069

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2007

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	0.31	
Sole	Sizewell	2	<25		<0.09	0.23	
Spurdog	Sizewell	1	<25		<0.04	0.38	
Crabs	Sizewell	2		48	<0.11	<0.13	0.00013
Lobsters	Sizewell	1			<0.05	0.26	0.00014
Native oysters	Blyth Estuary	1			<0.07	0.13	
Pacific oysters	Butley Creek	1			<0.08	<0.07	
Mussels	River Alde	2	<25		<0.11	<0.10	
Sediment	Rifle range	2[E]				<0.39	
Sediment	Aldeburgh	1[E]				<0.42	
Sediment	Southwold	2[E]				6.8	
Seawater	Sizewell	2[E]	<4.5		<0.26	<0.23	

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		<0.07				
Sole	Sizewell	2		<0.15				
Spurdog	Sizewell	1		<0.04				
Crabs	Sizewell	2	0.00076	0.00090	0.000028	0.000023		
Lobsters	Sizewell	1	0.00071	0.00091	*	0.000018		
Native oysters	Blyth Estuary	1		<0.05				
Pacific oysters	Butley Creek	1		<0.06				
Mussels	River Alde	2		<0.09				
Sediment	Rifle range	2[E]		<0.27				
Sediment	Aldeburgh	1[E]		<0.30				
Sediment	Southwold	2[E]		<1.4				770
Seawater	Sizewell	2[E]		<0.30			<3.3	16

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	<4.7	15	<0.31	<0.20		
Milk	max		<5.0	17	<0.38			
Milk[d]		2	<6.0	13				
Milk[e]		2	<5.0	13				
Milk[f]		2	6.5	18				
Apples		1	<4.0	15	<0.20	<0.30		
Barley		1	<7.0	83	1.2	<0.20		
Blackberries		1	<4.0	16	0.30	<0.20		
Cabbage		1	<5.0	<3.0	0.90	<0.20		
Honey		1	<7.0	58	<0.20	<0.20		
Onions		1	<4.0	4.0	0.40	<0.20		
Potatoes		1	<5.0	17	0.10	<0.20		
Rabbit		1	<5.0	22	3.1	<0.20		
Runner beans		1	<4.0	8.0	<0.20	<0.20		
Freshwater	Nature Reserve	2[E]	<4.0		<1.0	<0.25	<0.040	0.24
Freshwater	The Meare	2[E]	<4.5		<1.0	<0.28	<0.016	0.28
Freshwater	Leisure Park	2[E]	<4.5		<1.0	<0.23	<0.085	0.23

* *Not detected by the method used.*

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

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

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

[d] *Additional milk sampling week commencing 9 July 2007*

[e] *Additional milk sampling week commencing 16 July 2007*

[f] *Additional milk sampling week commencing 23 July 2007*

[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, 2007

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	0.054
Sizewell Beach	Sand	1	0.049
Dunwich	Sand and shingle	1	0.048
Dunwich	Shingle	1	0.056
Rifle Range	Sand and shingle	2	0.050
Aldeburgh	Shingle	2	0.051
Southwold Harbour	Mud	2	0.065

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2007

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	^{106}Ru
Marine samples									
Flounder	Inner Solway	4		60	<0.15	<0.38	<0.10	0.63	<1.3
Salmon	Inner Solway	1	<5.0		<0.23	<0.73			<2.4
Sea trout	Inner Solway	1	<5.0		<0.20	<0.70			<2.2
Shrimps	Inner Solway	2	<5.0		<0.10	<0.24	<0.10	2.4	<0.78
Cockles	North Solway	2[F,S]			1.4	<0.23	0.80		<0.75
Mussels	North Solway	5[F,S]	<5.5	<34	0.33	<0.18		61	<0.48
Winkles	Southerness	4	<5.7		0.53	<0.29	0.24	62	<0.95
Fucus vesiculosus	Pipeline	4			0.45	<0.18		750	<0.53
Fucus vesiculosus	Redkirk	4			0.37	<0.17			<0.51
Sediment	Pipeline	4	<7.3		2.5	<0.66			3.3
Sediment	Southerness	1			0.25	<0.29			<0.76
Seawater	Pipeline	4	2.2		<0.10	<0.15			<0.45
Seawater	Southerness	4	3.1		<0.10	<0.11			<0.36

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{110}mAg	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu
Marine samples									
Flounder	Inner Solway	4	<0.20	<0.37	<0.14	16	<0.18	<0.34	0.020
Salmon	Inner Solway	1	<0.27	<0.59	<0.24	<0.23	<0.29	0.52	
Sea trout	Inner Solway	1	<0.38	<0.52	<0.21	5.3	<0.23	<0.43	
Shrimps	Inner Solway	2	<0.13	<0.22	<0.10	4.1	<0.11	<0.20	0.0049
Cockles	North Solway	2[F,S]	<0.14	<0.43	<0.09	5.1	<0.15	<0.18	2.0
Mussels	North Solway	5[F,S]	<0.10	<0.31	<0.09	2.7	<0.11	<0.16	0.44
Winkles	Southerness	4	<0.15	<0.28	<0.11	1.6	<0.13	<0.25	0.20
Fucus vesiculosus	Pipeline	4	<0.10	<0.40	<0.10	15	<0.10	<0.36	6.9
Fucus vesiculosus	Redkirk	4	<0.10	<0.23	<0.10	12	<0.10	<0.22	
Sediment	Pipeline	4	<0.27	3.5	<0.20	240	<0.91	<1.1	22
Sediment	Southerness	1	<0.12	<0.18	<0.10	21	<0.17	0.59	3.6
Seawater	Pipeline	4	<0.10	<0.15	<0.10	<0.12	<0.10	<0.14	
Seawater	Southerness	4	<0.10	<0.11	<0.10	0.16	<0.10	<0.11	<0.00054

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									
Flounder	Inner Solway	4	0.097		0.092				
Salmon	Inner Solway	1			<0.31				
Sea trout	Inner Solway	1			<0.29				
Shrimps	Inner Solway	2	0.024		0.047				
Cockles	North Solway	2[F,S]	11	57	31	0.061	0.025		
Mussels	North Solway	5[F,S]	2.5	34	5.3				
Winkles	Southerness	4	1.0	3.0	2.2				
Fucus vesiculosus	Pipeline	4	34		6.4			27	420
Fucus vesiculosus	Redkirk	4			9.1			25	<210
Sediment	Pipeline	4	130		200				
Sediment	Southerness	1	15		26				
Seawater	Pipeline	4			<0.10				
Seawater	Southerness	4	<0.0015		<0.0028				

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	<8.2	<15	<0.57	<0.05	<0.12	<0.19
Milk		max		20	18	<0.61		<0.21	
Apples			1	14	<15	<0.50	<0.05	<0.10	<0.05
Barley			1	<5.0	86	<0.84	<0.05	0.11	<0.20
Blackberries			1	20	<15	<0.10	<0.07	0.16	<0.17
Cabbage			1	26	<15	<0.58	<0.07	0.085	<0.42
Carrots			1	47		<0.28	<0.06	0.230	<0.64
Crab Apples			1	<5.0	20	<0.50	<0.05	<0.10	<0.07
Hawthorn berries			1	<5.0	54	0.44	<0.05	0.33	<0.07
Honey			1	46	52		<0.05	2.1	<0.06
Mallard			1	<5.0	29		<0.08	0.18	<0.32
Pheasant			1	<5.0	28		<0.08	<0.10	<0.33
Potatoes			1	<5.0	16	<0.19	<0.05	<0.10	<0.13
Rosehips			1	44	44	<0.26	<0.19	1.1	<0.27
Teal			1	<5.0	27		<0.06	0.22	<0.23
Turnips			1	120		<0.75	<0.08	0.27	<0.95
Venison			1	<5.0	25	<0.98	<0.06	<0.10	<0.15
Widgeon			1	<5.0	21		0.10	<0.10	<0.51
Grass			4	<530	<15	<0.72	<0.05	<0.20	<0.14
Grass		max		1200		1.5		0.40	<0.28
Soil			4	<8.7	<16	<2.4	<0.08	1.1	<0.57
Soil		max		17	<18	<3.3	<0.10	1.9	<0.83
Concrete - cooling tower 1	20m above ground		3	36					
Concrete - cooling tower 1	40m above ground		3	49					
Concrete - cooling tower 2	20m above ground		3	42					
Concrete - cooling tower 2	40m above ground		3	48					
Concrete - cooling tower 3	20m above ground		3	42					
Concrete - cooling tower 3	40m above ground		3	61					
Concrete - cooling tower 4	20m above ground		3	42					
Concrete - cooling tower 4	40m above ground		3	42					

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{137}Cs	^{155}Eu	^{241}Am	Gross Alpha	Gross Beta
Terrestrial samples								
Milk			12	<0.05		<0.05		
Milk		max				<0.07		
Apples			1	<0.05		<0.06		
Barley			1	<0.05		<0.10		
Blackberries			1	<0.06		<0.07		
Cabbage			1	<0.06		<0.09		
Carrots			1	0.15		<0.08		
Crab Apples			1	<0.05		<0.12		
Hawthorn berries			1	<0.05		<0.13		
Honey			1	<0.05		<0.15		
Mallard			1	0.11		<0.10		
Pheasant			1	0.37		<0.11		
Potatoes			1	0.05		<0.09		
Rosehips			1	<0.19		<0.28		
Teal			1	1.3		<0.08		
Turnips			1	<0.08		<0.12		
Venison			1	2.3		<0.14		
Widgeon			1	0.16		<0.16		
Grass			4	<0.13		<0.11	<7.7	320
Grass		max		0.18		0.18	12	370
Soil			4	13	1.2	<0.34	240	990
Soil		max		18	1.3	<0.40	300	1100

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

Table 4.9(b). Monitoring of radiation dose rates near Chapelcross, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.066
Glencaple Harbour	Mud and sand	4	0.085
Priestside Bank	Salt marsh	4	0.061
Powfoot Merse	Mud	4	0.079
Pipeline	Sand	4	0.091
Pipeline	Salt marsh	4	0.090
Battlehill	Sand	4	0.070
Dornoch Brow	Mud and sand	4	0.085
Dornoch Brow	Salt marsh	4	0.079
Browhouses	NA	4	0.077
Redkirk	NA	4	0.068
Mean beta dose rates			µSv h^{-1}
Pipeline 500m east	NA	4	<1.0
Pipeline 500m west	NA	4	<1.0
Pipeline	Stake nets	3	<1.0

NA *Not available*

Table 4.9(c). Radioactivity in air near Chapelcross, 2007

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.010	<0.0066	0.15
Kirtlebridge	11	<0.011	<0.0073	0.15
Brydekirk	12	<0.010	<0.0076	0.16

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{54}Mn	^{58}Co	^{60}Co	^{90}Sr	^{99}Tc	^{110m}Ag
Marine samples									
Cod	Millport	2		<0.10	<0.15	<0.10			<0.10
Hake	Millport	2		<0.16	<0.33	<0.15			<0.19
Crabs	Millport	2		<0.17	<0.31	<0.17		8.5	<0.18
Nephrops	Millport	2		<0.10	<0.13	<0.10			<0.10
Lobsters	Largs	1		<0.10	<0.10	<0.10		57	<0.10
Squat lobsters	Largs	3		<0.10	<0.13	<0.10	<0.10	2.9	<0.10
Winkles	Pipeline	2		0.45	<0.23	<0.28			0.31
Scallops	Largs	4		<0.11	<0.15	<0.12			<0.11
Oysters	Hunterston	1		<0.10	<0.16	<0.10			<0.10
Fucus vesiculosus	N of pipeline	2		0.71	<0.12	0.19			<0.10
Fucus vesiculosus	S of pipeline	2		1.4	<0.13	<0.31			<0.10
Sediment	Fairlie	1		<0.10	<0.15	<0.10			<0.11
Sediment	Millport	1		<0.10	<0.10	<0.10			<0.10
Sediment	Gull's Walk	1		<0.10	<0.10	0.81			<0.10
Sediment	Ardneil Bay	1		<0.10	<0.10	<0.10			<0.10
Seawater	Pipeline	2	2.2						

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{125}Sb	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine samples									
Cod	Millport	2	<0.16	1.7	<0.40	<0.19			<0.17
Hake	Millport	2	<0.29	2.3	<0.73	<0.27			<0.19
Crabs	Millport	2	<0.32	0.41	<0.77	<0.33	<0.0040	0.0075	0.0070
Nephrops	Millport	2	<0.34	0.62	<0.27	<0.14			<0.15
Lobsters	Largs	1	<0.10	0.32	<0.21	<0.10			<0.10
Squat lobsters	Largs	3	<0.16	0.35	<0.33	<0.16	0.0045	0.022	0.0091
Winkles	Pipeline	2	<0.36	0.42	<0.78	<0.33	0.023	0.11	0.025
Scallops	Largs	4	<0.21	0.44	<0.47	<0.22	<0.00084	0.011	0.0064
Oysters	Hunterston	1	<0.20	0.29	<0.44	<0.19			<0.11
Fucus vesiculosus	N of pipeline	2	<0.10	0.94	<0.28	<0.13			<0.10
Fucus vesiculosus	S of pipeline	2	<0.15	0.61	<0.31	<0.14			<0.11
Sediment	Fairlie	1	<0.33	8.1	<0.60	<0.30			<0.28
Sediment	Millport	1	<0.10	3.8	<0.29	<0.15			0.21
Sediment	Gull's Walk	1	0.39	6.3	<0.39	<0.12			0.61
Sediment	Ardneil Bay	1	<0.10	2.8	<0.28	0.39			0.13

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	<5.0	<15	<0.60	<0.05	<0.25	<0.20
Milk	max				<0.61		<0.65	<0.22
Beetroot		1	<5.0	<15	<0.10	<0.08	<0.10	<0.48
Boar		1	<5.0	16		<0.20	<0.10	<0.90
Carrots		1	<5.0	<15	<0.50	<0.05	0.13	<0.09
Crab apples		1	<5.0	16	<0.06	<0.23	0.15	<0.94
Curly kale		1	<5.0	<15	<0.91	<0.07	0.16	<0.19
Eggs		1	<5.0	24	<0.73	<0.05	<0.10	<0.05
Hawthorn berries		1	<5.0	55	<0.27	<0.25	0.13	<0.86
Honey		1	<5.0	82		<0.05	<1.3	<0.06
Leeks		1	<5.0	<15	<0.20	<0.05	<0.10	<0.15
Potatoes		1	<5.0	17	<0.49	<0.05	<0.10	<0.11
Rabbit		3	<5.0	<21	<1.0	<0.06	<0.11	<0.95
Rabbit	max			28	<1.4	<0.08	0.13	<1.4
Rosehips		1	<5.0	27	<0.15	<0.05	1.6	<0.07
Turnips		1	<5.0	<15	<0.27	<0.07	0.26	<0.28
Wild berries		1	<5.0	<15	<0.10	<0.05	0.58	<0.24
Grass		3	<5.0	<18	<1.2	<0.05	0.50	<0.14
Grass	max			24	2.0	<0.06	0.88	<0.20
Soil		3	<5.0	<15	<1.8	<0.11	1.2	<0.97
Soil	max				<2.1	<0.14	1.7	<1.1

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	<0.09		<0.05		
Milk	max			<0.26		<0.06		
Beetroot		1	<0.08	<0.07		<0.11		
Boar		1	<0.21	<0.20		<0.26		
Carrots		1	<0.05	0.10		<0.11		
Crab apples		1	<0.23	<0.13		<0.29		
Curly kale		1	<0.06	<0.05		<0.16		
Eggs		1	<0.05	<0.05		<0.07		
Hawthorn berries		1	<0.24	<0.22		<0.31		
Honey		1	<0.06	0.96		<0.14		
Leeks		1	<0.05	<0.05		<0.13		
Potatoes		1	<0.05	0.24		<0.11		
Rabbit		3	<0.08	0.45		<0.09		
Rabbit	max		<0.10	0.81		<0.10		
Rosehips		1	<0.05	0.21		<0.09		
Turnips		1	<0.07	0.17		<0.21		
Wild berries		1	<0.05	<0.05		<0.05		
Grass		3	<0.05	0.16		<0.12	8.3	310
Grass	max		<0.06	0.23		<0.18	12	500
Soil		3	<0.17	17	0.41	<0.45	270	570
Soil	max		<0.22	21	0.55	<0.57	330	1100

[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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Largs Bay	Stones	2	0.055
Kilchatten Bay	Sand	2	0.051
Millport	Sand	2	<0.047
Gulls Walk	Mud	2	0.056
0.5 km north of pipeline	Sand	2	0.055
0.5 km south of pipeline	Sand and stones	2	0.068
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	0.051
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, 2007

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	12	<0.011	<0.011	0.17
West Kilbride	11	<0.012	<0.0075	<0.12
Crosbie Mains	12	<0.012	<0.0059	0.12

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2007

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			<0.21	<0.21		<0.21
Cod	Pipeline	2			<0.20	<0.18		<0.21
Crabs	Cove	2		32	<0.15	<0.14	0.67	<0.16
Lobsters	Cove	1			<0.14	<0.12	13	<0.14
Nephrops	Dunbar	2			<0.10	<0.10		<0.10
Winkles	Pipeline	2			<0.23	<0.13		0.59
Fucus vesiculosus	Pipeline	2			0.60	0.21		<0.12
Fucus vesiculosus	Thornton Loch	2			0.40	<0.18	82	<0.13
Fucus vesiculosus	White Sands	2			<0.13	<0.13		<0.13
Fucus vesiculosus	Pease Bay	2			<0.10	<0.10		<0.10
Fucus vesiculosus	Coldingham Bay	2			<0.13	<0.12		<0.13
Sediment	Dunbar	1			<0.10	<0.10		<0.11
Sediment	Barns Ness	1			<0.10	<0.10		<0.13
Sediment	Thornton Loch	1			<0.10	<0.10		<0.10
Sediment	Heckies Hole	1			<0.10	<0.10		<0.10
Sediment	Eyemouth	1			<0.10	<0.10		<0.10
Salt marsh	Belhaven Bay	1			<0.10	<0.10		<0.11
Seawater	Pipeline	2	16		<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	^{241}Am	Gross alpha	Gross beta
Marine Samples							
Cod	White Sands	1	0.25	<0.42	<0.24		
Cod	Pipeline	2	0.35	<0.48	<0.20		
Crabs	Cove	2	<0.13	<0.32	<0.17		
Lobsters	Cove	1	0.17	<0.26	<0.14		
Nephrops	Dunbar	2	<0.15	<0.15	0.023		
Winkles	Pipeline	2	<0.14	<0.32	<0.16	3.3	130
Fucus vesiculosus	Pipeline	2	0.28	<0.19	<0.13		
Fucus vesiculosus	Thornton Loch	2	0.31	<0.20	<0.14		
Fucus vesiculosus	White Sands	2	0.18	<0.22	<0.15		
Fucus vesiculosus	Pease Bay	2	<0.14	<0.15	<0.11		
Fucus vesiculosus	Coldingham Bay	2	0.15	<0.20	<0.13		
Sediment	Dunbar	1	2.5	0.73	<0.28		
Sediment	Barns Ness	1	2.4	1.6	<0.37		
Sediment	Thornton Loch	1	1.4	<0.23	<0.19		
Sediment	Heckies Hole	1	4.9	0.83	<0.25		
Sediment	Eyemouth	1	2.0	<0.26	<0.23		
Salt marsh	Belhaven Bay	1	2.8	0.68	<0.26		
Seawater	Pipeline	2	<0.10	<0.11	<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	<0.64	<0.05	<0.10	<0.22
Goats' milk		1	<5.0	<15	<0.27	<0.05	<0.16	<0.10
Blackberries		1	<5.0	<15	<0.50	<0.05	<0.10	<0.08
Broccoli		1	<5.0	16	<0.64	<0.05	0.14	<0.05
Cauliflower		1	<5.0	<15	3.70	<0.05	<0.10	<0.05
Eggs		1	<5.0	28	<0.41	<0.05	<0.10	<0.05
Elderberries		1	<5.0	18	<0.47	<0.05	<0.10	<0.06
Honey		1	<5.0	85		<0.05	<0.27	<0.09
Leeks		1	<5.0	<15	<0.27	<0.10	<0.10	<0.34
Plums		1	<5.0	<15	3.2	<0.05	<0.10	<0.33
Potatoes		1	<5.0	16	0.49	<0.05	<0.10	<0.12
Rosehips		1	<5.0	23	<0.50	<0.05	0.36	<0.20
Rowan berries		1	<5.0	<15	<0.50	<0.05	0.21	<0.15
Runner beans		1	12	<15	0.13	<0.05	0.10	<0.11
Grass		3	<5.4	<24	<0.77	<0.05	<0.32	<0.12
Grass	max		6.1	33	<1.3		0.77	<0.17
Soil		3	<5.0	<15	<2.1	<0.10	1.6	<1.5
Soil	max				<2.3	<0.15	2.6	<1.9

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	<0.05	<0.05		<0.05		
Blackberries		1	<0.05	<0.05		<0.05		
Broccoli		1	<0.05	<0.05		<0.05		
Cauliflower		1	<0.05	<0.05		<0.07		
Eggs		1	<0.05	<0.05		<0.05		
Elderberries		1	<0.05	<0.05		<0.11		
Honey		1	<0.05	0.24		<0.09		
Leeks		1	<0.10	<0.09		<0.13		
Plums		1	<0.06	<0.05		<0.07		
Potatoes		1	<0.05	<0.05		<0.05		
Rosehips		1	<0.05	<0.05		<0.07		
Rowan berries		1	<0.05	<0.05		<0.08		
Runner beans		1	<0.05	<0.05		<0.07		
Grass		3	<0.05	<0.06		<0.09	7.1	500
Grass	max			0.08		<0.11	11	530
Soil		3	<0.17	9.7	1.1	<0.42	250	880
Soil	max		<0.24	12	1.2	<0.65	330	1100

[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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Heckies Hole	Sediment	2	0.080
Dunbar Inner Harbour	Sand	2	0.085
Belhaven Bay	Salt marsh	2	<0.055
Barns Ness	Mud, sand and stones	2	0.050
Skateraw	Sand	2	<0.047
Thornton Loch	Sand	2	<0.047
Pease Bay	Sand	2	0.058
St Abbs Head	Mud	2	0.099
Coldingham Bay	Sand	2	<0.047
Eyemouth	Mud	2	0.059
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, 2007

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	11	<0.010	<0.0070	0.13
Cockburnspath	11	<0.010	<0.0078	0.13

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2007

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			<0.10	2.0	<0.12	41	<0.34
Rainbow trout	Trawsfynydd Lake	6			<0.09		<0.09	3.0	<0.28
Perch	Trawsfynydd Lake	6			<0.25	1.7	<0.27	110	<0.71
Rudd	Trawsfynydd Lake	1			<0.39		<0.37	80	<1.1
Sediment	Lake shore	2[E]			<0.96	<2.0	<0.84	300	
Sediment	Bailey Bridge	2[E]			<3.5	25	<3.5	570	
Sediment	Fish farm	2[E]			<7.9	7.0	<2.1	1200	4.2
Sediment	Footbridge	2[E]			<1.2	<4.0	<1.0	190	
Sediment	Cae Adda	2[E]			<1.0	<2.0	<0.89	190	
Sediment	Lake bed (0-2cm)	1[E]			7.8	<2.0	<3.9	1500	<31
Sediment	Lake bed (3-15cm)	1[E]			16	<2.0	<5.2	4700	<31
Freshwater	Public supply	2[E]	<4.0	<1.0	<0.31		<0.29	<0.26	
Freshwater	Gwylan Stream	2[E]	<4.0	<1.0	<0.31		<0.29	<0.25	
Freshwater	Diversion culvert	1[E]	<4.0	<1.0	<0.45		<0.43	<0.39	
Freshwater	Hot Lagoon	2[E]	<4.0	<1.0	<0.42		<0.39	<0.33	
Freshwater	Afon Prysor	2[E]	<4.0	<1.0	<0.36		<0.36	<0.31	
Freshwater	Trawsfynydd Lake	2[E]	<4.0	<1.0	<0.16		<0.15	<0.13	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{155}Eu	^{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	<0.30	0.000059	0.00027	0.00048	*	*		
Rainbow trout	Trawsfynydd Lake	6	<0.20			<0.19				
Perch	Trawsfynydd Lake	6	<0.63	0.000067	0.00033	0.00059	*	*		
Rudd	Trawsfynydd Lake	1	<0.55			<0.29				
Sediment	Lake shore	2[E]		<0.55	0.94	3.1				
Sediment	Bailey Bridge	2[E]		<0.45	1.1	2.9				
Sediment	Fish farm	2[E]		6.1	14	26				
Sediment	Footbridge	2[E]		<0.50	<0.69	1.4				
Sediment	Cae Adda	2[E]		<0.35	<0.49	0.98				
Sediment	Lake bed (0-2cm)	1[E]	<7.2	6.0	21	36				
Sediment	Lake bed (3-15cm)	1[E]	<10	32	86	140				
Freshwater	Public supply	2[E]							<0.020	<0.10
Freshwater	Gwylan Stream	2[E]							<0.025	<0.10
Freshwater	Diversion culvert	1[E]							<0.030	<0.10
Freshwater	Hot Lagoon	2[E]							<0.050	<0.10
Freshwater	Afon Prysor	2[E]							<0.025	<0.10
Freshwater	Trawsfynydd Lake	2[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	<4.8	15	<0.22	0.069	
Milk	max		<5.0		<0.23	0.094	
Apples		1	<4.0	16	<0.10		0.20
Blackberries		1	<5.0	18	<0.10		0.40
Eggs		1	<5.0	16	<0.10		<0.20
Marrow		1	<5.0	4.0	<0.20		0.20
Potatoes		1	<5.0	24	<0.20		0.50
Sloe berries		1	<4.0	13	<0.20		<0.20
Sheep muscle		2	<5.0	27	<0.15	<0.011	
Sheep muscle	max		<6.0	29	<0.20	0.014	
Sheep offal		2	<12	27	<0.20	0.056	
Sheep offal	max		14	35		0.077	

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	0.20			
Milk	max		0.30			
Apples		1		<0.00020	0.00010	<0.00020
Blackberries		1		<0.00020	0.00010	<0.00020
Eggs		1		<0.00010	<0.00020	0.00030
Potatoes		1		<0.00010	0.00010	<0.00030
Sloe berries		1		<0.00020	0.00030	0.00090
Sheep muscle		2	0.78	<0.00015	<0.00015	<0.00020
Sheep muscle	max		1.2	<0.00020	<0.00020	
Sheep offal		2	0.98	<0.00015	<0.00025	<0.00025
Sheep offal	max		1.4	<0.00020	<0.00030	0.00030

* *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 58 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, 2007

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Grass and rock	1	0.086
Footbridge	Pebbles	1	0.10
Lake shore	Pebbles and sand	1	0.084
Lake shore	Concrete	1	0.094
Bailey Bridge	Mud	1	0.081
Bailey Bridge	Grass	1	0.068
Fish Farm	Pebbles	1	0.099
Fish Farm	Stones	1	0.097
Cae Adda	Grass	1	0.078
Cae Adda	Pebbles	1	0.087

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2007

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	53		<0.23	2.0	
Bass	Outfall	1					<0.13	3.9	
Crabs	Pipeline	2				1.9	<0.18	0.47	0.0051
Lobsters	Pipeline	2				86	<0.13	0.72	
Winkles	Cemaes Bay	2	<25	<25	45		<0.13	0.33	0.024
Seaweed	Cemaes Bay	2[E]				500	<7.9	<1.4	
Sediment	Cemaes Bay	2[E]						3.7	
Sediment	Cemlyn Bay	2[E]						3.0	
Seawater	Cemaes Bay	2[E]		<4.0				<0.32	
Seawater	Cemlyn Bay	1[E]						<0.27	

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			<0.26				
Bass	Outfall	1			<0.21				
Crabs	Pipeline	2	0.031		0.080	*	0.00020		
Lobsters	Pipeline	2			<0.19				180
Winkles	Cemaes Bay	2	0.14	2.3	0.20	*	*		
Seaweed	Cemaes Bay	2[E]			<1.5				
Sediment	Cemaes Bay	2[E]			1.1				
Sediment	Cemlyn Bay	2[E]			1.1				
Seawater	Cemaes Bay	2[E]			<0.43			<2.1	9.7
Seawater	Cemlyn Bay	1[E]			<0.34			<2.3	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		5	<5.2	15	<0.40	<0.20		
Milk	max		<6.8	17	0.48			
Apples		1	<4.0	12	<0.20	<0.20		
Barley		1	<8.0	110	2.6	<0.30		
Blackberries		1	<5.0	17	2.1	<0.20		
Broad beans		1	<5.0	16	0.80	<0.30		
Honey		1	<6.0	66	<0.20	<0.20		
Leaf beet		1	<5.0	6.0	0.50	<0.20		
Parsnips		1	<4.0	17	<0.20	<0.40		
Potatoes		1	<5.0	19	<0.20	<0.30		
Freshwater	Public supply	1[E]	<4.0		<1.0	<0.39	<0.030	0.13

* *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*

[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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	2	0.067
Cemlyn Bay	Pebbles and sand	2	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, 2007).

Key points

- Generally, concentrations and dose rates similar to 2006 for all establishments (including Barrow, Derby, Faslane and Coulport, Holy Loch, Rosyth and Vulcan NRTE)
- Rosyth (RRDL) requested variation in two existing authorisations

Aldermaston, Berkshire

- A new authorisation came into force in March 2007
- Discharges, concentrations and dose rates similar to 2006. Decrease in gaseous tritium discharge, consistent with reduced concentrations in terrestrial foods and gullypot samples
- Terrestrial food consumption assessment included other gaseous discharge pathways
- Radiation doses (Table 5.1) were less than 0.5 per cent of the dose limit
- The *total dose* from all sources was less than 0.5 per cent of the dose limit

Devonport, Devon

- A variation of existing approval to dispose of radioactive waste from Devonport Naval Base was effective from June 2007
- Concentrations and dose rates similar to 2006
- Terrestrial food consumption assessment included other gaseous discharge pathways
- Radiation doses (Table 5.1) were less than 0.5 per cent of the dose limit

5.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston is authorised to discharge low concentrations of radioactive waste to the environment. New authorisation limits were effective from 1 March 2007 (Appendix 2). The site is authorised to discharge aqueous radioactive waste to the sewage works at Silchester and to Aldermaston Stream. Alpha and beta/gamma discharges to Silchester were reduced in 2007. Samples of milk, other terrestrial foodstuffs, freshwater, fish and sediments were collected. The sampling locations are shown in Figure 3.1.

The results of measurements of radionuclides 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 2006. Concentrations of tritium were generally below the LoD. In 2007, no enhancements of tritium were observed in sediments collected from road gullypots very close to the site. Caesium-137 concentrations were detected in sediment from the River Thames and watercourses near the site and were similar to those observed in recent years. Currently, routine discharges from AWE do not include significant concentrations of radiocaesium. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. A habits survey (in 2002) has established that the critical group affected by discharges into the river can be represented by anglers whose occupancy of the river-bank has been assessed to estimate their external exposures. No consumption of freshwater fish has been established but the assessment has conservatively included consumption of fish at a low rate of 1 kg per year. No pike were sampled in 2007 and estimates of activity concentrations have been based on earlier data using variations in sediment concentrations as a measure of changes in fish concentrations. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5 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. Gross alpha and beta activities in the freshwater samples were below the WHO screening levels for drinking water. The drinking water pathway has been shown to be insignificant (Environment Agency, 2002a).

The concentrations of radioactivity in milk, crops, fruit and environmental indicator materials were also very low. Results for tritium, caesium-137, uranium and transuranic radionuclides were generally similar to those for 2006. Natural background

or weapon test fallout would have made a significant contribution to the levels detected. Concentrations of tritium were generally below the LoD and detected values were reduced in comparison to corresponding 2006 data. These data (and gullypot data) are consistent with reduced discharges of gaseous tritium in 2007. The reported results for caesium-137 in soils were broadly similar to the values observed in 2006. Concentrations of uranium in soil were broadly similar to those found elsewhere in the area. Taking into account measured concentrations of plutonium and other radionuclides in local foodstuffs, the dose from consumption of local food in 2007, including contributions from the natural and fallout sources, was less than 0.005 mSv. In 2007, 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, including both food and non-food pathways, in 2007 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.

Early in 2006, the Environment Agency began a review of radioactive waste disposals from AWE. Public consultation on the limits and conditions under which AWE can dispose of radioactive waste at its two sites, at Aldermaston and Burghfield, was held between May and October 2006 (Environment Agency, 2006h). The Environment Agency issued an explanatory document to assist the consultation process (Environment Agency, 2006i). A decision document on two new separate authorisations for Aldermaston and Burghfield was issued in March 2007.

5.2 Barrow, Cumbria

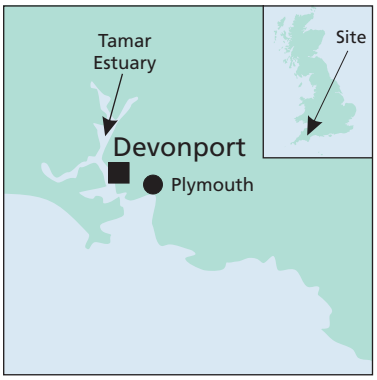
During 2007, authorised discharges from Barrow were below the monitor LoD. The Food Standards Agency's monitoring is limited to grass sampling. In 2007, tritium activity was detected either below, or close to, the LoD (Table 5.3(a)). Any significant effects of discharges from Barrow in the marine environment 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 2007.

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.

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

5.4 Devonport, Devon

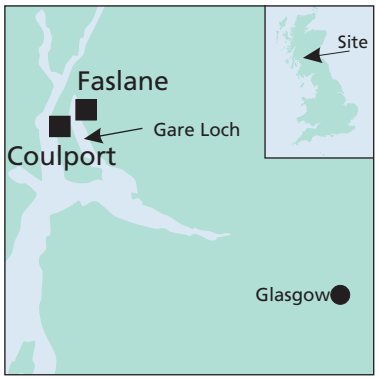


Devonport consists of two parts: the Naval Base which is owned and operated by the MoD, and Devonport Royal Dockyard which is owned by Devonport Royal Dockyard Limited (DRDL). DRDL refits, refuels, repairs and maintains the Royal Navy's nuclear powered submarines and has an authorisation granted by the Environment Agency to discharge liquid wastes to the Hamoaze, which is part of the Tamar Estuary, and to the local sewer, and gases, mists and dusts to atmosphere. Babcock International Group plc acquired DML, the operators of DRDL, in July 2007. DRDL continues to hold the authorisation.

The existing approval for the disposal of radioactive waste from HM Naval Base at Devonport has been revised. Following the consultation process, a decision document was issued (Environment Agency, 2007c) and the approval was issued in April 2007 and became effective in June 2007.

The routine monitoring programme in 2007 consisted of measurements of gamma dose rate and analysis of fish, shellfish, vegetables, fruit, sediments and seawater. The results given in Tables 5.3(a) and (b) were similar to those in 2006. Trace quantities of caesium-137 and americium-241 were found in the marine environment. These were most likely to have originated from Chernobyl and from spent fuel reprocessing elsewhere. Activation products were below LoDs. The most recent habits survey in 2004 established that there are two dominant critical groups for marine pathways, (i) fish and shellfish consumers and (ii) occupants of houseboats. Taking account of relevant consumption of marine foods and occupancy times, doses to both groups were estimated to be less than 0.005 mSv which was less than 0.5 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 high-rate consumption of fruit and vegetables was less than 0.005 mSv. In 2007, 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, including food and non-food pathways, in 2007 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 at HMNB Clyde in partnership with 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 discharges released during 2007 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 2007.

The MoD has reviewed plans to build a new effluent plant at Faslane in terms of the long-term strategy for the base. The MoD has now decided to refurbish the existing effluent treatment plant and has requested that the application made to SEPA in 2003 is withdrawn. The discharges arising from the refurbished plant may be made under existing agreements.

During 2007, SEPA wrote to the Naval Base Commander, Clyde regarding an inadvertent release of potentially radioactive effluent. SEPA considered that there was no discernable environmental impact.

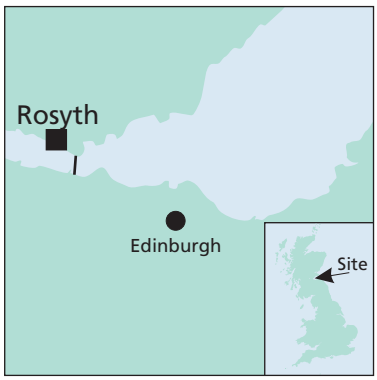
The most recent habits survey was undertaken in 2006. The monitoring programme consisted of the analysis of seawater and seaweed samples, and gamma dose rate measurements. Samples of non-migratory fish species were not available. In 2007, SEPA collected samples of mussels and had the shell and flesh analysed separately to assess the impact of utilising the mussel shell as a fertiliser. The samples were prompted by the recent habits survey. Results are given in Tables 5.3(a) and (b), including mussel data. These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield, and to weapons testing and Chernobyl fallout. The concentrations of radioactivity in shells were very small and of no radiological significance. Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background. Taking into account the occupancy and consumption rate data from the 2006 habit survey, and seafood concentration data from 2007, 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 March 1992. The radioactivity concentrations detected were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. As in 2006, the concentrations of cobalt-60 in sediment from the Loch were below the LoD. Measurements of gamma dose rates in 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 2007, 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



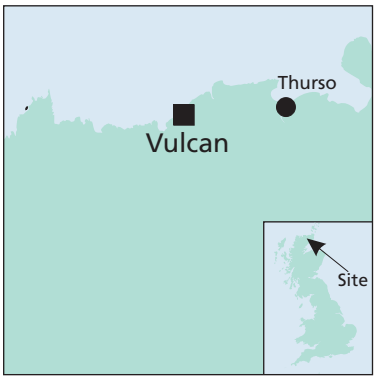
The site is operated by Babcock Engineering Services who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006, and is expected to be completed within four years. To date, more than 99 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. Following volume reduction and the recovery of reusable metals, the radioactive waste will be returned to Rosyth for disposal by authorised routes. In May 2007, SEPA issued a consultation document to assist the process (Scottish Environment Protection Agency, 2007a). In September 2007, SEPA received an application from RRDL requesting variation of two existing authorisations to reflect the change of operator at the low level waste repository near Drigg in Cumbria. SEPA has commenced the consultation process.

During 2007, authorised gaseous discharges from Rosyth were below the LoD. Small volumes of liquid radioactive waste associated with site decommissioning were discharged to the Firth of Forth. In all cases the activity in the liquid discharged was well below authorised limits.

SEPA's routine monitoring programme included analysis of crabs, seaweed and sediment, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 5.3(a) and (b). The radioactivity levels detected were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2005. The resultant dose to the critical groups of local fishermen and beach users in 2007 were estimated to be less than 0.005 mSv, which were 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, 2007

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	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally harvested crayfish[b]	<0.005	<0.005	-	-	-	-
	Inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005
	All sources[d]	<0.005	-	-	-	-	-
Derby	Consumers of drinking water[c]	0.007	-	-	-	0.007	-
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-
	Prenatal children of inhabitants and 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*

Table 5.2 (a). Concentrations of radionuclides in food and the environment near Aldermaston, 2007

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	*	0.11			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	*	<0.11	0.026	0.00031	0.021
Sediment	Pangbourne	4[E]				11	11	<0.79	10
Sediment	Mapledurham	4[E]				16	13	<1.3	12
Sediment	Aldermaston	4[E]				<5.3	12	<0.82	11
Sediment	Spring Lane	4[E]				<1.8	6.3	<0.60	6.7
Sediment	Stream draining south	4[E]				<3.0	8.3	<1.2	7.7
Sediment	Reading (Kennet)	4[E]				<5.2	12	<0.63	12
Gullypot sediment	Falcon Gate	1[E]		<25		<2.7	13	<0.70	13
Gullypot sediment	Main Gate	1[E]		<25		<0.94	11	<0.50	11
Gullypot sediment	Tadley Entrance	1[E]		<25		32	15	<0.60	16
Gullypot sediment	Burghfield Gate	1[E]		<25		<1.4	14	<0.70	13
Freshwater	Pangbourne	4[E]		<4.0		<0.23	<0.011	<0.0050	<0.012
Freshwater	Mapledurham	4[E]		<4.3		<0.26	<0.012	<0.0050	<0.0073
Freshwater	Aldermaston	4[E]		<5.9		<0.25	<0.010	<0.0050	<0.0073
Freshwater	Spring Lane	4[E]		<4.4		<0.26	<0.0070	<0.0053	<0.0055
Freshwater	Reading (Kennet)	4[E]		<4.3		<0.26	<0.012	<0.0050	<0.0060
Crude liquid effluent	Silchester treatment works	4[E]		<22	17	<0.27	<0.011	<0.0050	<0.0068
Final Liquid effluent	Silchester treatment works	4[E]		<34		<0.26	<0.014	<0.0050	<0.0070
Sewage sludge	Silchester treatment works	4[E]		<25		<0.27	0.40	<0.032	0.37

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			<0.05				
Signal crayfish	Ufton Bridge - Theale	1	0.00011	0.00026	0.00054	*	*		
Sediment	Pangbourne	4[E]	<0.88	<0.72	<1.2			280	340
Sediment	Mapledurham	4[E]	<0.78	<0.63	<1.4			220	330
Sediment	Aldermaston	4[E]	<0.70	2.6	1.8			240	400
Sediment	Spring Lane	4[E]	<0.70	<2.2	<4.0			<180	340
Sediment	Stream draining south	4[E]	<0.65	<0.51	<0.60			180	280
Sediment	Reading (Kennet)	4[E]	<0.50	<0.65	<1.4			180	350
Gullypot sediment	Falcon Gate	1[E]	<0.70	<0.30	<3.3			390	660
Gullypot sediment	Main Gate	1[E]	<0.70	<0.20	<1.3			710	480
Gullypot sediment	Tadley Entrance	1[E]	<0.80	0.67	<2.6			450	500
Gullypot sediment	Burghfield Gate	1[E]	<0.40	<0.20	<1.9			220	480
Freshwater	Pangbourne	4[E]	<0.0055	<0.0050	<0.022			<0.040	<0.20
Freshwater	Mapledurham	4[E]	<0.013	<0.0050	<0.013			<0.050	0.17
Freshwater	Aldermaston	4[E]	<0.010	<0.0065	<0.012			<0.045	<0.19
Freshwater	Spring Lane	4[E]	<0.013	<0.0055	<0.013			<0.025	<0.14
Freshwater	Reading (Kennet)	4[E]	<0.010	<0.0050	<0.012			<0.030	<0.11
Crude liquid effluent	Silchester treatment works	4[E]	<0.014	<0.0053	<0.35			<0.093	0.56
Final Liquid effluent	Silchester treatment works	4[E]	<0.013	<0.0058	<0.36			<0.058	0.52
Sewage sludge	Silchester treatment works	4[E]	<0.53	<0.53	<0.39			<100	<100

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	Total U
Terrestrial samples									
Milk			4	<5.2	<0.20				<0.0061
Milk		max		<5.5					
Beetroot			1	<5.0	<0.30				0.041
Blackberries			1	<4.0	<0.20				<0.032
Honey			1	11	<0.20				<0.030
Potatoes			1	<5.0	<0.30				<0.031
Rabbit			1	6.0	<0.20	0.0011	<0.00070	<0.0013	
Rhubarb			1	<5.0	<0.30				<0.031
Runner beans			1	<5.0	<0.40				<0.031
Wheat			1	<7.0	<0.20				<0.032
Grass	Location 5		1[E]	26	<2.2	<0.30	<0.20	<0.30	
Grass	Location 7		1[E]	<25	6.2	<0.40	<0.20	<0.50	
Grass	Location 8		1[E]	27	<3.4	1.0	<0.20	0.87	
Grass	Location 9		1[E]	30	<0.92	<0.20	<0.30	<0.40	
Soil			1[#]			6.1	0.28	6.4	
Soil	Location 5		1[E]	<25	61	12	<0.70	14	
Soil	Location 7		1[E]	<25	8.5	20	<2.0	22	
Soil	Location 8		1[E]	<25	17	14	<0.90	14	
Soil	Location 9		1[E]	<25	24.0	12	<0.90	14	

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	<0.00011	<0.00010	<0.00013		
Milk		max		<0.00015		<0.00015		
Beetroot			1	<0.00010	<0.00010	<0.00030		
Blackberries			1	<0.00010	0.00010	<0.00020		
Honey			1	<0.00030	<0.00020	<0.00040		
Potatoes			1	<0.00010	<0.00010	<0.00020		
Rabbit			1	<0.00070	0.00050	<0.00050		
Rhubarb			1	<0.00020	0.00010	<0.00030		
Runner beans			1	<0.00010	<0.00010	0.00020		
Wheat			1	<0.00020	<0.00030	0.00020		
Grass	Location 5		1[E]	<0.20	<0.060		<100	170
Grass	Location 7		1[E]	<0.20	<0.20		<100	120
Grass	Location 8		1[E]	<0.10	<0.20		<100	340
Grass	Location 9		1[E]	<0.10	<0.060		<100	41
Soil	Location 5		1[E]	<0.60	1.4		140	370
Soil	Location 7		1[E]	<1.0	<0.70		310	600
Soil	Location 8		1[E]	<0.50	0.87		230	450
Soil	Location 9		1[E]	<0.40	0.89		220	430

** 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*

[#] *Fresh concentrations*

Table 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	4	0.068
Mapledurham, riverbank	Mud and stones	2	0.062
Mapledurham, riverbank	Grass and mud	1	0.063
Mapledurham, riverbank	Grass	1	0.069

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2007

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	^{95}Zr	^{106}Ru	^{110m}Ag	^{125}Sb
Barrow													
Grass	Barrow	2[F]		<9.0									
	max			12									
Derby													
Sediment	River Derwent, downstream	3						<0.79					
Sediment	River Derwent, upstream	1						<0.47					
Water	River Derwent, downstream	3						<0.34					
Water	River Derwent, upstream	1						<0.30					
Devonport													
Lesser spotted dogfish	Plymouth Sound	2[F]				<0.06	<0.15	<0.06	<0.16	<0.29	<0.55	<0.12	<0.12
Crabs	Plymouth Sound	2[F]			26	<0.09	<0.25	<0.08	<0.24	<0.48	<0.93	<0.18	<0.19
Winkles	Torpoint (South)	1[F]				<0.16	<0.40	<0.15	<0.42	<0.79	<1.7	<0.31	<0.34
Cockles	Southdown	1[F]				<0.14	<0.49	<0.11	<0.33	<0.95	<1.4	<0.25	<0.26
Pacific oysters	Southdown	1[F]		<25									
Mussels	R Lynher	2[F]	<25	<25		<0.14	<0.36	<0.13	<0.36	<0.72	<1.5	<0.27	<0.29
Whelks	R Lynher	1[F]			25	<0.07	<0.13	<0.08	<0.18	<0.24	<0.65	<0.13	<0.15
Seaweed[c]	Kinterbury	1						<0.73					
Sediment[d]	Kinterbury	1		<25				<2.3					
Sediment	Torpoint (South)	2		<25				<1.2					
Sediment	Lopwell	2		<25				<1.9					
Seawater	Torpoint (South)	2		<4.0	<4.0			<0.40					
Seawater	Millbrook Lake	2		<4.0	<4.0			<0.38					
Beetroot		1[F]		<5.0				<0.20		<0.30	<1.7	<0.20	
Blackberries		1[F]		<5.0				<0.20		<0.30	<1.7	<0.20	
Courgettes		1[F]		<5.0				<0.20		<0.30	<1.2	<0.20	
Lettuce		1[F]		<4.0				<0.20		<0.40	<1.3	<0.20	
Faslane													
Mussels (flesh)		1				<0.11	0.68	<0.05			<0.94	0.21	<0.26
Mussels (shell)						<0.02	0.04	0.09		<0.03	<0.19	0.05	<0.06
Fucus vesiculosus	Rhu	1				<0.10	<0.10	<0.10	<0.10	<0.14	<0.26	<0.10	<0.10
Seawater	Carnban boatyard	2		<14		<0.10	<0.10	<0.10	<0.11	<0.13	<0.30	<0.10	<0.12
Holy Loch													
Sediment	Mid Loch	1				<0.10	<0.10	<0.10	<0.22	<0.15	<0.49	<0.10	<0.16
Rosyth													
Crabs	East of dockyard	1				<0.10	<0.22	<0.10	<0.24	<0.42	<0.78	<0.10	<0.21
Whelks	East of dockyard	1				<0.11	<0.25	<0.10	<0.28	<0.49	<0.94	<0.12	<0.25
Fucus vesiculosus	East of dockyard	1				<0.10	<0.15	<0.10	<0.19	<0.30	<0.41	<0.10	<0.11
Sediment	East of dockyard	1				<0.10	<0.19	<0.10	<0.29	<0.36	<0.62	<0.11	<0.18
Sediment	Port Edgar	1				<0.10	<0.28	<0.10	<0.37	<0.59	<0.86	<0.15	<0.24
Sediment	West of dockyard	1				<0.10	<0.19	<0.10	<0.26	<0.27	<0.64	<0.11	<0.18
Sediment	East Ness Pier	1				<0.10	<0.15	<0.10	<0.22	<0.31	<0.52	<0.10	<0.15
Sediment	Blackness Castle	1				<0.10	<0.35	<0.10	<0.49	<0.74	<1.1	<0.18	<0.30
Sediment	Charlestown Pier	1				<0.10	<0.16	<0.10	<0.23	<0.32	<0.53	<0.10	<0.15
Seawater	East of dockyard	2		<1.3		<0.10	<0.10	<0.10	<0.13	<0.16	<0.30	<0.10	<0.11

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	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Derby													
Sediment	River Derwent, downstream	3			5.1			28	0.93	27		430	1100
Sediment	River Derwent, upstream	1			2.9			20	0.77	18		220	320
Grass		4[F]					<0.12						
Grass	max						0.23						
Soil		4[F]					75						
Soil	max						120						
Water	River Derwent, downstream	3										<0.080	0.21
Water	River Derwent, upstream	1										<0.050	0.10
Devonport													
Lesser spotted dogfish	Plymouth Sound	2[F]	*	<0.05	0.18	<0.10					<0.06		
Crabs	Plymouth Sound	2[F]	*	<0.09	<0.07	<0.13					<0.07		
Winkles	Torpoint (South)	1[F]	*	<0.16	<0.13	<0.21					<0.10		
Cockles	Southdown	1[F]	*	<0.12	<0.10	<0.17					<0.08		
Mussels	R Lynher	2[F]	*	<0.14	<0.12	<0.19					<0.10		
Whelks	R Lynher	1[F]	*	<0.07	<0.06	<0.12					<0.07		
Seaweed[c]	Kinterbury	1	1.9										
Sediment[d]	Kinterbury	1			4.1						1.3		
Sediment	Torpoint (South)	2			1.5								
Sediment	Lopwell	2			7.1								
Beetroot		1[F]		<0.20	<0.20								
Blackberries		1[F]		<0.20	<0.30								
Courgettes		1[F]		<0.20	<0.20								
Lettuce		1[F]		<0.20	<0.20								
Faslane													
Mussels (flesh)		1		0.46	0.34	<0.09					<0.06		
Mussels (shell)				<0.02	<0.02	<0.04					<0.03		
Fucus vesiculosus	Rhu	1		<0.10	0.58	<0.10					<0.10		
Seawater	Carnban boatyard	2		<0.10	<0.10	<0.13					<0.10		
Holy Loch													
Sediment	Mid Loch	1		<0.10	3.1	0.73					0.52		
Rosyth													
Crabs	East of dockyard	1		<0.10	<0.10	<0.21					<0.12		
Whelks	East of dockyard	1		<0.10	<0.10	<0.25					<0.14		
Fucus vesiculosus	East of dockyard	1		<0.10	0.25	<0.14					<0.11		
Sediment	East of dockyard	1		<0.10	3.7	0.47					0.32		
Sediment	Port Edgar	1		<0.11	23	2.3					2.7		
Sediment	West of dockyard	1		<0.10	1.3	<0.24					<0.27		
Sediment	East Ness Pier	1		<0.10	6.0	0.41					<0.20		
Sediment	Blackness Castle	1		<0.14	7.7	1.0					1.0		
Sediment	Charlestown Pier	1		<0.10	2.2	0.39					<0.19		
Seawater	East of dockyard	2		<0.10	<0.10	<0.11					<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}, and Total Uranium in soil which is dry*

[c] *The concentration of ^{99}Tc was 2.1 Bq kg^{-1}*

[d] *The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.40, and 0.95 Bq kg^{-1} respectively*

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

Table 5.3(b). Monitoring of radiation dose rates near defence establishments, 2007

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 shale	1	0.10
Devonport	Torpoint South	Mud and rock	1	0.10
Devonport	Kinterbury Access Gate	Mud and stones	1	0.094
Devonport	Lopwell	Mud and stones	1	0.077
Devonport	Lopwell	Mud and rock	1	0.083
Faslane	Gareloch Head	Mud, sand and stones	2	0.052
Faslane	Gulley Bridge Pier	Sand and stones	2	0.057
Faslane	Rhu	Gravel	2	0.062
Faslane	Helensburgh	Sand	2	0.051
Faslane	Carnban boatyard	Gravel	2	0.075
Holy Loch	North Sandbank	Mud and sand	1	0.062
Holy Loch	Kilmun Pier	Sand and stones	1	0.067
Holy Loch	Mid-Loch	Sand	1	0.049
Rosyth	Blackness Castle	Mud and sand	2	0.055
Rosyth	Charlestown Pier	Sand	2	0.054
Rosyth	East Ness Pier	Sand	2	0.067
Rosyth	East of Dockyard	Sand	2	0.056
Rosyth	Port Edgar	Mud	2	0.066
Rosyth	West of Dockyard	Mud and rock	2	0.057

6. Radiochemical production

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- Discharges, concentrations and dose rates similar to 2006, slight increase in gaseous radon-222 discharge
- New boreholes have been installed on-site and local drinking water supplies remain unaffected by tritium in groundwater
- Radiation doses from discharges (Table 6.1) were less than 2 per cent of the dose limit
- The *total dose* from all sources was 23 per cent of the dose limit

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- Report produced considering crop uptake of tritium present in Cardiff sewage sludge concluded uptake was small
- Paragon Plant is being commissioned for tritium recycling using non-radioactive materials
- Tritium levels in Glamorganshire canal water below LoD and sediment concentrations reduced
- Further reduction of tritium in fish and resultant dose from fish consumption from 2006
- Liquid carbon-14 discharges reduced, others similar to 2006
- Further reductions of carbon-14 concentrations in seafood and resultant dose from seafood consumption, from 2006
- The critical group was prenatal children receiving exposure as a consequence of adult seafood consumption but the doses were negligible at less than 2 per cent of the dose limit (Table 6.1). The adult dose was similar
- The *total dose* of 0.012 mSv from all sources was approximately 1 per cent of the dose limit

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.

6.1 Grove Centre, Amersham, Buckinghamshire

The company's principal establishment is located in Amersham, Buckinghamshire, which houses a wide range of plants for manufacturing radiopharmaceutical products, using short half-life radionuclides such as fluorine-18 and technetium-99m, for use in medicine and research. The company also uses small quantities of some short half-life radionuclides, such as sulphur-35, phosphorous-32 and iodine-125, for quality assurance analysis of non-radioactive products. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials. 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.

Gaseous discharges and terrestrial monitoring

Discharges of radon-222 were increased in 2007 (4.48 TBq) in comparison to 2006 (2.92 TBq). The activity concentrations in milk, grass and soil crops were generally lower than the limits of detection (Table 6.2). However, low concentrations of sulphur-35 and caesium-137 were detected in a few samples. Caesium-137 activity detected in soil near the site is likely to be due to global fallout from testing of weapons or from the Chernobyl accident.

Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive wastes are made to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. The results are presented in Table 6.2. Tritium concentrations in freshwater were below the LoD. Concentrations in material from Maple

Lodge Sewage Works were similar to those in 2006. 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.

New monitoring boreholes have been installed on-site by the operator to better understand the nature and extent of the tritium found in groundwater originally identified by the operator in 2005. The off-site radiological impact of the tritium in the groundwater remains very low and local drinking water supplies are not affected.

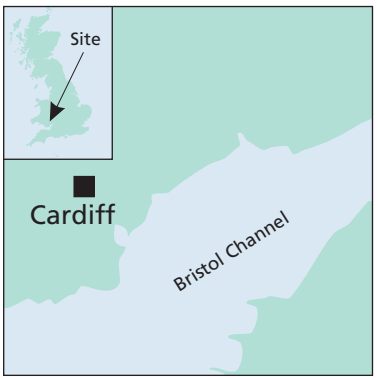
Doses to the public

The maximum estimated dose from local terrestrial food consumption was to the 1-year-old age group (infants), and as in 2006, the dose to this group was less than 0.005 mSv. The largest contribution was from selenium-75 in milk (below LoD). Adding the contribution from non-food pathways, using the methods and data given in Appendix 1, the critical group dose in 2007 was 0.020 mSv which was 2 per cent of the dose limit for members of the public of 1 mSv (Table 6.1). Considering pathways downstream of the release point for discharges of liquid effluents, no consumers of fish, shellfish or freshwater plants were identified directly in the most recent habits survey. 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 therefore been assumed. Estimates of activity concentrations have been used from previous data for pike, taking recent variations in sediment concentrations into account. The dose in 2007 from fish consumption and 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 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 2007, 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 0.23 mSv or 23 per cent of the dose limit. This dose was to an individual member of the public who constituted the critical group.

6.2 Maynard Centre, Cardiff



A second laboratory is located 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.

In December 2006, the Environment Agency reported that GE Healthcare had announced that their major recycling initiative (Project Paragon) has been successful in developing a process to recycle tritium (Environment Agency, 2006j). GE Healthcare is undertaking commissioning of the tritium recycling plant. Full commissioning of the plant is subject to approval from the Nuclear Installations Inspectorate and the Environment Agency. GE Healthcare continues to withhold some higher activity effluents (including a significant proportion of the organic form) on-site as feedstock for the plant. Once commissioned, the plant will treat both the waste stored on-site and future waste arisings. Discharges of organic tritium in 2007 were similar to those in 2006.

Following the conclusion that the carbon-14 element of Project Paragon was not feasible at the required scale, the site reviewed its Best Practicable Environmental Option assessment for carbon-14 waste and determined that an increased amount could be sent for treatment by incineration at an off-site commercial incinerator. This has reduced the amount of carbon-14 waste that is discharged to sewer and put into storage on site each year. Gaseous discharges will remain approximately proportionate to the scale of the manufacturing operations, which fluctuate annually.

A research project was commissioned by the Food Standards Agency to evaluate tritium concentrations in crops, fertilised with sewage sludge from a waste water treatment works in Cardiff (Ham *et al*., 2007). The study concluded, that although not necessarily applicable in general radiological assessments, the tritium transfer into crops from soil treated with sludge would be small. Earlier monitoring and research has targeted organic tritium in foodstuffs (Food Standards Agency, 2001b, Swift, 2001; Williams *et al*., 2001; Leonard *et al*., 2001 and McCubbin *et al*., 2001). A past review was undertaken of monitoring data for tritium bioaccumulation (Rowe *et al*., 2001).

Routine monitoring, conducted on behalf of the Welsh Assembly Government, includes consideration of consumption of locally produced food 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 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. The incidence of detection of enhanced tritium activities in a wide range of terrestrial samples is relatively high in comparison with other nuclear sites, although the implications for the critical group dose are low. Carbon-14 activities were also enhanced in some foodstuffs, particularly noticeable in samples that are known to contain low natural levels, such as fruit (e.g. blackberries). Sulphur-35, which is not discharged by GE Healthcare, was detected at concentrations similar to those found in the general diet survey (see Section 8). All these measurements were of low radiological significance. The operator has measured low levels (i.e. below the UK drinking water investigation level of 100 Bq l^{-1}) of tritium in the groundwater under the site attributed to wash-out from gaseous discharges, but this is unlikely to affect drinking waters due to the prevailing hydrological environment.

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. In comparison to 2006, discharges of carbon-14 to the sewer were reduced by 50 per cent.

The results of routine monitoring in 2007 are presented in Tables 6.3(a) and (b). The main effects of liquid discharges were

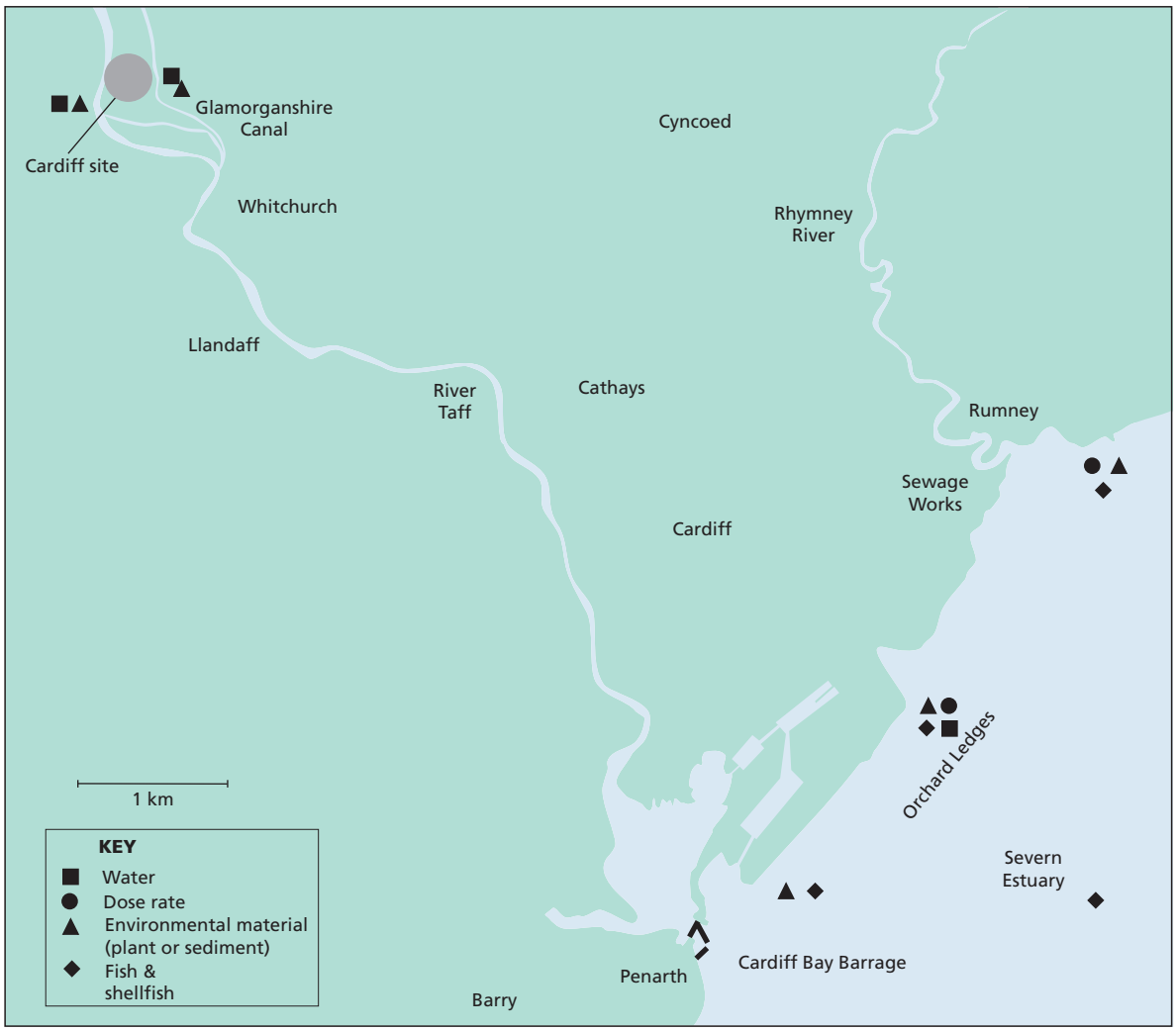


Figure 6.1. Monitoring locations at Cardiff (not including farms)

observed in enhanced tritium and carbon-14 activities in samples above background levels. The results of sample analyses show that virtually all of the total tritium in marine samples was associated with organic matter. The tritium is strongly bound to organic matter and has the potential to transfer through the marine food chain from small organisms to accumulate in fish. As illustrated by Figure 6.2, concentrations of tritium in fish continued to decline. Consistent with a reduction in discharge, carbon-14 concentrations in seafood were lower in 2007, compared to 2006. The trends in concentrations of tritium and carbon-14 in seafood and their relationship to discharges are shown in Figures 6.2 and 6.3. The lower tritium concentrations, in comparison to previous years (from 1998), were most probably due to a reduction in the organically bound components of the discharge and more recent reductions of liquid discharges.

Low levels of tritium continued to be detected in sediment from Glamorganshire canal, which is not used as a source of water for the public water supply. As in 2006, concentrations in water run-off from the site into the River Taff were below the LoD. Concentrations in sediment from the local canal were substantially lower than those in 2006. 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.

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. Gamma dose rates over sediment were generally difficult to distinguish from expected natural background levels, although rates at the East of Pipeline were slightly higher than in 2006.

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 0.007 mSv. The largest contribution was from phosphorus-32 in milk (below LoD). After allowing for non-food pathways, using the methods and data given in Appendix 1, the critical group dose in 2007 was 0.008 mSv which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 6.1).

The dose coefficients for organically bound tritium (OBT) differ from those for tritiated water (see Appendix 1) and the estimates of dose for 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. For ingestion of other food, the ICRP dose coefficient is applied for OBT. Using an increased dose

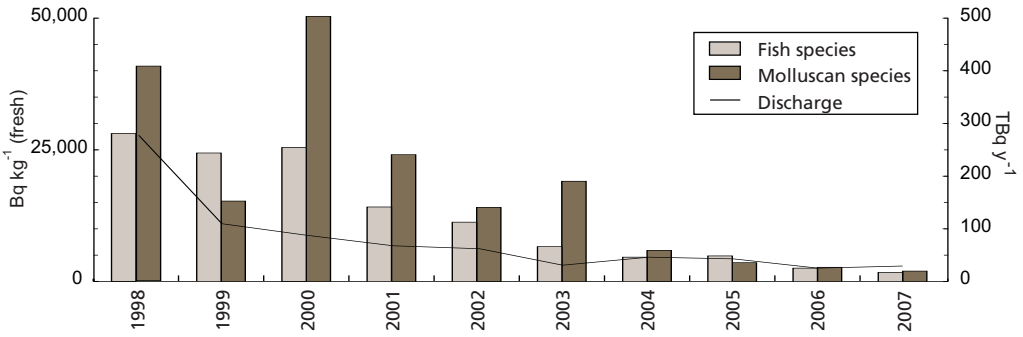


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

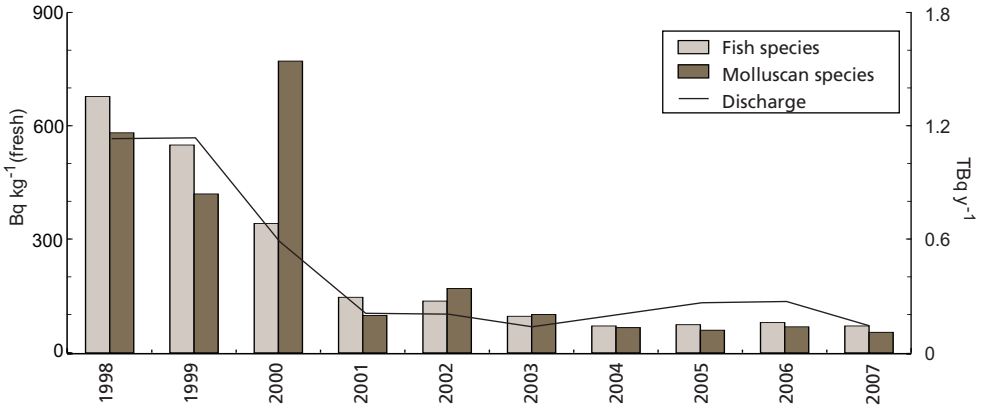


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

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 2007 was 0.014 mSv. This was less than 2 per cent of the dose limit for members of the public of 1 mSv (Table 6.1). The dose to the next highest age group (adults) in 2007 was 0.012 mSv. These estimates include a significant contribution due to external radiation, which was slightly increased to 0.007 mSv in 2007 (Table 6.1) from less than 0.005 mSv in 2006, due to slightly increased dose rates possibly as a result of natural variation and/or discharges from Hinkley or Oldbury nuclear power stations. Therefore, the reduction from 0.015 mSv in 2006 reflects further lowering of the tritium activity in fish. 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 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. However, as in 2006, the largest contribution was estimated from the inadvertent ingestion of iodine-131 (which is not discharged from the Maynard Centre) in sediment or water (which was below the LoD).

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. Issues of the RIFE report prior to RIFE-11 (2005) contain different doses because they are based on the old assessment method and data applicable at the time of publication. 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 2007, 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 0.008 mSv or less than 1 per cent of the dose limit.

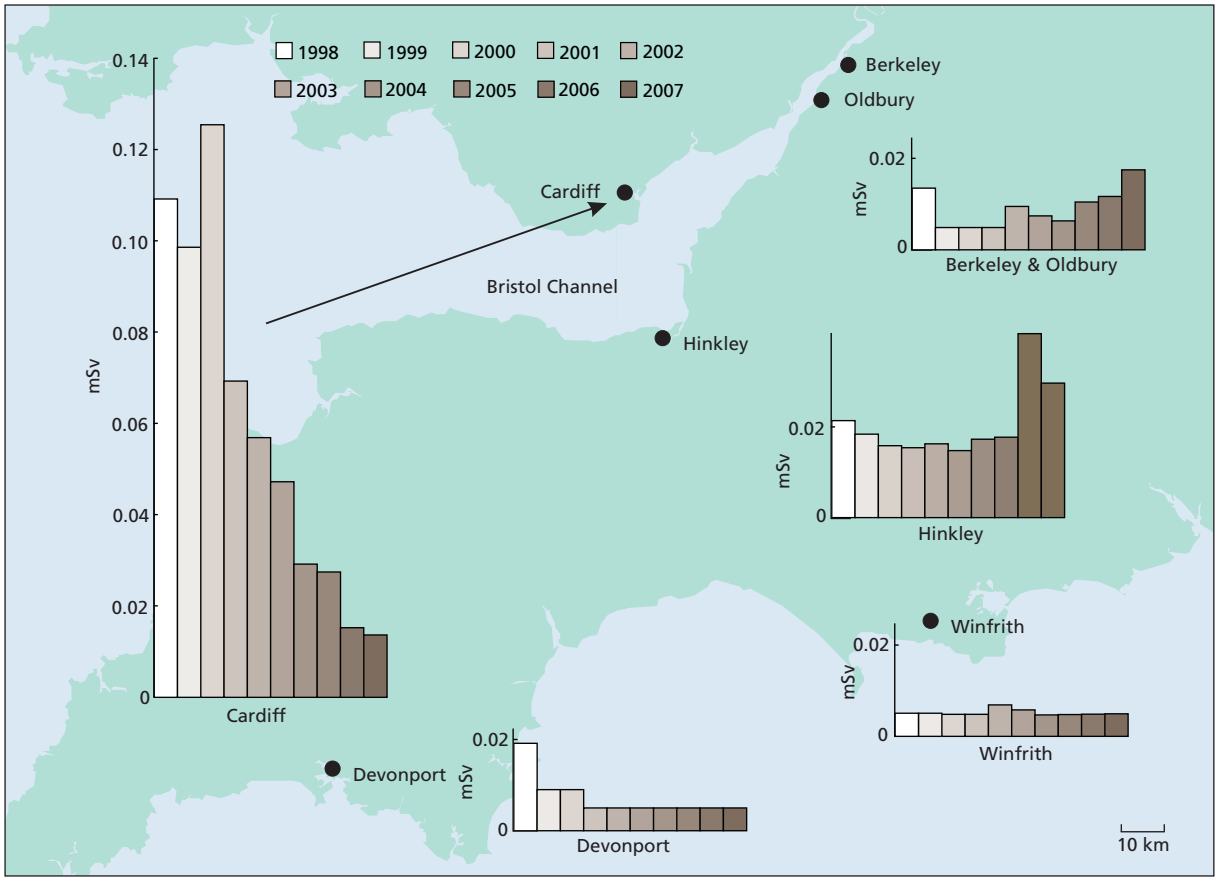


Figure 6.4. Individual radiation exposures from marine pathways for artificial radionuclides in the Severn Estuary and the south coast, 1998-2007.
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Table 6.1. Individual radiation exposures - radiochemical sites, 2007

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	-	-
	Inhabitants and consumers of locally grown food[b]	0.020	-	<0.005	-	-	0.016
	All sources[c]	0.23	-	-	-	-	-
Cardiff	Prenatal children of seafood consumers	0.014	0.006	-	0.007	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.008	-	0.007	-	-	<0.005
	All sources[c]	0.008	-	-	-	-	-

[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*

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2007[f]

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			<0.03	<0.13			0.11	<0.05		
Sediment	Outfall (Grand Union Canal)	2[E]				<6.6	<4.2	<10	<8.4	<2.9		160	300
Sediment	Upstream of outfall (Grand Union Canal)	2[E]				<7.9	<4.8	<16	<51	11		130	210
Freshwater	Maple Cross	2[E]	<4.0			<1.1	<0.58	<1.6	<0.45	<0.25		<0.13	0.55
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<4.0			<1.1	<0.61	<1.6	<0.47	<0.25		<0.055	<0.14
Freshwater	River Chess	1[E]	<4.0			<1.3	<0.71	<6.0	<62	<0.26		<0.070	0.15
Freshwater	River Misbourne	1[E]	<4.0			<1.1	<0.71	<4.0	<0.45	<0.32		0.13	0.10
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<23	<2.9	<1.1	<1.1	<0.61	<0.29		<0.27	<0.36	<0.24	0.69
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<25	<5.3	1.6	<1.1	<0.61	<0.26		<0.25	<0.34	<100	<100
Final effluent[e]	Maple Lodge Sewage Treatment Works	4[E]	<22	<3.7	<1.1	<1.0	<0.60	<0.26		<0.25	<0.33	<0.10	0.46

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	<6.3	<0.25			<0.30	<0.021	<0.0045	<0.21		
Milk	max		7.3	<0.30			<0.33	<0.023	<0.0048	<0.23		
Apples		1	<5.0	<0.20			<0.30	<0.050		<0.20		
Beetroot		1	6.0	<0.20			<0.30	<0.032		<0.30		
Blackberries		1	<4.0	3.1			<0.20	<0.026		<0.30		
Courgettes		1	<4.0	<0.20			<0.30	<0.060		<0.30		
French beans		1	<5.0	<0.20			<0.30	<0.052		<0.30		
Runner beans		1	<5.0	<0.20			<0.20	<0.050		<0.20		
Spinach		1	<4.0	0.60			<0.30	<0.028		<0.30		
Wheat		1	<8.0	2.0			<0.20	<0.12		<0.30		
Grass	Next to site	1[E]		9.8	<2.5	<1.5		<7.0	<0.87	<0.63	<100	130
Grass	Orchard next to site	1[E]		6.2	<4.5	<2.8		<20	<1.5	<1.1	<100	96
Grass	Water Meadows (River Chess)	1[E]		5.3	<3.9	<2.3		<20	<1.4	<0.96	<100	150
Soil	Next to site	1[E]			<1.9	<0.97		<5.0	<0.98	11	380	640
Soil	Orchard next to site	1[E]			<2.2	<1.1		<6.0	<1.2	14	300	790
Soil	Water Meadows (River Chess)	1[E]			<1.7	<0.90		<5.0	<1.0	11	140	240

[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 <4.8 Bq l^{-1}*

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

[f] *The gamma dose rates in air at 1m over grass and grass and mud on the bank of the Grand Union Canal were 0.058 and 0.053 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, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H[g]	^{3}H	^{14}C	^{99}Tc	^{125}I	^{131}I	^{134}Cs	^{137}Cs
Marine samples										
Cod	East of new pipeline	1		930	43			*	<0.04	0.50
Flounder	East of new pipeline	4	2000	2300	70			*	<0.06	0.46
Sole	East of new pipeline	2		2400	160			*	<0.05	0.36
Mullet	East of new pipeline	1		53	30			*	<0.12	0.52
Lesser spotted dogfish	Off Orchard Ledges	2	540	600	52			*	<0.15	0.57
Skates/Rays	Off Orchard Ledges	2	1600	1800	64			*	<0.06	0.98
Mussels	Orchard Ledges	2	1800	2000	53			*	<0.08	0.23
Seaweed[j]	Orchard Ledges	2[E]		55	<28	19	<1.4	3.8		<0.97
Sediment	East of new pipeline	2[E]		72	<25		<0.59			13
Sediment[i]	West of new pipeline	2[E]		97	<25		<1.5			22
Seawater[h]	Orchard Ledges	2[E]		<25	<15		<0.28			<0.31

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}										
			Organic ^{3}H[g]	^{3}H	^{14}C	^{32}P	^{35}S	^{125}I	^{131}I	^{134}Cs	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples													
Milk		6	<6.0	<8.3	17	<0.35	<0.38	<0.023		<0.20	<0.20		
Milk	max		<9.1	<19	19	<0.37	<0.53	<0.026					
Barley		1		<7.0	94		1.4	<0.064		<0.20	<0.20		
Blackberries		1	3.0	64	19		0.20	<0.051		<0.20	<0.20		
Cabbage		1	<22	22	9.0		1.1	<0.12		<0.20	<0.20		
Honey		1		<8.0	58		<0.10	<0.030		<0.20	<0.30		
Leeks		1	17	78	23		0.20	<0.047		<0.30	<0.30		
Onions		1	1.0	20	8.0		0.40	<0.065		<0.20	<0.30		
Potatoes		1	11	34	24		<0.10	<0.089		<0.20	<0.30		
Rape oil		1		82	88		4.8	<0.069		<0.20	<0.30		
Raspberries		1	7.0	57	9.0		0.30	<0.023		<0.20	<0.20		
Swede			7.0	85	10		0.40	<0.024		<0.20	<0.20		
Grass		5	<51	180	44					<0.20	<0.20		
Grass	max		110	540	53						0.20		
Silage		2	18	23	41								
Silage	max		27	35	46								
Soil		3								<0.23	7.2		
Soil	max									<0.30	8.2		
Sediment	Canal	2[E]		73	<25			<3.9			10		
Freshwater[d]	Run off into River Taff	2[E]		<25	<15			<0.44	<0.54	<0.29	<0.050		0.27
Freshwater[e]	Canal	2[E]		<23	<15			<0.50	<0.58	<0.28	<0.075		0.11
Freshwater[f]	River Taff	2[E]		<25	<15			<0.35	<0.62	<0.29	<0.060		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*

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

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

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

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

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

[i] *The concentration of ^{3}H as tritiated water was 18 Bq l^{-1}*

[j] *The concentration of ^{3}H as tritiated water was 12 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, 2007

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud	1	0.084
East of Pipeline	Mud and sand	1	0.080
West of Pipeline	Mud and stones	1	0.095
West of Pipeline	Pebbles and rock	1	0.10
Peterstone Wentlooge	Salt marsh	2	0.080

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

- New operator for Drigg in 2007
- Some disposals of solid radioactive waste were reduced in 2007
- Concentrations and dose rates at LLWR near Drigg were similar to those in 2006
- Doses for LLWR near Drigg were less than 2 per cent of dose limit (Table 7.1)
- 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 (from non-nuclear industrial activity) at Whitehaven from phosphate processing now very difficult to detect
- Dose from Whitehaven enhancement estimated to be up to 28 per cent of dose limit
- Contamination on Aberdeen Beach with naturally-occurring radionuclides continued but no restriction on access was required
- Radium-226 contamination requires further investigation near Dalgety Bay, Fife

7.1 Low Level Waste Repository near Drigg, Cumbria

The main function of the national Low level Waste Repository (LLWR) near Drigg is to receive low level solid radioactive wastes from Sellafield and other UK sites and to dispose of them in vaults on land. LLW Repository Limited separated from the Sellafield site (29 July 2007) and became the operator as a stand alone site licence company.

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 which 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).

Following a public consultation on the future regulation of radioactive waste disposals at the site, the Environment Agency published a proposed Decision Document, which it submitted to Defra and Department of Health Ministers in February 2006 (Environment Agency, 2006k). Ministers published their conclusions and chose not to exercise their powers of direction under section 23 of RSA 93 (Department for Environment, Food and Rural Affairs and Department of Health, 2006). The Environment Agency issued a new authorisation, effective from 1st May 2006.

The most recently revised disposal authorisation allows for the discharge of leachate from the trenches 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 that is 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 2007, be distinguished from those due to Sellafield. In 2007, disposals of solid radioactive waste were reduced for carbon-14, and radium–226 plus thorium-232 (Appendix 2).

The authorisation for disposal to the Drigg Stream is now revoked but reassurance monitoring of spot samples of water and sediment taken from the Drigg stream have continued. The results are given in Table 7.2. The gross beta concentrations were below the WHO screening levels for drinking water. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use by, for example, campers could take place. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2006. 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. The concentrations of gross alpha and gross beta activity were similar to those for 2006 and were approximately the same as WHO screening values for drinking water. Low concentrations of tritium were detected.

The monitoring programme of terrestrial foodstuffs at the site is primarily directed at the potential migration of radionuclides from the waste burial site via ground water. Results for 2007 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, including a component due to Chernobyl and weapon test fallout, was 0.015 mSv which was less than 2 per cent of the dose limit for members of the public of 1 mSv (Table 7.1).

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 2007 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). 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). SEPA has received an application for disposal of conditioned NORM containing waste arising from oil and gas production at a landfill site near Aberdeen. This is currently being determined by SEPA.

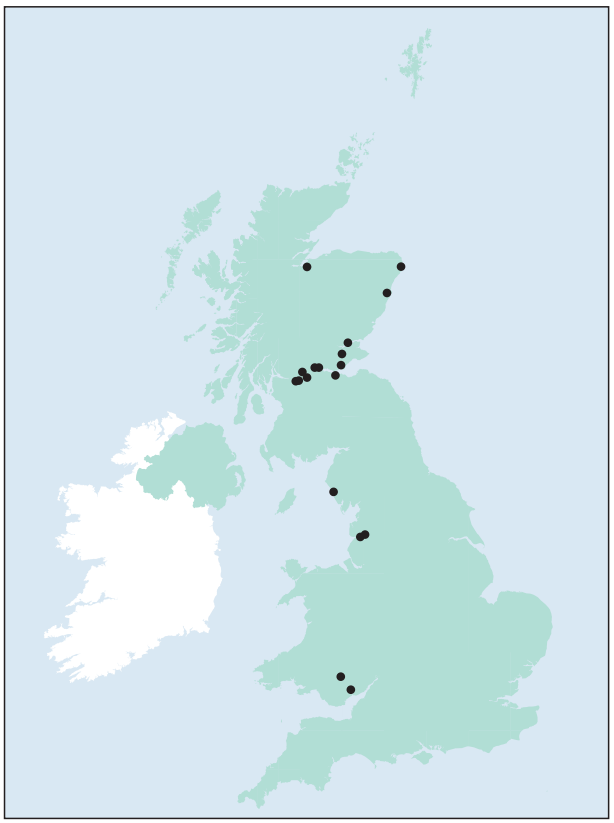


Figure 7.1. Landfill sites monitored in 2007

Results of radium isotope in landfill leachate at Stoneyhill in Aberdeen were close to or at limits of detection. There have been no known radium disposals made to the site, but additional sampling will be undertaken in 2008 to provide a baseline for future use.

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 2007 are shown in Table 7.5. Analytical effort has focused on lead-210 and polonium-210 that concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally-occurring radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. 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 in these samples in 2007 compared with 2006. 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

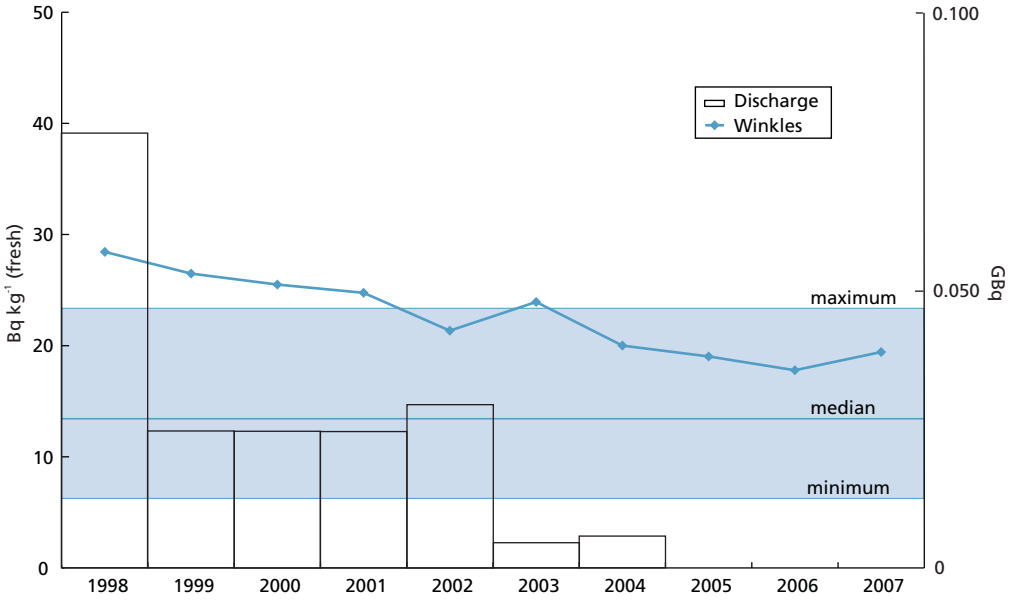


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton

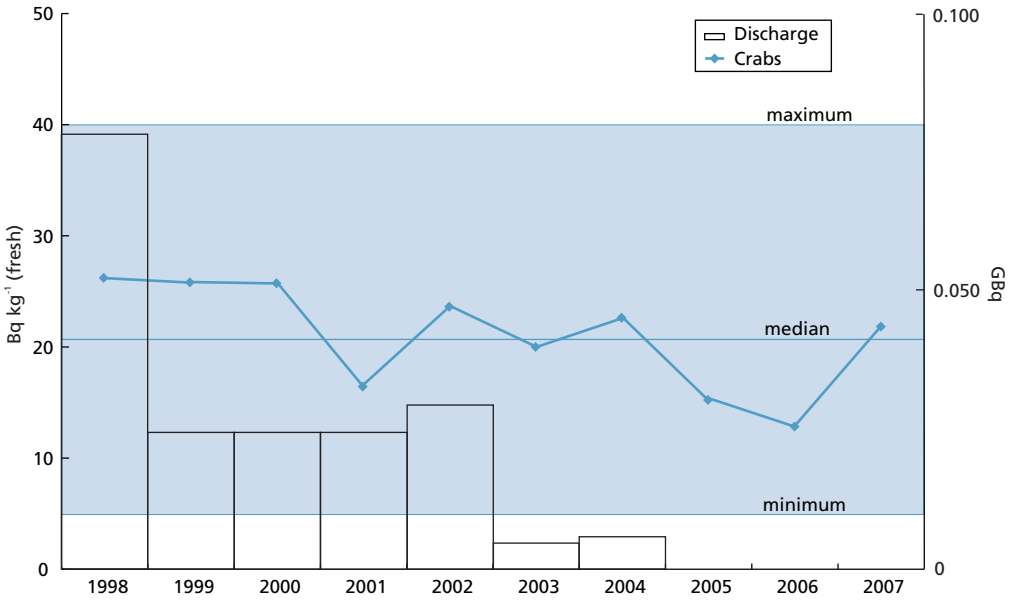


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton

concentrations and median levels indicative of natural background.

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 2007. The assessment is based on averaging the consumption rates over a five-year period from 2003 – 2007. Dose coefficients for polonium-210 were updated this year to reflect new results from research involving the consumption of crabs, mussels and cockles containing natural concentrations of polonium-210 (Appendix 1). Previously, a conservative gut transfer factor of 0.8 was taken to apply to seafood generally, but we have now adopted a value of 0.5 for all food to reflect the most recent advice.

The critical group dose from enhanced naturally-occurring radionuclides from non-nuclear industrial activity (i.e. TNORM) was 0.28 mSv in 2007 (Table 7.1), an increase from the estimate for 2006 of 0.22 mSv (adjusted to use the same dose coefficient as in 2007). The increase is largely due to small increases in concentrations of polonium-210. On the same basis, 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 (excluding winkles). 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 2007, these exposures added a further 0.24 mSv to the doses above resulting in a total dose to this group of up to 0.52 mSv rounded to 2 significant figures. The estimated doses in 2007 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 requires use of the discharge pipeline to cease by December 2008. Scotoil have appealed to Scottish Ministers against certain conditions contained in the variation notice. Evidence was presented by SEPA and Scotoil at a public hearing held in Aberdeen over 7 days in March and April 2008. The reporter has submitted his recommendations concerning the appeal to Scottish Ministers for their consideration.

During 2007, the dose rate on the beach was 0.22 Gy h^{-1} and the concentration of radium – 226 was 1500 Bq kg^{-1} (dry). These data are similar to those previously found.

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)

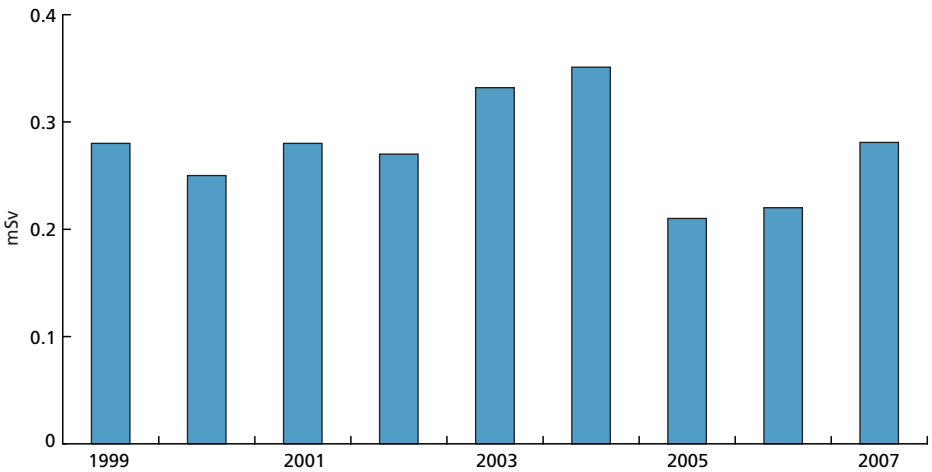


Figure 7.4. Trend in dose to seafood consumers from naturally-occurring radionuclides near Whitehaven, 1999 - 2007

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 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) and Scottish Environment Protection Agency (2006d)). The screening risk assessment considered the range of activities of radium-226 in samples removed from the beach, the likelihood of encountering such items and various modes of exposure – ingestion, inhalation and external exposure. The report is available on the SEPA website at http://www.sepa.org.uk/radioactivity/publications.htm.

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. However, the risks from use of the public open spaces investigated are relatively low. Further survey work is planned in 2008 to characterise the contamination and to provide data for a determination, in accordance with the Scottish Government's Statutory Guidance on the Radioactive Contaminated Land (Scotland) Regulations 2007.

7.6 Other non-nuclear sites

Other small-scale studies of the effects of waste discharges from non-nuclear sites were conducted in 2007.

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 7.6). Low concentrations of phosphorus-32 were not detected as they were in 2006, however this is likely to be because limits of detection were higher in 2007, otherwise results were similar to those in 2006. 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.

The Environment Agency has investigated the behaviour of phosphorous-32 in river systems. Initial results from the River Cam in Cambridgeshire were reported in last year's RIFE report. In 2007, a research study was initiated to determine what the main controlling factors that influence phosphorous uptake into freshwater fish might be. Two particular issues were pursued. Firstly, whether the presence of high concentrations of stable phosphorous in solution downstream of a sewage works might reduce the uptake of phosphorous-32 into fish. Secondly, what is the uptake of phosphorous, is it via the food chain and if so would the time taken for phosphorous to transfer through the food chain allow significant radioactive decay as part of the process. A report on this work, when completed, will be reviewed in a future issue of this report.

SEPA undertook a series of sampling exercises at sewage treatment works in Glasgow and Dundee to examine the effects of disposal of liquid wastes from hospital, research establishments and other industries (Scottish Environment Protection Agency, 2008). Discharges were reviewed using RSA 93 schedules and sampling was targeted to coincide with the timing of expected disposals. The results of the sampling were used to undertake a dose assessment to potential critical groups and also to biota. Doses to man from radionuclides that were identifiable in the discharge authorisation schedule were trivial and ranged from 0.004 to 0.026 mSv per year. In addition the potential dose contribution from anthropogenic radionuclides measured but not listed in the authorisations ranged from 0.006 to 0.066 mSv per year.

The dose to biota from anthropogenic radionuclides were less than 70 Gy h^{-1} which is much less than the IAEA/UNSCEAR benchmark of 400 Gy h^{-1} for aquatic organisms.

Table 7.1. Individual radiation exposures - industrial and landfill sites, 2007

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]	0.015	-	-	0.015	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers[b]	<0.005	-	-	-	-	<0.005
Whitehaven	Seafood consumers[c]	0.52	0.21	0.28	-	0.031	-

[a] *Adults are the most exposed group unless stated otherwise*
[b] *Children aged 1y*
[c] *Includes the effects of discharges from the adjacent Sellafield site*

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2007

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	<5.3	14	<0.21	0.073	<0.32	<0.28	<0.0045	<1.3	<0.43
Blackberries		1	<4.0	19	<0.20	0.49	<0.30	<0.20		<1.1	<0.30
Cabbage		1	8.0	7.0	<0.20	0.51	<0.20	<0.30	<0.033	<2.0	<0.50
Deer muscle		1	<6.0	21	<0.10	<0.0080	<0.20	<0.20	<0.022	<0.90	<0.30
Eggs		1	<6.0	30	<0.10	0.0090	<0.30	<0.20		<1.2	<0.40
Potatoes		1	<4.0	18	<0.20	0.078	<0.30	<0.20	<0.022	<1.5	<0.40
Rabbit		1	8.0	20	<0.30	0.017	<0.30	<0.20	<0.022	<1.5	<0.40
Sheep muscle		1	10	31	<0.20	<0.0060	<0.40	<0.30	<0.011	<1.1	<0.40
Sheep offal		1	9.0	17	<0.10	0.42	<0.30	<0.30	<0.011	<1.5	<0.50
Turnips		1	<5.0	8.0	<0.20	0.50	<0.40	<0.30		<1.9	<0.60
Grass		2							0.031		
Grass	max								0.037		
Sediment	Drigg Stream	3[E]			<0.76	<7.0	<2.0	<0.57		<5.7	<6.6
Freshwater	Drigg Stream	3[E]	12		<0.32	<0.087					
Freshwater	Railway Drain	1[E]	37		<0.30	2.1					

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	<0.0080	<0.18	<0.24		<0.93				
Blackberries		1	<0.033			0.12	<0.70				
Cabbage		1	<0.041			0.10	<0.90				
Deer muscle		1	<0.052			0.44	<0.60				
Eggs		1	<0.026			0.065	<0.50				
Potatoes		1	0.041			0.33	<0.70				
Rabbit		1	<0.041			0.87	<1.1				
Sheep muscle		1	<0.039			0.75	<0.90				
Sheep offal		1	<0.049			0.72	<0.90				
Turnips		1	<0.027			0.26	<0.80				
Sediment	Drigg Stream	3[E]		<0.66	190		<3.3	14	18	13	11
Freshwater	Drigg Stream	3[E]		<0.29	<0.27			<0.011	<0.013	<0.0077	<0.0067
Freshwater	Railway Drain	1[E]		<0.28	<0.24			<0.020	<0.0060	<0.0060	<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	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1					<0.00015	<0.00015	<0.032	<0.00013		
Blackberries		1					<0.00020	0.00050	<0.039	0.00070		
Cabbage		1					<0.00020	0.00020	<0.066	0.00030		
Deer muscle		1					<0.00010	0.00040	0.083	0.00050		
Eggs		1					<0.00030	<0.00010	<0.074	0.00030		
Potatoes		1					<0.00030	0.00030	<0.036	0.00020		
Rabbit		1					0.00020	<0.00030	<0.068	<0.00030		
Sheep muscle		1					0.00030	0.00050	<0.075	0.00060		
Sheep offal		1					0.0019	0.0083	<0.076	0.011		
Turnips		1					<0.00020	<0.00040	<0.16	<0.00020		
Grass		2				0.096						
Grass	max					0.13						
Soil		1	4.5	0.19	4.5							
Sediment	Drigg Stream	3[E]	100	2.4	57		4.3	24	110	21	420	940
Freshwater	Drigg Stream	3[E]	<0.010	<0.0050	<0.0080		<0.015	<0.0080	<1.0	<0.013	<0.12	0.42
Freshwater	Railway Drain	1[E]	0.033	<0.0050	0.026		<0.0060	<0.0050	<1.0	<0.010	0.69	5.5

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

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

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

[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, 2007

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{3}H	^{14}C	^{137}Cs	^{210}Po	^{226}Ra	$^{228}Ra^{a}$	^{241}Am
Aberdeen City	Ness Tip	1	360	<15	<0.05				<0.05
Aberdeenshire	Stoneyhill, Burnwater North of site	1				0.0084	<0.21	<0.032	
Aberdeenshire	Stoneyhill, Burnwater South of site	1				0.0011	<0.10	<0.016	
Aberdeenshire	Stoneyhill	1				0.0093	0.28	0.61	
City of Glasgow	Summerston Tip	1	250	<15	0.08				<0.05
City of Glasgow	Cathkin	1	160	<15	<0.05				<0.05
Clackmannanshire	Black Devon	1	<5.0	<15	<0.05				<0.05
Dunbartonshire	Birdstone	1	<5.0	<15	<0.05				<0.05
Dundee City	Riverside	1	<5.0	<15	<0.05				<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05				<0.05
Fife	Balbarton	1	71	<15	<0.05				<0.05
Fife	Melville Wood	1	100	<15	<0.05				<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05				<0.05
North Lanarkshire	Dalmacoulter	1	260	<15	<0.05				<0.05
Stirling	Lower Polmaise	1	<5.0	<15	<0.05				<0.05

[a] *Assumes ^{228}Ra in equilibrium with ^{228}Ac*

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2007

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	1	1700	1300	<4.0													
Lancashire																		
Clifton Marsh	Borehole 6	2		60		<6.4	<0.30			<0.26	<0.0060	<0.0070	<0.0050	0.081	<0.0060	0.079	<0.25	3.3
Clifton Marsh	Borehole 19	2		5.6		<6.5	<0.30			<0.25	<0.0055	<0.0050	<0.0050	0.019	<0.0050	0.014	<0.30	2.5
Clifton Marsh	Borehole 40	2		<5.5		<6.3	<0.29			<0.26	<0.015	<0.020	<0.0060	<0.0090	<0.0050	<0.0095	<0.075	0.95
Clifton Marsh	Borehole 59	2		43		<6.5	<0.30			<0.27	<0.012	<0.0050	<0.0050	<0.0060	<0.0050	<0.0055	<0.20	2.9
Ulnes Walton	Pond	1		<4.0		<6.2	<0.29			<0.25	0.0080	<0.0050	<0.0050	0.46	0.016	0.42	0.31	0.47
South Glamorgan																		
Lamby Way Tip	Borehole 1A	1		9.3	<4.0	<6.5	<0.31	<0.29	<0.67	<0.26							<0.30	0.57

[a] *As tritiated water*

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2007

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	20	2.1						
Winkles	Parton	4	19	1.3	0.86	1.2	0.52	1.3	0.049	1.2
Winkles	North Harrington	1	23							
Winkles	Nethertown	4	19							
Winkles	Drigg	1			0.71	0.71	0.46			
Winkles	Tarn Bay	1	12							
Mussels	Parton	4	48	1.4						
Mussels	Nethertown	4	47	1.6						
Limpets	St Bees	2	15							
Cockles	Ravenglass	2	34							
Crabs	Parton	4	22	0.072	0.060	0.015	0.0058	0.058	0.0034	0.052
Crabs	Sellafield coastal area	4	21	0.13						
Lobsters	Parton	4	11	0.0010	0.046	0.0089	0.0044	0.031	0.0010	0.028
Lobsters	Sellafield coastal area	4	13	0.050						
Cod	Parton	2	0.51	0.042	0.038	0.010	0.0058	0.0016	*	0.0012
Dabs	Whitehaven	1	1.5							
Other samples										
Winkles	South Gare (Hartlepool)	2	11	0.46						
Winkles	Paddy's Hole (Hartlepool)	1	20							
Winkles	Kirkcudbright	1	4.0							
Mussels	Ribble Estuary	2			0.16	0.19	0.074			
Limpets	Kirkcudbright	1	15							
Cockles	Southern North Sea	1			0.31	0.14	0.18			
Cockles	Flookburgh	2	19							
Cockles	Ribble Estuary	1			0.10	0.30	0.14			
Queens	Kirkcudbright	1	0.98							
Crabs	Kirkcudbright	1	4.3							
Lobsters	Kirkcudbright	1	1.0							
Shrimps	Ribble Estuary	2			0.0061	0.0055	0.0025			
Wild fowl	Ribble Estuary	1			<0.00029	0.025	0.0052			
Sediment	Kirkcudbright	1						13	0.92	10
Sediment	Rascarrel Bay	1						6.0	0.50	6.4

** Not detected by the method used*

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

Table 7.6 Monitoring in the River Clyde, 2007[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	<45		11	<0.62
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1			<15		93	<0.24
14 km downstream of Dalmuir	Sediment	1		<15	<120			1.1
Downstream of Dalmuir	Freshwater	4			<0.38			<0.13
River Clyde	Freshwater	4	<1.3			<0.0047		
Daldowie	Sludge pellets	4			<180			<0.83

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	0.34	<0.72	<0.42		
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1	0.87	<0.24	<0.15		
14 km downstream of Dalmuir	Sediment	1	53	0.66	<0.70		
Downstream of Dalmuir	Freshwater	4	<0.10	<0.13	<0.10		
River Clyde	Freshwater	4	<0.10			<0.039	0.39
Daldowie	Sludge pellets	4	6.2	<0.92	<0.47		

[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 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. Restrictions still in place on movement, sale and slaughter of sheep. 95 per cent of restrictions have been lifted since 1986
- 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 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 live monitoring, 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 monitoring programme for 2007 are given in Table 8.1.

In the summer of 2007, whole flock monitoring surveys of sheep on selected farms in the post-Chernobyl restricted areas of England and Scotland were conducted with the aim of removing restrictions where controls are no longer necessary (Food Standards Agency, 2008a,b). The results of the survey in Scotland identified two farms where controls could be lifted and this decision was implemented in January 2008, leaving 5 farms subject to restrictions. The results of the survey in England did not identify any farms where controls could be lifted. It had been planned that surveys would also be conducted on selected farms in Wales. However, the outbreak of Foot and Mouth Disease (FMD) in late July of 2007, meant that it was not possible to proceed with these.

There remain a total of 369 farms, or part farms, and approximately 200,000 sheep within the restricted areas of England, Scotland and Wales. This represents a reduction of over 95 per cent since 1986, when approximately 9,700 farms and 4,225,000 sheep were under restriction across the UK. All remaining restrictions in Northern Ireland were lifted in 2000.

During the summer of 2007, a field calibration exercise was also conducted for new monitors purchased by the Food Standards Agency. These replaced the existing monitors used in the Mark and Release Scheme, with effect from the 1st April 2008. The calibration exercise was conducted on restricted farms across England, Wales and Scotland and compared live monitoring results with laboratory determined concentrations of caesium contamination in the muscle tissue. The exercise consisted of the live monitoring of over 1,000 sheep, of which over 100 were selected as kill samples for laboratory analysis.

Sampling locations for freshwater fish are now limited to Cumbria in England and southern Scotland, both areas of relatively high deposition of fallout from Chernobyl. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 8.2 presents concentrations of caesium-134 and caesium-137 in fish and water. Other artificial radionuclides from the Chernobyl accident are no longer detectable. The highest concentration was 140 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 (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have much lower radiocaesium concentration. In 2007, 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. 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 2007 are given in Table 8.3. Radionuclides, which can be attributed to routine releases from the nuclear industry, were detected in some samples (cobalt-60 and technetium-99). However, all concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the critical group of high-rate fish and shellfish consumers gives a dose of less than 0.005 mSv in 2007, 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 given in Table 8.10 and Table 8.11, respectively, and form parts of the programme 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 was detected in local milk and crops at activity concentrations close to the natural background values observed in the regional network of sampling locations remote from nuclear sites. Concentrations of strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites, at those locations known to have received similar levels of Chernobyl and weapon test fallout. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2007.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2007 was 0.012 mSv (0.016 mSv in 2006) which is less than 2 per cent of the dose limit for members of the public of 1 mSv.

The effects of liquid discharges from Sellafield Limited in the Irish Sea are discussed fully in Section 2. The dose to the critical group of Manx fish and shellfish consumers was 0.006 mSv in 2007 (similar to 2006) 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 2007, the main effects of Sellafield were evident as concentrations of technetium-99, caesium-137 and actinides in marine samples. Observed concentrations and dose rates were less than those found nearer to Sellafield and were generally similar to those in 2006. Increases of technetium-99 in seaweed were found at Carlingford Lough and 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 the results from monitoring the marine environment in 2007 was 0.015 mSv, which is less than 2 per cent of the dose limit for members of the public.

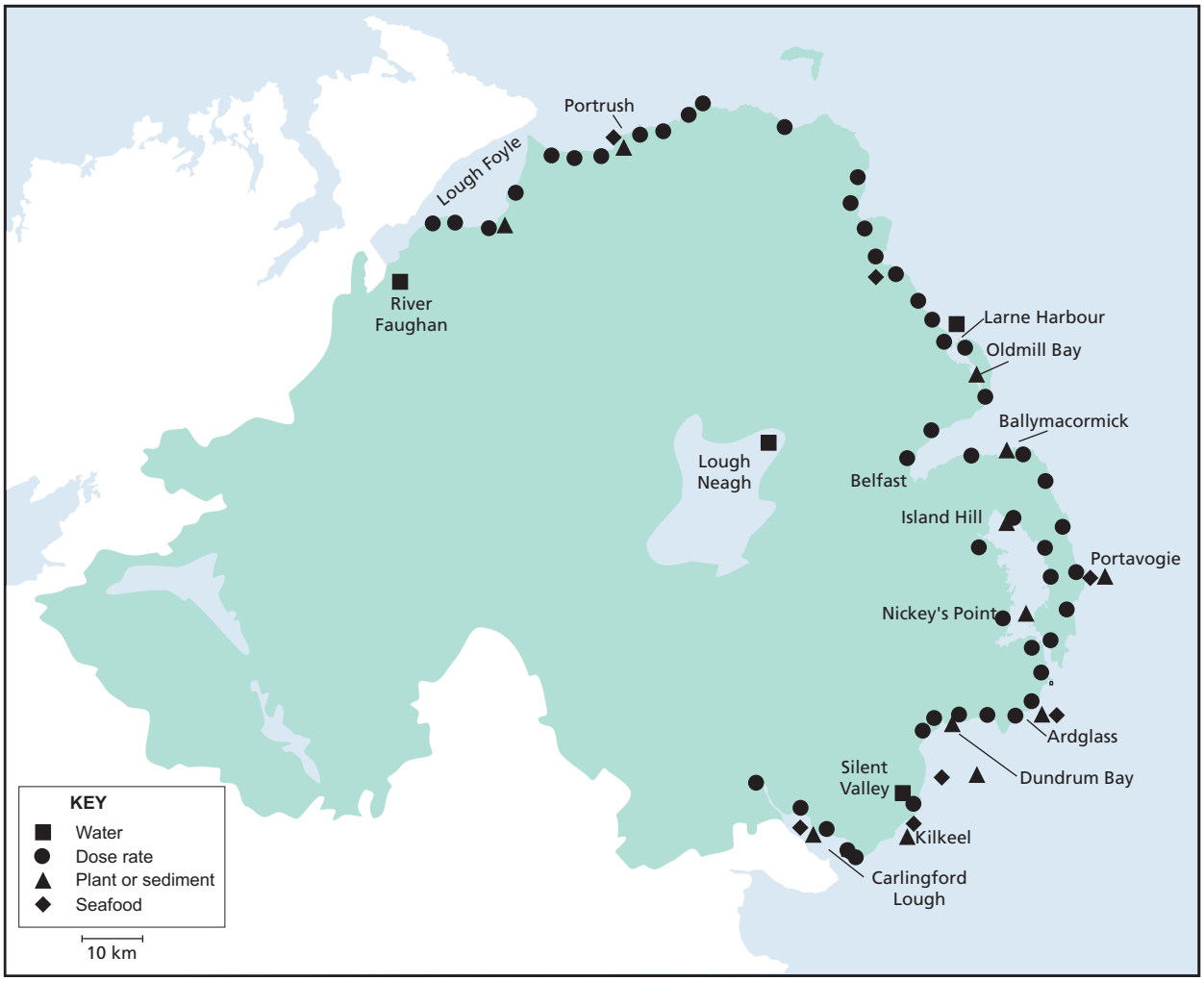


Figure 8.1. Monitoring locations in Northern Ireland

8.5 General diet

As part of the Government's general responsibility for food safety, radioactivity in whole diet is determined on a regional basis. Measurements are made on samples of mixed diet from regions throughout the UK. Most samples are derived from the Food Standards Agency's 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 and is based on an average of three previous years of consumption data from the National Food Survey (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). These samples are analysed for a range of food constituents including radioactivity. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both naturally-occurring and man-made origins were measured in samples in 2007. The results are provided in Tables 8.6 and 8.7.

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. There was some variability from region to region, but in general no more than is usually detected from the programme. Concentrations of polonium-210 were higher at Swaffham in Norfolk than in other areas. Within the normal variability observed from previous data, 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 summarized 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 0.056 mSv, similar to the value for 2007 of 0.049 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 1 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 0.20 mSv based on sampling at Greenock in Renfrewshire, with over 90 per cent of the dose being derived from lead-210 and polonium-210. In 2006, the highest exposure in the UK was 0.17 mSv.

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 at dairies in the UK continued in 2007. 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 2007 were similar to those for previous years. These results are summarized 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 0.04 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 concentrationsare 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 dairy milk at average rates were highest for the one-year-old infant age group. For the range of radionuclides analysed, the dose was less than 0.005 mSv. Previous surveys (e.g. Food Standards Agency and Scottish Environment Protection Agency, 2002) have shown that if a full range of nuclides are analysed and assessed the dose is dominated by naturally-occurring lead-210 and polonium-210 and man-made radionuclides contribute less than 10 per cent.

8.7 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2007 (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. Higher values of natural radionuclides were found in vegetables from Flintshire. However, within the normal variability observed, the concentrations of other radionuclides in crops were similar to those observed in 2006.

In 2007, 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. Eight samples were analysed and the results are given in Table 8.12. The activity concentrations ranged from < 1.9 – 1,327 Bq kg^{-1}. No action on food restrictions was necessary.

8.8 Airborne particulate, rain and freshwater

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 or close to 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 2006. 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 2007 (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

* *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*

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.

Results for the River Thames, which receives authorised discharges from GE Healthcare, UKAEA Harwell and AWE Aldermaston, are consistent with those from the regulatory monitoring in the vicinity of the sites' discharge points.

The mean annual dose from consumption of drinking water in the UK was assessed as 0.028 mSv in 2007 (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 0.055 mSv due to radionuclides in a source of drinking water from the River Dee in Cheshire.

During 2007, 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 demonstrate that variability within the samples, seasonally and geographically, was low. Sampling will continue in 2008.

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). OSPAR in 2006 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 the 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 of 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 2007 cruises are presented in Figures 8.3 – 8.7. Shoreline sampling is also conducted around the UK, and the data are given in Table 8.19. 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 2007 caesium-137 data for the Irish Sea (Figure 8.3) show a similar range of levels to those observed in recent years, the general distribution being one of falling concentrations as the distance from Sellafield increases. Concentrations of caesium-137 were reasonably uniform (< 0.05 Bq l^{-1}) in a large proportion of the Irish Sea. Slightly increased levels, from most recent discharges, were observed along the Cumbrian and southern Scottish coastline. Relatively higher caesium-137 concentrations south of the Isle of Man were most likely due to the variability of circulation patterns, largely driven by meteorological conditions (McCubbin *et al.*, 2002). Overall, 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 predominant source term is remobilization 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 Irish Sea (Figure 8.5) were generally higher than those observed in the North Sea (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007) due to the influence of discharges from Sellafield and other nuclear sites. The overall distribution of tritium in

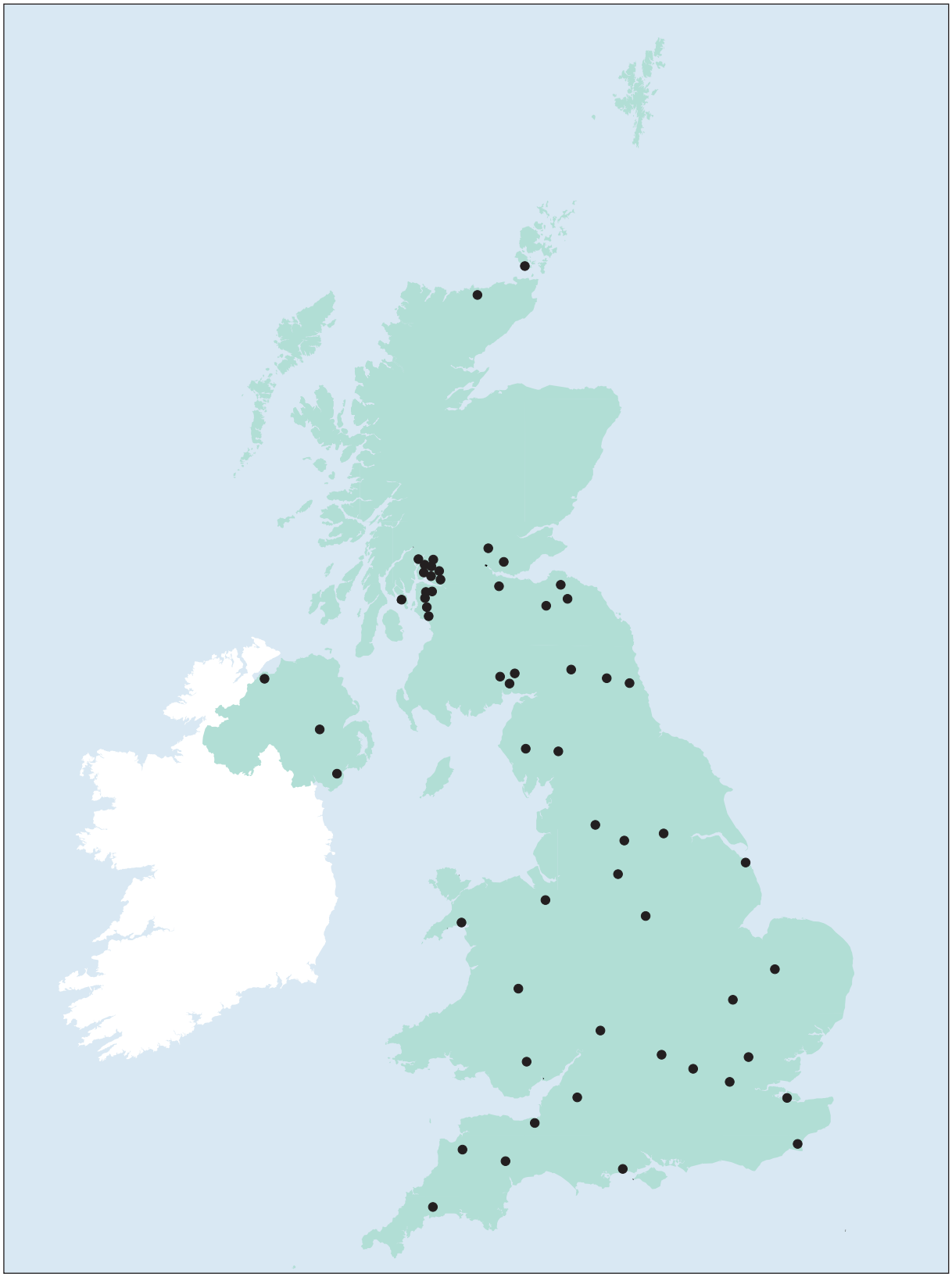


Figure 8.2. Drinking water sampling locations

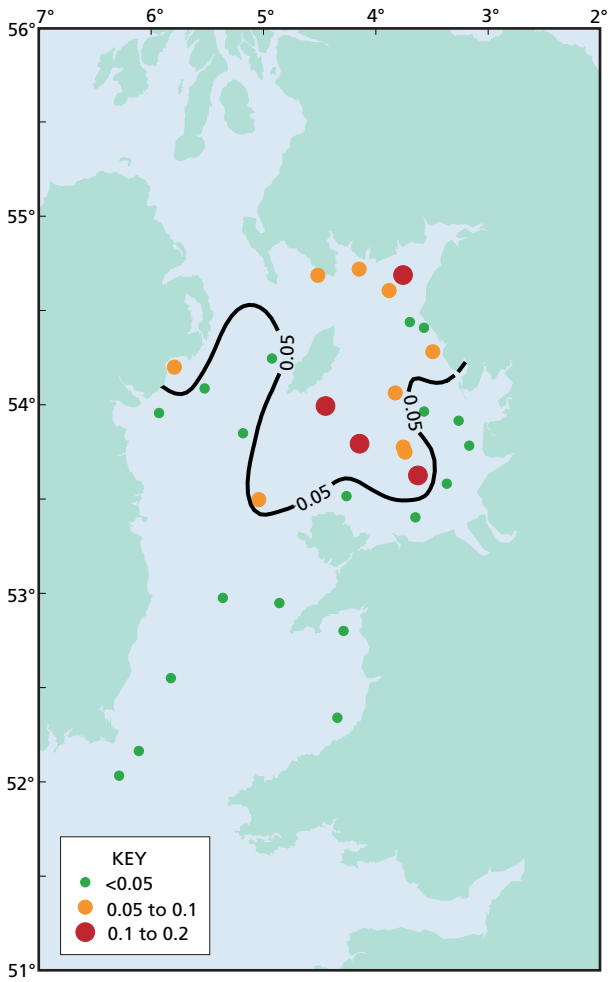


Figure 8.3. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the Irish Sea, June 2007

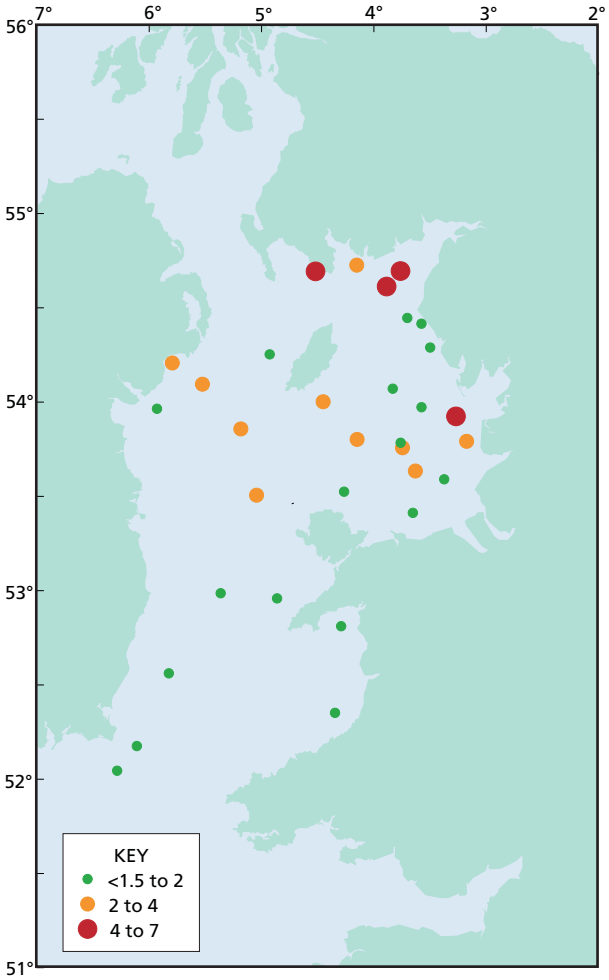


Figure 8.5. Concentrations (Bq l^{-1}) of tritium in surface water from the Irish Sea, June 2007

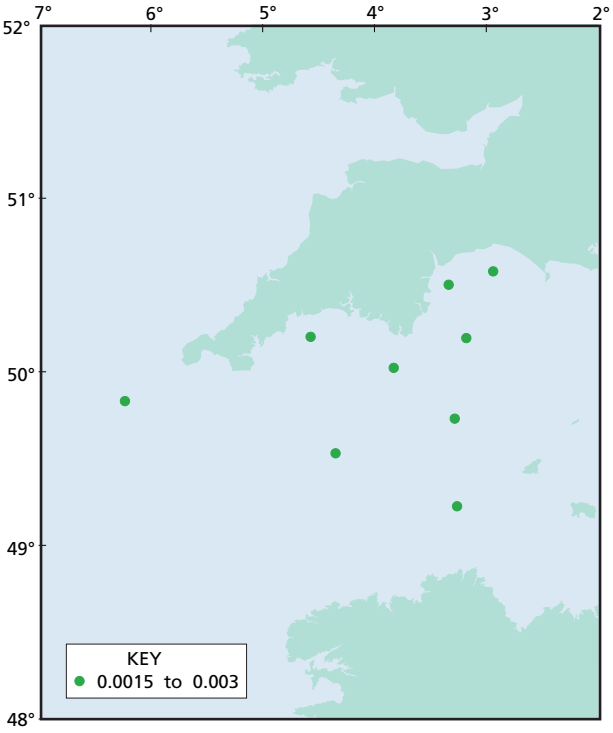


Figure 8.4. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the western English Channel, March 2007

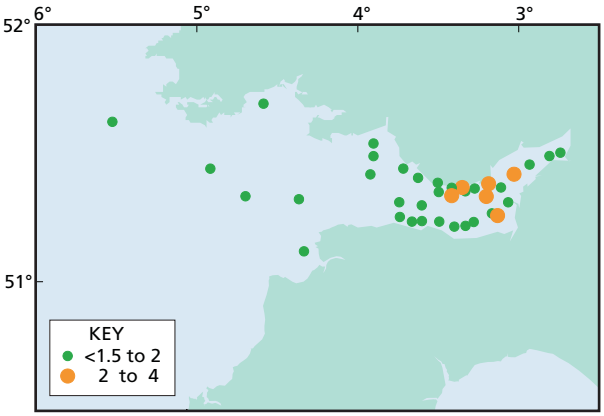


Figure 8.6. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, October 2007

the Irish Sea was similar to that observed from recent discharges of caesium-137 (Figure 8.3). In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 8.6). Concentrations in the western English Channel were below detection (Figure 8.7).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed since 1994. The results of research cruises to study this radionuclide have been published by Leonard *et al*., (1997a,b, 2004) and McCubbin *et al*., (2002). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*. (1999). A full review of the quality status of the north Atlantic has been published by OSPAR (2000b).

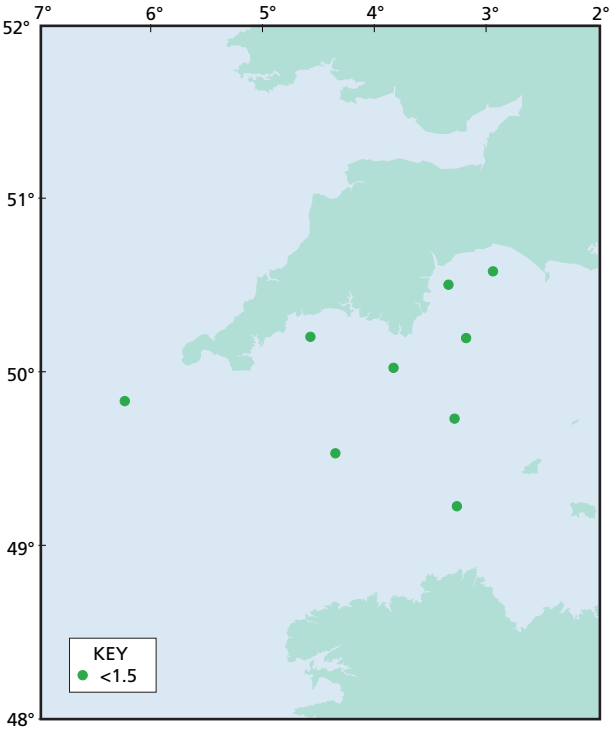


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water from the western English Channel, March 2007

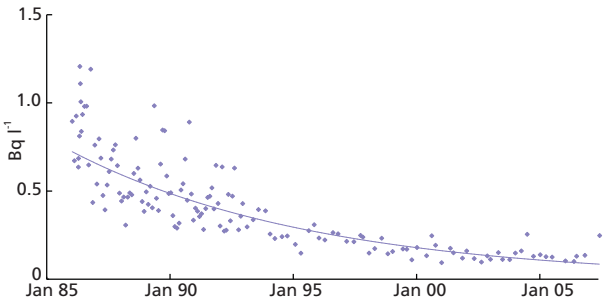


Figure 8.8. Temporal variation of dissolved caesium-137 in shoreline seawater close to Sellafield (at St Bees), 1986-2007

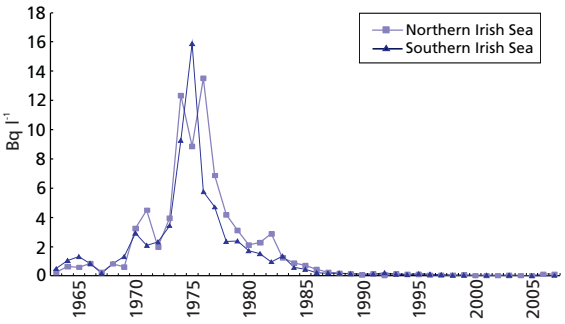


Figure 8.9. Concentrations of caesium-137 in the Irish Sea, 1963-2007

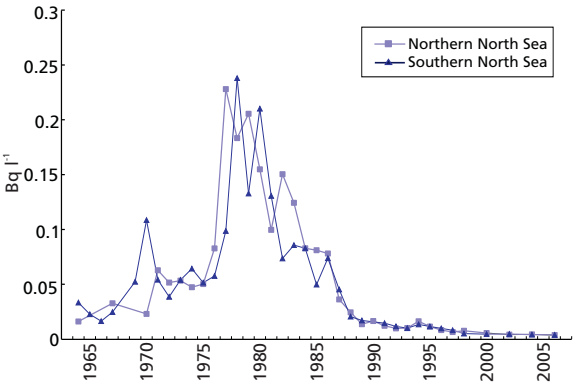


Figure 8.10. Concentrations of caesium-137 in the North Sea, 1964-2006

Table 8.1. Monitoring of sheep in England, Wales and Scotland, 2007

Country	Number of sheep monitored	Number of sheep above action level	Percentage of sheep above action level
England	6064	0	0
Wales	84543	8	<0.1
Scotland	3451	1559	45.2

Table 8.2. Concentrations of radiocaesium in the freshwater environment, 2007

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Brook char	1	<0.09	0.19
Cogra Moss	Rainbow trout	2	<0.06	0.40
Narborough[b]	Rainbow trout	1	<0.06	0.10
Low Wath	Rainbow trout	1	<0.05	0.26
Devoke Water	Brown trout	1	<0.11	50
Devoke Water	Perch	1	<0.29	140
Gilcrux	Rainbow trout	1	<0.07	0.17

[b] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 29, <0.000032, 0.000082 and 0.000041 Bq kg^{-1} respectively*

Table 8.3. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2007

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				<0.07			<0.71		0.13
Mackerel	Jersey	1				<0.05			<0.42		0.20
Bass	Guernsey	1				<0.07			<0.74		0.27
Bass	Jersey	1				<0.05			<0.56		0.29
Edible crabs	Guernsey	1				<0.06			<0.60		<0.05
Edible crabs	Jersey	1				<0.06			<0.59		<0.05
Edible crabs	Alderney	2	<25	<25	29	<0.07		<1.0	<0.63		<0.05
Spiny spider crab	Jersey	1				<0.15			<1.5		<0.12
Spiny spider crab	Alderney	1				<0.27			<2.6		<0.19
Lobsters	Guernsey	1				<0.06			<0.58		<0.05
Lobsters	Jersey	1				<0.15		0.36	<1.6		<0.12
Lobsters	Alderney	1				<0.06			<0.60		<0.05
Oysters	Jersey La Rocque	1				<0.04			<0.39		<0.03
Limpets	Guernsey	1				<0.14			<1.7		<0.12
Limpets	Jersey La Rozel	1				<0.04			<0.38		<0.03
Toothed winkle	Alderney	1	<25	<25	23	<0.19	<0.050		<1.8		<0.14
Scallops	Guernsey	1				<0.19			<2.2		<0.16
Scallops	Jersey	2				0.11			<0.40		<0.05
Ormers	Guernsey	1				<0.05			<0.55		<0.05
Porphyra	Guernsey	2				<0.10			<1.2		<0.09
Porphyra	Fermain Bay Jersey Plemont Bay	4				<0.14			<1.2		<0.10
Fucus vesiculosus	Jersey La Rozel	4				<0.15	0.050	2.0	<0.82		<0.07
Fucus vesiculosus	Alderney	2								1.3	
Fucus serratus	Quenard Point Guernsey	2				<0.08	<0.052	1.8	<0.44		<0.04
Fucus serratus	Fermain Bay Alderney	4				<0.26	<0.038	1.9	<0.72		<0.07
	Quenard Point										
Laminaria digitata	Jersey Verclut	4				<0.08			<0.83		<0.07
Laminaria digitata	Alderney Quenard Point	4				<0.08			<0.68		<0.06
Mud	Guernsey	1				0.88			<2.5		1.4
	St. Sampson's Harbour										
Mud	Jersey St Helier	1				4.0			<3.1		2.5
Sand	Alderney	1				1.1			<2.4		1.6
	Lt. Crabbe Harbour										
Seawater	Guernsey	4									0.002
Seawater	Jersey	1									0.001
Seawater	Alderney East	4		4.1							0.002

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	<0.35	<0.13	<0.000037	0.00017	0.00034	0.000055	0.000022	230
Mackerel	Jersey	1	<0.20	<0.08	<0.000095	0.00014	0.00022	*	*	
Bass	Guernsey	1	<0.35	<0.12	0.00063	0.00017	0.00032	*	*	150
Bass	Jersey	1	<0.25	<0.09			<0.06			140
Edible crabs	Guernsey	1	<0.30	<0.11	0.00028	0.00081	0.00021	0.000042	0.00038	74
Edible crabs	Jersey	1	<0.30	<0.11	0.00023	0.00070	0.0024	*	*	100
Edible crabs	Alderney	2	<0.30	<0.11	0.00027	0.00083	0.0030	*	0.00042	110
Spiny spider crab	Jersey	1	<0.76	<0.31			<0.28			96
Spiny spider crab	Alderney	1	<1.4	<0.60	0.0013	0.0041	0.0057	0.000075	0.00047	93
Lobsters	Guernsey	1	<0.28	<0.10			<0.06			110
Lobsters	Jersey	1	<0.63	<0.22	0.00019	0.00052	0.0035	*	0.00051	110
Lobsters	Alderney	1	<0.41	<0.18	0.00039	0.0015	0.0065	*	0.00078	78
Oysters	Jersey La Rocque	1	<0.19	<0.07	0.0020	0.0054	0.0063	*	0.00079	110
Limpets	Guernsey	1	<0.63	<0.20			<0.10			99
Limpets	Jersey La Rozel	1	<0.20	<0.07	0.0019	0.0052	0.0090	0.000099	0.0014	83
Toothed winkle	Alderney	1	<0.65	<0.23	0.0040	0.013	0.017	0.00028	0.0020	77
Scallops	Guernsey	1	<1.1	<0.45	0.00054	0.0022	0.0012	*	0.00015	140
Scallops	Jersey	2	<0.26	<0.11	0.011	0.040	0.042	*	0.0048	120
Ormers	Guernsey	1	<0.40	<0.17			<0.26			94
Porphyra	Guernsey Fermain Bay	2	<0.60	<0.25	0.0039	0.014	0.018	0.00025	0.0015	110
Porphyra	Jersey Plemont Bay	4	<0.46	<0.18			<0.12			140
Fucus vesiculosus	Jersey La Rozel	4	<0.43	<0.18	0.0034	0.0094	0.0048	0.00012	0.00053	210
Fucus vesiculosus	Alderney Quenard Point	2								
Fucus serratus	Guernsey Fermain Bay	2	<0.26	<0.10	0.0048	0.019	0.0094	*	0.0010	160
Fucus serratus	Alderney Quenard Point	4	<0.42	<0.18	0.0046	0.017	0.0054	<0.000023	0.00083	210
Laminaria digitata	Jersey Verclut	4	<0.46	<0.20			<0.27			280
Laminaria digitata	Alderney Quenard Point	4	<0.33	<0.14			<0.12			360
Mud	Guernsey St. Sampson's Harbour	1	<1.6	<0.57	0.059	0.29	0.44	*	0.054	440
Mud	Jersey St Helier	1	<2.2	0.67	0.63	1.7	3.1	*	0.27	380
Sand	Alderney Lt. Crabbe Harbour	1	<1.8	<0.89			<1.5			800

* *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, 2007[c]

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Cod	4	<0.06	<0.36	<0.73		<0.58	<0.13	<0.06	2.3
Herring	3	<0.08	<0.36	<0.59		<0.76	<0.17	<0.08	0.92
Mackerel	1	<0.11	<0.79	<1.6		<1.3	<0.31	<0.13	0.82
Lobsters	4	<0.06	<0.38	<0.76	75	<0.62	<0.14	<0.06	0.47
Scallops	4	<0.05	<0.28	<0.54		<0.49	<0.11	<0.05	0.40
Seaweed	1[E]	<2.0	<2.9	<1.5	110	<13	<11	<1.7	<1.6
Sediment	1[E]	<0.34	<0.53	<0.30		<1.9	<1.8	<0.30	5.7

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], 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	<0.30	0.00012	0.00068	0.0012	*	*		
Herring	3	<0.36	0.0019	0.012	0.024	*	0.000055		
Mackerel	1	<0.77			<0.30				
Lobsters	4	<0.30			<0.12				170
Scallops	4	<0.27	0.030	0.15	0.038	*	0.000085		
Seaweed	1[E]	<5.6			<1.7				
Sediment	1[E]	<1.2			1.3			120	540

Material or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Terrestrial samples									
Milk	2	<4.8	13	<0.30	<0.21	0.031	<0.65	<0.86	<0.0030
Milk max		<5.0	15	<0.40	<0.23	0.035	<0.68	<0.88	
Cabbage	1	8.0	6.0	0.50	<0.20	0.27	<0.20	<0.20	<0.010
Potatoes	1	<5.0	20	0.50	<0.10	0.035	<0.40	<0.20	<0.011
Strawberries	1	<4.0	9.0	<0.30	<0.10	0.14	<0.20	<0.30	

Material or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
		^{106}Ru	^{125}Sb	^{129}I	Total Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples										
Milk	2	<1.7	<0.49	<0.0080	0.078	<1.2	<0.00010	<0.00010	<0.025	<0.00010
Milk max			<0.50		0.080	<1.3				
Cabbage	1	<1.3	<0.40	<0.029	0.0060	<0.60	<0.00030	<0.00030	<0.075	0.00020
Potatoes	1	<1.6	<0.40	<0.030	0.029	<0.90	<0.00030	<0.00020	<0.091	0.00020
Strawberries	1	<1.6	<0.80		<0.012	<1.7				

* *Not detected by the method used*

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

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

[c] *The gamma dose rate in air at 1m over pebbles and sand at Ramsey[E] was 0.080 μGy h^{-1}*

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

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

Table 8.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2007

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs
Cod	Kilkeel	4	35	<0.11		<0.24	1.4
Plaice	Kilkeel	4		<0.06		<0.17	1.8
Haddock	Kilkeel	4		<0.09		<0.19	0.82
Herring	Ardglass	2		<0.09		<0.22	1.4
Spurdog	North coast	5		<0.09		<0.22	2.2
Spurdog	Kilkeel	3		<0.07		<0.21	2.0
Crabs	Kilkeel	4		<0.08		<0.18	0.21
Lobsters	Ballycastle	2		<0.17	83	<0.45	0.26
Lobsters	Kilkeel	4		<0.11	62	<0.24	0.42
Nephrops	Kilkeel	4		<0.14	21	<0.32	0.86
Winkles	Ards Peninsula	1		<0.16		<0.35	0.38
Winkles	Minerstown	2		<0.19		<0.36	<0.35
Mussels	Carlingford Lough	2		<0.13	9.8	<0.31	0.61
Scallops	Co. Down	2		<0.17		<0.33	0.45
Ascophyllum nodosum	Ardglass	2		<0.11		<0.31	0.62
Ascophyllum nodosum	Carlingford Lough	1		<0.10		<0.22	0.46
Fucus spp.	Carlingford Lough	3		<0.17	360	<0.37	0.64
Fucus spp.	Portrush	3		<0.06		<0.14	<0.13
Fucus vesiculosus	Ardglass	1		<0.12	650	<0.31	0.75
Rhodymenia spp.	Strangford Lough	4		<0.11	9.3	<0.23	0.71
Mud	Carlingford Lough	2		<0.49		<1.6	44
Mud	Dundrum Bay	2		<0.43		<1.3	4.8
Mud	Oldmill Bay	2		<0.60		<1.8	30
Mud	Strangford Lough-Nicky's point	2		<0.50		<1.6	27
Mud	Ballymacormick	2		<0.47		<1.4	11
Mud and sand	Carrichue	1		<0.48		<1.1	2.1
Sand	Portrush	2		<0.35		<0.97	0.77
Shell and sand	Carrichue	1		<0.39		<1.4	2.1
Seawater	North of Larne	12			0.0062		0.02

Table 8.5(a). continued

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
Cod	Kilkeel	4			<0.10		
Plaice	Kilkeel	4			<0.16		
Haddock	Kilkeel	4			<0.08		
Herring	Ardglass	2			<0.24		
Spurdog	North coast	5			<0.21		
Spurdog	Kilkeel	3			<0.25		
Crabs	Kilkeel	4			<0.10		
Lobsters	Ballycastle	2			<0.53		
Lobsters	Kilkeel	4			<0.10		
Nephrops	Kilkeel	4	0.0039	0.024	0.083	0.00046	*
Winkles	Ards Peninsula	1			0.22		
Winkles	Minerstown	2	0.026	0.14	0.13	*	*
Mussels	Carlingford Lough	2			<0.18		
Scallops	Co. Down	2			<0.16		
Ascophyllum nodosum	Ardglass	2			<0.41		
Ascophyllum nodosum	Carlingford Lough	1			<0.11		
Fucus spp.	Carlingford Lough	3			<0.33		
Fucus spp.	Portrush	3			<0.14		
Fucus vesiculosus	Ardglass	1			0.44		
Rhodymenia spp.	Strangford Lough	4	0.058	0.34	0.46	*	0.00041
Mud	Carlingford Lough	2	2.3	14	9.0	*	*
Mud	Dundrum Bay	2			<2.3		
Mud	Oldmill Bay	2			15		
Mud	Strangford Lough-Nicky's point	2			6.9		
Mud	Ballymacormick	2			6.7		
Mud and sand	Carrichue	1	0.037	0.26	0.35	*	*
Sand	Portrush	2			<1.1		
Shell and sand	Carrichue	1			<3.0		

** Not detected by the method used*

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

Table 8.5(b). Monitoring of radiation dose rates in Northern Ireland, 2007

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lishally	Mud	1	0.067
Eglington	Shingle	1	0.056
Carrichue	Mud	1	0.066
Bellerena	Mud	1	0.060
Benone	Sand	1	0.062
Castlerock	Sand	1	0.060
Portstewart	Sand	1	0.058
Portrush, Blue Pool	Sand	1	0.059
Portrush, White Rocks	Sand	1	0.060
Portballintrae	Sand	1	0.058
Giant's Causeway	Sand	1	0.063
Ballycastle	Sand	1	0.057
Cushendun	Sand	1	0.063
Cushendall	Sand and stones	1	0.063
Red Bay	Sand	1	0.066
Carnlough	Sand	1	0.059
Glenarm	Sand	1	0.057
Half Way House	Sand	1	0.058
Ballygally	Sand	1	0.058
Drains Bay	Sand	1	0.060
Larne	Sand	1	0.064
Whitehead	Sand	1	0.072
Carrickfergus	Sand	1	0.065
Jordanstown	Sand	1	0.067
Helen's Bay	Sand	1	0.058
Groomsport	Sand	1	0.067
Millisle	Sand	1	0.063
Ballywalter	Sand	1	0.068
Ballyhalbert	Sand	1	0.065
Cloghy	Sand	1	0.074
Portaferry	Shingle and stones	1	0.091
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.074
Ards Maltings	Mud	1	0.088
Island Hill	Mud	1	0.080
Nicky's Point	Mud	1	0.078
Strangford	Shingle and stones	1	0.096
Kilclief	Sand	1	0.073
Ardglass	Mud	1	0.087
Killough	Mud	1	0.086
Rocky Beach	Sand	1	0.074
Tyrella	Sand	1	0.081
Dundrum	Mud	1	0.092
Newcastle	Sand	1	0.11
Annalong	Sand	1	0.10
Cranfield Bay	Sand	1	0.083
Mill Bay	Mud	1	0.11
Greencastle	Sand	1	0.086
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.094

Table 8.6. Concentrations of radionuclides in regional diet (TDS survey), 2007[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
England	Ross-on-Wye	1	<1.2	30	<0.23	80	0.030	0.04	0.010
England	Swaffham	1	<2.5	70	<0.080	80	0.060	<0.07	0.015
Wales	Cardigan	1	<2.4	60	<0.19	70	0.039	0.03	<0.010
England	Farnborough	1	<2.4	40	<0.17	80	<0.049	<0.05	0.0090
Northern Ireland	Carrickfergus	1	<2.5	23	<0.23	80	0.067	0.07	0.050
England	Bournemouth	1	<2.4	20	<0.19	70	0.047	0.03	<0.010
England	Aigburth	1	<3.5	50	<0.42	70	0.057	<0.04	0.016
England	Broadway	1	<3.6	39	<0.16	80	0.088	0.04	0.016
England	Okehampton	1	<3.4	21	<0.18	80	<0.073	<0.05	<0.010
England	Redcar	1	<3.5	26	<0.19	80	0.091	0.03	0.009
England	Barnsley	1	<3.6	36	<0.18	61	<0.10	0.02	0.015
Mean			<2.8	38	<0.20	76	<0.064	<0.04	<0.015

Country	Town	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{210}Po	^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
England	Ross-on-Wye	1	0.033	0.042	0.00065	0.033	<0.000050	0.00018	0.00013
England	Swaffham	1	0.12	0.038	0.0013	0.032	<0.000040	0.00021	0.00010
Wales	Cardigan	1	0.052	0.038	0.00084	<0.018	<0.000050	0.00015	<0.010
England	Farnborough	1	0.034	0.050	0.00052	0.026	<0.00010	0.00015	0.00043
Northern Ireland	Carrickfergus	1	0.041	0.050	0.00036	0.036	0.00078	0.00035	0.00022
England	Bournemouth	1	0.060	0.038	0.00049	0.020	<0.000050	0.00016	<0.00020
England	Aigburth	1	0.040	0.034	0.00039	0.024	<0.00022	0.00016	<0.00020
England	Broadway	1	0.060	0.039	0.0020	0.019	0.00012	0.00034	0.00054
England	Okehampton	1	<0.020	0.039	<0.0010	0.023	0.000055	0.00028	0.00080
England	Redcar	1	0.052	0.030	0.0012	<0.018	<0.00020	0.00028	0.00040
England	Barnsley	1	0.050	0.037	0.0013	0.026	0.00014	0.00070	0.000052
Mean			<0.051	0.040	<0.00091	<0.025	<0.00016	0.00027	<0.0012

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

Table 8.7. Concentrations of radionuclides in regional diet in Scotland, 2007[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
Dalkeith (Midlothian)	1	<20	41	<1.0	<0.050	<0.40	<0.37	0.085	0.042
Greenock (Renfrewshire)	1	<20	50	<1.0	<0.050	<0.40	<0.58	0.098	0.044

Area	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
		^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239+240}$Pu	^{241}Am
Dalkeith (Midlothian)	1	0.0021	0.011	<0.0033	0.0077	0.0020	<0.00033	0.0066
Greenock (Renfrewshire)	1	<0.0012	0.021	<0.0062	0.010	0.00080	<0.00033	0.0013

[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, 2007[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	0.036	0.037	Swaffham	0.072
Wales	0.001	0.040	0.041	Cardigan	0.041
Northern Ireland	0.001	0.039	0.040	Carrickfergus	0.040
Scotland	0.003	0.16	0.17	Greenock	0.20
UK	0.001	0.056	0.058	Greenock	0.20

[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, 2007[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	4	34	120	<0.070	<0.05
Northern Ireland	4	38	120	<0.073	0.06
Scotland	12	30		<0.054	<0.03
Wales	4	33	98	<0.075	<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, 2007

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	<4.0	12	0.023	0.18
Co. Armagh		2	<4.5	15	0.022	0.094
	max		<5.0	16	0.023	0.089
Cambridgeshire		1	<3.0	14	0.016	0.071
Cheshire		1	<5.0	17	0.015	0.12
Clwyd		1	<4.5	17	0.025	0.071
Cornwall		1	<4.0	15	0.030	0.084
Devon		1	<5.0	18	0.032	0.073
Dorset		1	<4.5	18	0.017	0.086
Co. Down		1	<4.0	19	0.027	0.12
Essex		1	<5.0	14	0.015	0.063
Co. Fermanagh		1	<4.5	15	0.022	0.11
Gloucestershire		1	<4.0	8.5	0.023	0.067
Guernsey		1	<2.5	12	0.021	0.064
Gwent		1	<2.8	12	0.031	0.072
Gwynedd		1	<4.0	13	0.025	0.069
Hampshire		1	<4.5	16	0.020	0.075
Humberside		1	<4.5	12	0.016	0.061
Kirkcudbrightshire		1	<5.1	<16	<0.10	<0.05[c]
Kent		1	<5.0	15	0.020	0.090
Lanarkshire		1			<0.16	<0.08[c]
Lancashire		1	<4.5	19	0.021	0.079
Leicestershire		2	<5.0	14	0.019	0.079
	max			17		0.086
Lincolnshire		1	<5.0	16	0.015	0.062
Middlesex		1	<5.0	18	0.019	0.067
Midlothian		1	<5.0	<15	<0.10	<0.12[c]
North Yorkshire		1	<4.5	16	0.017	0.072
Nairnshire		1	<5.0	<18	<0.10	<0.05[c]
Norfolk		1	<5.0	16	0.015	0.068
Renfrewshire		1	<5.2	<15	<0.10	<0.05[c]
Tyneside		1	<4.5	14	0.024	0.073
Co. Tyrone		2	<2.9	16	0.022	0.12
	max		<4.5	17	0.023	
Mean Values						
Channel Islands			<2.5	12	0.021	0.064
England			<4.6	15	0.020	0.076
Northern Ireland			<4.0	15	0.023	0.13
Wales			<3.8	14	0.027	0.070
Scotland			<5.0	<16	<0.11	<0.07[c]
United Kingdom			<4.5	<15	<0.036	<0.083

[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, 2007[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
Channel Islands								
Guernsey	Blackberries	1	<4.0	13	0.14	0.036	0.11	0.040
	Lettuce	1	4.0	4.0	0.048	0.091	<0.050	0.012
Jersey	Potatoes	1	<5.0	14	0.049	0.023		
	Strawberries	1	<5.0	8.0	0.058	0.064		
Cornwall								
Falmouth	Gooseberries	1	<4.0	5.0	0.18	0.029	0.095	0.061
	Lettuce	1	6.0	<3.0	0.036	0.048	<0.039	0.0055
Devon								
Barnstaple	Cabbage	1	<4.0	3.0	0.14	0.039	0.076	0.031
	Potatoes/Beetroot	1	<5.0	11	0.040	0.061	<0.039	0.0087
Dumfriesshire								
Dumfries	Lettuce	4			<0.10	<0.08[b]		
East Lothian								
North Berwick	Lettuce	4			<0.10	<0.05[b]		
Flintshire								
Mold	Lettuce	1	<4.0	9.0	0.78	0.066	1.2	0.57
	Potatoes	1	<4.0	17	0.019	0.034	0.054	0.0053
Herefordshire								
Leominster	Carrots	1	<5.0	11	0.14	<0.014	0.12	0.020
	Lettuce	1	8.0	<3.0	0.11	0.045	0.11	0.070
Hertfordshire								
Bishop's Stortford	Lettuce	1	<5.0	<3.0	0.069	0.12	<0.052	0.027
	Potatoes	1	<5.0	15	0.026	0.026	<0.041	0.011
Kent								
Tonbridge	Cabbage	1	<5.0	14	0.49	0.13	0.51	0.20
	Carrots	1	<4.0	12	0.077	0.047	0.037	0.025
Leicestershire								
Leicester	Potatoes	1	<5.0	17	0.064	0.063	<0.041	0.0034
	Spinach	1	<5.0	6.0	0.29	0.055	0.63	0.26
Lincolnshire								
Market Rasen	Leafy Green Veg	1	<5.0	6.0	0.33	0.041	<0.037	0.017
	Strawberries	1	8.0	9.0	0.033	<0.012	0.045	0.012
North Yorkshire								
Pickering	Cabbage	1	5.0	5.0	0.13	<0.012	0.11	0.083
	Potatoes	1	10	18	0.081	0.022	<0.047	0.0044
Northumberland								
Morpeth	Lettuce	1	<4.0	7.0	0.17	0.056	0.21	0.067
	Strawberries	1	<4.0	12	0.078	0.039	0.11	0.031
Ponteland	Lettuce	1	<4.0	<3.0	0.13	0.057	0.063	0.016
	Potatoes	1	<4.0	15	0.051	0.016	<0.042	0.0069
Renfrewshire								
Paisley	Lettuce	4			<0.10	<0.05[b]		
Ross-shire								
Dingwall	Lettuce	4			<0.10	<0.06[b]		
Shropshire								
Wem	Beetroot	1	<4.0	11	0.14	0.060	<0.041	0.0042
	Strawberries	1	<4.0	10	0.085	<0.012	<0.046	0.019
Somerset								
Chard	Blackberries	1	<4.0	15	0.075	0.026	0.15	0.056
	Swiss Chard	1	<5.0	<3.0	0.38	0.068	0.54	0.25
Frome	Cabbage	1	<5.0	4.0	0.092	0.048	<0.036	0.012
	Potatoes	1	<4.0	14	0.020	0.051	0.050	0.0061
Suffolk								
Ipswich	Cabbage	1	<5.0	4.0	1.8	0.053	0.67	0.26
	Raspberries	1	<5.0	17	0.029	0.018	<0.046	0.0021
Surrey								
Esher	Cabbage	1	<4.0	4.0	0.13	0.012	<0.040	0.022
	Strawberries	1	<4.0	6.0	0.024	<0.0050	0.094	0.015
Weybridge	Beef Kidney	1	<7.0	25	0.067	0.14		
	Beef Liver	1	<7.0	20	0.038	0.17		
	Beef Muscle	1	<6.0	23	<0.0070	0.17		
	Sheep Kidney/Liver	1	<8.0	32	0.10	0.24		
	Sheep Muscle	1	<5.0	32	<0.0080	0.12		
Worcestershire								
Great Malvern	Cabbage	1	<5.0	7.0	0.19	<0.0050	0.15	0.051
	Strawberries	1	<4.0	12	0.049	<0.0040	<0.040	0.015
Mean Values[c]								
Channel Isles			<4.5	<9.8	0.073	0.054	0.079	0.026
England			<5.2	<11	<0.16	<0.057	<0.14	0.052
Wales			<4.0	13	0.40	0.050	0.64	0.29
Scotland					<0.10	<0.06		
Great Britain			<5.1	<11	<0.21	<0.053	<0.17	0.066

Table 8.11. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Channel Islands								
Guernsey	Blackberries	1	0.014	<0.0012	<0.031	<0.00010	<0.00020	0.00020
	Lettuce	1	0.011	0.0040		<0.00010	<0.00010	0.00020
Jersey	Potatoes	1				<0.00010	0.00010	0.00030
	Strawberries	1				<0.00020	0.00010	<0.00030
Cornwall								
Falmouth	Gooseberries	1	0.038	0.0018	<0.029			
	Lettuce	1	<0.0030	0.00050				
Devon								
Barnstaple	Cabbage	1	0.0080	0.00070				
	Potatoes/Beetroot	1	0.016	<0.0012				
Flintshire								
Mold	Lettuce	1	0.069	0.073	0.29			
	Potatoes	1	0.016	0.0026				
Herefordshire								
Leominster	Carrots	1	0.027	0.0073	<0.030			
	Lettuce	1	0.031	0.0082				
Hertfordshire								
Bishop's Stortford	Lettuce	1	0.0090	0.0048				
	Potatoes	1	0.010	0.0022				
Kent								
Tonbridge	Cabbage	1	0.015	<0.0015	0.080			
	Carrots	1	0.064	0.011				
Leicestershire								
Leicester	Potatoes	1	0.0090	0.0073				
	Spinach	1	0.086	0.014	0.064			
Lincolnshire								
Market Rasen	Leafy Green Veg	1	0.12	0.0031				
	Strawberries	1	0.019	0.00080				
North Yorkshire								
Pickering	Cabbage	1	0.043	0.0030				
	Potatoes	1	0.014	0.0021	<0.030			
Northumberland								
Morpeth	Lettuce	1	0.024	0.0017				
	Strawberries	1	0.032	0.00080	<0.030			
Ponteland	Lettuce	1	0.037	0.0061				
	Potatoes	1	0.011	0.0016				
Shropshire								
Wem	Beetroot	1	0.048	<0.0016	<0.032			
	Strawberries	1	0.027	<0.00080				
Somerset								
Chard	Blackberries	1	0.023	<0.0012				
	Swiss Chard	1	0.27	0.0030	<0.032			
Frome	Cabbage	1	0.015	<0.0012				
	Potatoes	1	0.011	0.0038				
Suffolk								
Ipswich	Cabbage	1	0.093	0.010				
	Raspberries	1	0.013	0.00020	<0.031			
Surrey								
Esher	Cabbage	1	0.034	<0.00080				
	Strawberries	1	0.0060	<0.00090				
Weybridge	Beef Kidney	1				<0.00020	0.00010	0.00040
	Beef Liver	1				<0.00020	<0.00020	<0.00020
	Beef Muscle	1				<0.00020	0.00030	<0.00010
	Sheep Kidney/Liver	1				<0.00030	<0.00030	0.00040
	Sheep Muscle	1				<0.00020	0.00010	0.00020
Worcestershire								
Great Malvern	Cabbage	1	0.014	<0.0011				
	Strawberries	1	0.016	<0.00090				
Mean Values[c]								
Channel Isles			0.013	<0.0026	<0.031	<0.00013	<0.00013	<0.00025
England			<0.037	<0.0034	<0.040	<0.00022	<0.00020	<0.00026
Wales			0.043	0.038	0.29			
Scotland								
Great Britain			<0.038	<0.0056	<0.065	<0.00022	<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, 2007

Port	Country of origin	Foodstuff	No. of sampling observations	Mean radioactivity concentration, Bq kg^{-1} (fresh)[a] ^{137}Cs	Dilution factor
Dover	Germany	Blueberry juice concentrate	1	370	0.1
		Blueberry juice concentrate	1	480	0.1
Felixstowe	Germany	Blueberry juice concentrate	1	1200	0.2
		Raspberry puree	1	<1.9	1.0
	Holland	Blueberry juice concentrate	1	460	0.2
		Blueberry juice concentrate	1	1300	0.2
		Raspberry juice concentrate	1	<110	0.2
		Strawberry puree	1	<50	0.2

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

Table 8.13. Concentrations of radionuclides in rainwater and air 2007

Location	Sample	Number of sampling observations	Mean radioactivity concentration,[a] ^{3}H	^{7}Be	^{40}K	^{90}Srb	^{137}Cs	^{210}Pb	^{210}Po	^{239}Pu+ ^{240}Pu[c]	^{241}Am[c]	Gross alpha[d]	Gross beta[d]
Ceredigion													
Aberporth	Rainwater	4	<0.66	<1.3			<0.044			<3.1 10^{-6}	<0.00013		
	Air	4		0.0024	0.00011		<8.9 10^{-7}	0.00015		3.7 10^{-10}	<5.5 10^{-10}		
Co. Down													
Conlig	Rainwater	4		1.8			<0.036						
	Air	4		0.0022	9.0 10^{-5}		<7.7 10^{-7}	0.00014					
Dumfries and Galloway													
Eskdalemuir	Rainwater	4	<0.69	1.5			<0.018						
	Air	4		0.0016	8.0 10^{-5}		<6.4 10^{-7}	0.00012					
Glasgow													
Glasgow	Air	12					<0.010						<0.0020
North Yorkshire													
Dishforth	Rainwater	4		<2.4			<0.066						
	Air	4		0.0016	0.00011		<7.6 10^{-7}	9.6 10-5					
Oxfordshire													
Chilton	Rainwater	4		<0.89		<0.00055	<0.032					0.039	0.11
	Air	4		0.0017	7.7 10^{-5}		<5.7 10^{-7}	0.00013					
	Air	13						0.00013	1.0 10^{-5}				
Shetland													
Lerwick	Rainwater	4		1.9			<0.029						
	Air	4		0.0020	0.00012		<1.1 10^{-6}	*					
Suffolk													
Orfordness	Rainwater	4	<0.54	<2.4			<0.083						
	Air	4		0.0026	9.9 10^{-5}		<7.5 10^{-7}	0.00019					

Location	Sample		Mean radioactivity concentration[a] ^{208}Tl	^{214}Bi
Additional radionuclides detected by gamma spectrometry in some quarters				
Co. Down				
Conlig	Rainwater		0.058	
	Air			2.4 10^{-6}

* *Not detected by the method used*

[a] *Bq l^{-1} for rainwater, Bq kg^{-1} (fresh) for grass and soil 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, 2007

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	<1.2	<0.0052	<0.01	<0.030	<0.058
Argyll and Bute	Auchengaich	1	1.5		<0.01	<0.0069	<0.013
Argyll and Bute	Helensburgh Reservoir	1	<1.0		<0.01	<0.010	0.028
Argyll and Bute	Loch Ascog	1	<1.2		<0.01	<0.010	0.14
Argyll and Bute	Loch Eck	1	<1.0		<0.01	<0.010	0.022
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.0		<0.01	<0.010	0.036
Argyll and Bute	Loch Finlas	1	<1.1		<0.01	<0.0073	0.017
Clackmannanshire	Gartmorn	1	<1.1		<0.01	<0.010	0.060
Dumfries and Galloway	Black Esk	1	1.4		<0.01	<0.010	<0.013
Dumfries and Galloway	Purdomstone	1	2.7		<0.01	<0.010	0.051
Dumfries and Galloway	Winterhope	1	5.3		<0.01	<0.010	0.016
East Lothian	Hopes Reservoir	1	1.2		<0.01	0.016	0.024
East Lothian	Thorters Reservoir	1	<1.1		<0.01	<0.010	0.044
East Lothian	Whiteadder	1	<1.1		<0.01	<0.010	0.043
Fife	Holl Reservoir	1	<1.1		<0.01	0.023	0.046
Highland	Loch Baligill	1	1.4		<0.01	0.012	0.047
Highland	Loch Calder	1	1.3		<0.01	<0.081	0.045
Highland	Loch Glass	4	<1.2	<0.0057	<0.01	<0.054	<0.072
Highland	Loch Shurrerey	1	<1.1		<0.01	0.013	0.042
North Ayrshire	Camphill	1	<1.0		<0.01	<0.010	0.042
North Ayrshire	Knockendon Reservoir	1	<1.2		<0.01	<0.010	0.046
North Ayrshire	Munnoch Reservoir	1	1.2		<0.01	<0.010	0.040
North Ayrshire	Outerwards	1	<1.0		<0.01	<0.010	<0.013
Orkney Islands	Heldale Water	1	<1.1		<0.01	<0.0084	0.058
Perth and Kinross	Castlehill	1	<1.0		<0.01	<0.010	0.026
Scottish Borders	Knowesdean	4	<1.5	<0.0050	<0.01	<0.031	<0.045
Stirling	Loch Katrine	12	<1.2	0.0040	<0.002	<0.0075	<0.024
West Dunbartonshire	Loch Lomond (Ross Priory)	1	1.7		<0.01	<0.0069	0.031
West Lothian	Morton No 2	1	1.8		<0.05	<0.0071	0.024

Table 8.15. Concentrations of radionuclides in sources of drinking water in England and Wales, 2007

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}					
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	^{210}Po
England								
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.045	<0.0010		<0.0010	<0.010
Cambridgeshire	Grafham Water	4	<4.0	0.30	0.0027		<0.0010	<0.010
Cheshire	River Dee, Chester	4	<4.0	0.14	0.0060	<0.0028	0.0060	0.022
Cornwall	River Fowey	4	<4.0	0.065	0.0027	<0.0020	<0.0010	<0.010
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.070	0.0044		<0.0010	<0.010
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	<0.025	0.0047		<0.0010	0.013
County Durham	River Tees, Darlington	4	<4.0	0.036	0.0049	<0.0020	<0.0010	<0.010
Cumbria	Haweswater Reservoir	4	<4.0	<0.011	0.0036		<0.0010	<0.010
Cumbria	Ennerdale Lake	4	<4.0	<0.019	0.0030		<0.0012	<0.010
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	<0.011	0.0015		<0.0010	<0.010
Derbyshire	Matlock, Groundwater	4	<4.0	0.055	<0.0010		<0.0010	<0.011
Devon	River Exe, Exeter	4	<4.0	0.080	0.0023	<0.0021	<0.0010	<0.010
Gloucestershire	River Severn, Tewkesbury	3	<4.0	0.17	0.0031	<0.0019	<0.0010	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.29	0.0021	<0.0020	<0.0010	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.094	<0.0016	<0.0027	<0.0010	<0.010
Humberside	Littlecoates, Groundwater	4	<4.0	0.11	<0.0010		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.0	0.14	0.0042		<0.0010	<0.010
Kent	Chatham, Deep Groundwater	4	<4.0	0.034	<0.0010		<0.0010	<0.010
Lancashire	Corn Close, Groundwater	4	<4.0	0.070	<0.0010		<0.0010	<0.010
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.10	0.0024	<0.0027	<0.0010	<0.010
Northumberland	Kielder Reservoir	4	<4.0	0.045	0.0029		<0.0012	<0.010
Oxfordshire	River Thames, Oxford	4	<4.0	0.13	0.0018	<0.0028	<0.0010	0.011
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.078	0.0011		<0.0010	0.0099
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0017		<0.0010	<0.010
Surrey	River Thames, Walton	4	<4.0	0.19	0.0020	<0.0033	<0.0010	<0.010
Surrey	River Thames, Chertsey	4	<4.0	0.18	0.0037	<0.0021	<0.0012	<0.010
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<4.0	<0.073	0.0089		<0.0026	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta[1]	Gross beta[2]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.054	<0.050
Cambridgeshire	Grafham Water	4	<0.010	<0.010	<0.010	<0.010	0.024	0.44	0.29
Cheshire	River Dee, Chester	4	<0.010	0.019	<0.010	<0.015	0.084	0.33	0.20
Cornwall	River Fowey	4	<0.010	<0.010	<0.010	<0.010	0.042	0.12	0.076
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.084	0.055
County Durham	Honey Hill Water Treatment Works, Consett	4	<0.010	<0.010	<0.010	<0.010	0.027	0.066	<0.052
County Durham	River Tees, Darlington	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.072	0.047
Cumbria	Haweswater Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.052	<0.050
Cumbria	Ennerdale Lake	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.056	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Derbyshire	Matlock, Groundwater	4	0.0093	0.039	<0.010	0.021	0.097	0.12	0.076
Devon	River Exe, Exeter	4	<0.010	<0.010	<0.010	<0.010	0.029	0.13	0.081
Gloucestershire	River Severn, Tewkesbury	3	<0.010	0.014	<0.010	<0.010	0.029	0.23	0.15
Greater London	River Lee, Chingford	4	<0.010	0.011	<0.010	0.0092	<0.021	0.37	0.22
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	0.020	0.12	0.076
Humberside	Littlecoates, Groundwater	4	<0.010	<0.010	<0.010	<0.010	0.028	0.16	0.10
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.21	0.14
Kent	Chatham, Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.059	<0.049
Lancashire	Corn Close, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.068	0.048
Norfolk	River Drove, Stoke Ferry	4	<0.010	0.012	<0.010	0.0099	<0.024	0.14	0.091
Northumberland	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.048	<0.050
Oxfordshire	River Thames, Oxford	4	<0.010	<0.010	<0.010	<0.010	<0.022	0.19	0.13
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	<0.010	<0.010	<0.010	0.022	0.086	0.061
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	0.011	<0.010	<0.010	0.020	0.15	0.10
Surrey	River Thames, Walton	4	<0.010	0.010	<0.010	<0.010	0.020	0.27	0.17
Surrey	River Thames, Chertsey	4	<0.010	0.010	<0.010	<0.010	0.029	0.27	0.16
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<0.010	<0.010	<0.010	<0.010	0.020	0.085	0.055

Table 8.15. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}				
			^{3}H	^{40}K	^{90}Sr	^{137}Cs	^{210}Po
Wales							
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.011	0.0082	0.0016	<0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.013	0.0047	<0.0010	0.011
Powys	Elan Valley Reservoir	4	<4.0	<0.010	0.0036	<0.0010	<0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta[1]	Gross beta[2]
Wales									
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.050	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.052	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.051	<0.050

[1] *Using ^{137}Cs standard*
[2] *Using ^{40}K standard*

Table 8.16. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2007

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	3	1.2	0.0032	<0.05	<0.010	0.024	<0.010	<0.010	<0.010	<0.020	0.077
Co. Antrim	Lough Neagh	3	<1.3	<0.0017	<0.05	<0.010	0.021	<0.010	<0.010	<0.010	<0.020	0.092
Co. Down	Silent Valley	3	<1.1	0.0027	<0.05	<0.010	0.027	<0.010	<0.010	<0.010	0.026	0.051

Table 8.17. Estimates of radiation exposure from radionuclides in drinking water, 2007[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	0.028	0.028	Cheshire, River Dee, Chester	0.055
Wales	<0.001	0.027	0.027	Mid-Glamorgan, Llwyn-on-Reservoir	0.029
Northern Ireland	<0.001	0.030	0.030	Co. Down, Silent Valley	0.031
Scotland[e]	<0.001			West Lothian, Morton No 2	<0.001[e]
UK[f]	<0.001	0.028	0.028	Cheshire, River Dee, Chester	0.055

[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*
[f] *Not including Scotland*

Table 8.18. Concentrations of radionuclides in groundwater in Scotland, 2007

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Aberdeenshire	Nr Peterhead, shallow well[a]	4	<3.3	<0.01	<0.013	0.10
Aberdeenshire	Nr Inverurie, Spring	2	<2.5	<0.01	0.021	0.098
Angus	Deep borehole	2	<2.5	<0.01	<0.013	0.069
Ayrshire	Girvan, Deep borehole	1	<4.0	<0.01	<0.024	0.072
Borders	Borehole	1	<1.0	<0.01	<0.018	0.21
Dumfriesshire	Nr Annan, Borehole	2	<3.2	<0.01	<0.015	0.066
Dumfriesshire	Dumfries, Deep borehole	4	<3.6	<0.01	<0.020	0.049
East Lothian	Deep borehole	1	<4.0	<0.01	0.025	0.096
Fife	Deep borehole	4	<3.3	<0.01	<0.010	0.072
Orkney	Shapinsay, Borehole	2	<2.5	<0.01	<0.011	0.060
Sutherland	Durness, Shallow well	1	<4.0	<0.01	<0.013	0.11

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

Table 8.19. Concentrations of radionuclides in seawater, 2007

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			<0.33	<0.10
Dounreay (Brims Ness)	4	<1.0		<0.10			<0.42	<0.10
Rosyth	2	<1.3		<0.10			<0.30	<0.10
Torness	2	16		<0.10			<0.38	<0.10
Hartlepool (North Gare)	2	59		<0.29			<2.0	<0.35
Sizewell	2	<4.5		<0.30			<1.9	<0.34
Bradwell	2			<0.35			<2.2	<0.40
Dungeness south	2	<5.0		<0.36			<2.2	<0.38
Winfrith (Lulworth Cove)	1			<0.47			<3.1	<0.56
Alderney	4[F]	4.1						
Devonport (Millbrook Lake)	2	<4.0	<4.0	<0.38				
Devonport (Tor Point South)	2	<4.0	<4.0	<0.40				
Hinkley	2			<0.37	<0.050		<2.2	<0.39
Berkeley and Oldbury	2			<0.38			<2.4	<0.41
Cardiff (Orchard Ledges)[a]	2	<25	<15	<0.36				
Holyhead	4[F]	<1.5						
Wylfa (Cemaes Bay)	2	<4.0		<0.40			<2.7	<0.46
Wylfa (Cemlyn Bay)	1			<0.33			<2.2	<0.39
Heysham (inlet)	2	12		<0.39			<2.6	<0.46
Seascale (Particulate)	2			<0.05	<0.025		<0.44	<0.08
Seascale (Filtrate)	2			<0.31	<0.065	<1.4	<2.1	<0.36
St. Bees	3	<5.4				<0.63		
St. Bees (Particulate)	2			<0.05	<0.21		<0.38	<0.07
St. Bees (Filtrate)	3	<4.4		<0.20	<0.070	<0.50	<1.5	<0.27
Seafield	4	2.2		<0.10			<0.45	<0.10
Southerness[b]	4	3.1		<0.10			<0.36	<0.10
Auchencairn	4	2.6		<0.10			<0.26	<0.10
Knock Bay	4	<1.4		<0.10			<0.33	<0.10
Knock Bay	4[F]	<2.1						
Hunterston	2	2.2						
North of Larne	12[N]					0.0062		
Faslane (Carnban)	2	<14		<0.10			<0.30	<0.10

Table 8.19. 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	<0.22	<0.10		
Dounreay (Brims Ness)	4	<0.10	<0.10	<0.27	<0.11		
Rosyth	2	<0.10	<0.10	<0.20	<0.10		
Torness	2	<0.10	<0.10	<0.22	<0.10		
Hartlepool (North Gare)	2	<0.25	<0.22	<0.88	<0.29	<3.5	19
Sizewell	2	<0.26	<0.24	<0.93	<0.30	<3.3	16
Bradwell	2	<0.31	<0.28	<1.1	<0.36	<3.5	15
Dungeness south	2	<0.30	<0.28	<1.2	<0.41	<3.5	13
Winfrith (Lulworth Cove)	1	<0.43	<0.38	<1.3	<0.50	<3.0	15
Alderney	4[F]	*	0.002				
Jersey	1[F]	*	0.001				
Guernsey	4[F]	*	0.002				
Hinkley	2	<0.31	<0.29	<1.1	<0.36	<2.5	13
Berkeley and Oldbury	2	<0.32	<0.30	<1.1	<0.37	<1.1	4.0
Cardiff (Orchard Ledges)[a]	2		<0.31				
Holyhead	4[F]	*	0.01				
Wylfa (Cemaes Bay)	2	<0.38	<0.32	<1.2	<0.43	<2.1	9.7
Wylfa (Cemlyn Bay)	1	<0.30	<0.27	<0.94	<0.34	<2.3	14
Llandudno	1[F]	*	0.03				
Prestatyn	1[F]	*	0.04				
New Brighton	1[F]	*	0.08				
Ainsdale	1[F]	*	0.05				
Rossall	1[F]	*	0.07				
Heysham (inlet)	2	<0.35	<0.33	<1.1	<0.37	<0.020	13
Half Moon Bay	1[F]	*	0.14				
Silecroft	1[F]	*	0.08				
Seascale (Particulate)	2	<0.05	<0.05	<0.21	<0.06	0.058	0.042
Seascale (Filtrate)	2	<0.28	<0.27	<1.1	<0.36	<3.0	12
St. Bees	3	<0.16	<0.25				
St. Bees (Particulate)	2	<0.05	<0.05	<0.16	<0.05	<2.1	2.5
St. Bees (Filtrate)	3	<0.16	<0.15	<0.85	<0.28	<4.0	9.4
Whitehaven	1[F]	*	0.09				
Maryport	1[F]	*	0.10				
Silloth	1[F]	*	0.11				
Seafield	4	<0.10	<0.12	<0.30	<0.10		
Southerness[b]	4	<0.10	0.16	<0.21	<0.0028		
Auchencairn	4	<0.10	<0.11	<0.16	<0.10		
Ross Bay	1[F]	*	0.07				
Isle of Whithorn	1[F]	*	0.04				
Drummore	1[F]	*	0.04				
Knock Bay	4	<0.10	<0.10	<0.23	<0.10		
Knock Bay	4[F]	*	0.03				
North of Larne	12[N]	*	0.02				
Faslane (Carnban)	2	<0.10	<0.10	<0.23	<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 <0.28 Bq l^{-1}*

[b] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were <0.00054 and <0.0015 Bq l^{-1} respectively*

[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*

9. References

(Includes references from Appendix 1: CD supplement)

Allot, R., 2005. Assessment of compliance with the public dose limit. Principles for the assessment of total retrospective public doses. NDAWG/2/2005. Environment Agency, Food Standards Agency, HPA, NII, Chilton

Allot, R. and Copplestone, D., 2008a. Update on habitats assessments for England and Wales. NDAWG Paper 13-04. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Allot, R. and Copplestone, D., 2008b. Impact of radioactive substances on Ribble and Alt estuarine habitats. Technical Report NMA/TR/2008/02. Environment Agency, Bristol and London.

Baxter, A.J. and Camplin, W.C., 1994. The use of caesium-137 to measure dispersion from discharge pipelines at nuclear sites in the UK. Proc. Instn. Civ. Engrs. Wat., Marit. And Energy, (106): 281 – 288.

Baxter, A.J., Camplin, W.C. and Steele, A.K., 1992. Radiocaesium in the seas of northern Europe: 1975 – 79. Fish. Res. Data Rep., MAFF Direct. Fish. Res., Lowestoft, (28): 1 – 166.

Beresford, N.A., Wood, M.D., Bescoby, M., Caborn, J.C., and Barnett, C.L., 2008. Sampling at Drigg sand dunes. SC070019. Environment Agency, Bristol and London.

BNFL, 2002. Discharges and monitoring of the environment in the UK. Annual Report 2001. BNFL, Warrington.

Brenk, H.D., Onishi, Y., Simmonds, J.R. and Subbaratnam, T., (unpublished). A practical methodology for the assessment of individual and collective radiation doses from radionuclides in the environment. International Atomic Energy Authority draft working document no. 1987 – 05 – 06, Vienna.

Bryan, S.E., Hill, R., McDonald, P. and Wilson, R.C., 2006. Sea to land transfer of anthropogenic radionuclides to the North Wales Coast. Westlakes Scientific Consulting, Moor Row.

Bunker, A., 2007. Personal communication. September 2007. Health and Safety Executive, Bootle.

Byrom, J., Robinson, C.A., Simmonds, J.R., Walters, C.B. and Taylor, R.R., 1995. Food consumption rates for use in generalised radiological dose assessments. J. Rad. Prot., 15(4): 335 – 342.

Camplin, W.C. and Jenkinson, S., 2007. Use of measurements in determining retrospective dose assessments in RIFE. (NDAWG/11/03) 2007. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Camplin, W.C., Rollo, S. and Hunt, G.J., 2000. Surveillance related assessments of sea-to-land transfer. In Proceedings of the Second RADREM – TESC Workshop held in London 21 January 1999. Edited by Ould-Dada, Z. DETR/RADREM/00.001. DETR, London.

Camplin, W.C., Grzechnik, M. and Smedley, C., 2005. Methods for assessment of total dose in the Radioactivity in Food and the Environment report. NDAWG/3/2005. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Carpenter, R., 2005. The determination of Technetium-99 in seaweed and sediment samples collected from the Menai Strait. RD1472. Harwell Scientifics, Harwell.

Codex Alimentarius Commission, 2006. Codex Alimentarius Commission Report, Twenty-ninth session 3-7 July 2006. AL INORM 06/29/41. Codex, Rome.

Commission of the European Communities, 1989. Council regulation (Euratom) No 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feeding stuffs following a nuclear accident or any other case of radiological emergency. OJ 11(L371), amended by Council Regulation 2218/89 OJ 1(L211).

Commission of the European Communities, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L206: 7 – 50.

Commission of the European Communities, 1996. Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. OJ 39(L159): 1 – 114.

Commission of the European Communities, 1998. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. OJ L330: 32 – 54.

Commission of the European Communities, 1999a. Council Directive 1999/2/EC of the European Parliament and of the Council of 22 February 1999 on the approximation of the laws of Member States concerning foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 16.

Commission of the European Communities, 1999b. Council Directive 1999/3/EC of the European Parliament and of the Council of 22 February 1999 on the establishment of a Community list of foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 24.

Commission of the European Communities, 2000a. Commission recommendation on the application of Article 36 of the Euratom Treaty concerning the monitoring of the concentrations of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole. OJ 27th July 2000. 2000/473/Euratom.

Commission of the European Communities, 2000b. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L327 22/12/2000 1 – 73.

Commission of the European Communities, 2004. Environmental risk from ionising contaminants: assessment and management. ERICA. Sixth Framework Programme Euratom Contract F16R-CT-2003 – 508847. CEC, Luxembourg.

Commission of the European Communities, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Directive). OJ L164.

Cooper, J. R., 2008. Review of risks from tritium – report of the AGIR – November 2007 Letter dated 17th April 2008. HPA, Chilton.

Copeland Borough Council *et al.*, 1999. The radiological implications of contaminated feral pigeons found at Sellafield and Seascale. CBC, DH, Environment Agency, HSE, MAFF and NRPB, Penrith. Copeland Borough Council *et al.*, 1999. The radiological implications of contaminated feral pigeons found at Sellafield and Seascale. CBC, DH, Environment Agency, HSE, MAFF and NRPB, Penrith.

Department for Environment, Food and Rural Affairs, 2002. UK strategy for radioactive discharges 2001 – 2020.Defra, London.

Department for Environment, Food and Rural Affairs, 2004a. National report on compliance with the obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Defra, London.

Department for Environment, Food and Rural Affairs, 2004b. Contribution of aerial radioactive discharges to radionuclide concentrations in the marine environment. DEFRA/RAS/04.002. Defra, London.

Department for Environment, Food and Rural Affairs, 2005a. 1: Marine Environment Quality. Report 1 of 5 contributing to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005b. 5: Integrated Regional Assessment. Report 5 of 5 contributing to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005c. The United Kingdom's second national report on compliance with the obligations of the joint convention on the safety of spent fuel management and on the safety of radioactive waste management. Defra, London.

Department for Environment, Food and Rural Affairs, 2005d. Water Environment Reports Submitted to the European Commission. News Release 142/05. Defra, London.

Department for Environment, Food and Rural Affairs, 2006a. Environmental Protection Act 1990: Part 2a. Contaminated land. Circular 01/2006. Defra, London.

Department for Environment, Food and Rural Affairs, 2006b. Industry profile. Industrial activities which have used materials containing radioactivity. Defra, London.

Department for Environment, Food and Rural Affairs, 2007a. UKMMAS News. No 3 Spring 2007. Defra, London.

Department for Environment, Food and Rural Affairs, 2007b. Low level radioactive waste policy announced. News release 26 March 2007. Defra, London.

Department for Environment, Food and Rural Affairs, 2007c. Miliband announces radioactive waste disposal plan. News release 2006. Defra, London.

Department for Environment, Food and Rural Affairs, 2008a. Summary of responses to the consultation on the standardised reporting of radioactive discharges, 22 August to 23 November 2007. Defra, London.

Department for Environment, Food and Rural Affairs, 2008b. Consultation on the draft statutory guidance under section 4 of the Environment Act 1995 to the Environment Agency concerning the regulation of radioactive discharges into the environment. Defra, London.

Department for Environment, Food and Rural Affairs, 2008c. The environment permitting programme – phase 2. http://www.defra.gov.uk/environment/ppc/envagency/meetings/pdf/epp2.pdf

Department for Environment, Food and Rural Affairs and Department of Health, 2006. Drigg review decision document. Defra and Department of Health, Bristol and London.

Department for Environment, Food and Rural Affairs and Department of Health, 2007. Sellafield review decision document. http://www.defra.gov.uk/environment/radioactivity/government/decisions/pdf/sellafieldreview-decision.pdf

Department for Environment, Food and Rural Affairs, Scottish Executive and Welsh Assembly Government, 2002. Safeguarding our seas. A strategy for the conservation and sustainable development of our marine environment. Defra, London.

Department for Environment, Food and Rural Affairs, The Scottish Government, Welsh Assembly Government, the Department of the Environment, 2008. UK strategy for radioactive discharges 2006-2030. Consultation Document June 2008, Defra, London.

Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005. Charting Progress. an Integrated Assessment of the State of UK Seas. Defra, London.

Department of the Environment, Transport and the Regions, 2000. Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. DETR, London.

Department for Environment, Food and Rural Affairs, Department for Business, Enterprise and Regulatory Reform, National Assembly for Wales and Northern Ireland Assembly, 2008. Managing Radioactive Waste Safely: A framework for Implementing Geological Disposal, 2008. Cm7386. The Stationery Office, London.

Dounreay Particle Advisory Group, 2006. 3rd Interim Report, September 2006. SEPA, Stirling.

DSTL Radiological Protection Services, 2007. Marine environmental radioactivity surveys at nuclear submarine berths 2006. The Stationery Office, London.

Environment Agency, 2002a. Radioactivity in the environment. Report for 2001. Environment Agency, Lancaster.

Environment Agency, 2002b. Radioactive Waste Regulation. Summary of Research 1996 – 2001. R&D Publication 129. Environment Agency, Bristol and London.

Environment Agency, 2005a. Water Framework Directive – Characterisation of impacts from radioactive substances. Technical Report: MAPG/TR/2004/004. Environment Agency, Bristol and London.

Environment Agency, 2005b. Environment Agency measurement of technetium-99 in samples from the Menai Strait. Environment Agency, Bristol and London.

Environment Agency, 2006a. Radioactive substances regulation: a strategy for 2006-11. Environment Agency, Bristol and London.

Environment Agency, 2006b. Sector report for the nuclear industry. Environment Agency, Bristol and London.

Environment Agency, 2006c. Sector plan for the nuclear industry. Environment Agency, Bristol and London.

Environment Agency, 2006d. Explanatory Document. BNGSL nuclear site at Capenhurst, near Cheshire, December 2006. Environment Agency, Bristol and London.

Environment Agency, 2006e. Decision on the application made by United Kingdom Atomic Energy Authority to dispose of radioactive wastes from its Winfrith site. BW2536, February 2006. Environment Agency, Bristol and London.

Environment Agency, 2006f. Decision on the application made by Waste Management Technology Limited to dispose of radioactive wastes from its facilities on the Winfrith site. BV3502, February 2006. Environment Agency, Bristol and London.

Environment Agency, 2006g. Explanatory Document and Draft Authorisation to Assist Public Consultation on the Application by Magnox Electric Limited under the Radioactive Substances Act 1993 for a Variation to its authorisation to Dispose of Radioactive Waste From Oldbury Power Station South Gloucestershire. BA5546/CA9538, November 2006. Environment Agency, Bristol and London.

Environment Agency, 2006h. Nuclear, consultation, AWE, Aldermaston, Burghfield. News Doc DF/78/06. Environment Agency, Bristol and London.

Environment Agency, 2006i. Explanatory Document and Draft Authorisation to Assist Public Consultation on the Application by AWE plc under the Radioactive Substances Act 1993 for a Variation to its Authorisation to Dispose of Radioactive Waste from the Atomic Weapons Establishment at Aldermaston, Reading Berkshire RG7 4PR and Burghfield, Reading Berkshire RG3 3PR. BR8441/BZ1994, May 2006. Environment Agency, Bristol and London.

Environment Agency, 2006j. GE Healthcare Limited Maynard Centre, Cardiff. News. TC262/06MW. Environment Agency, Bristol and London.

Environment Agency, 2006k. Decision document. Future regulation of disposals of radioactive waste on/from the Low level Waste Repository at Drigg, Cumbria operated by British Nuclear Group Sellafield Ltd. Environment Agency, Bristol and London.

Environment Agency, 2006l. Initial radiological assessment methodology – part 1 user report. SC030162/SR1. Environment Agency, Bristol and London.

Environment Agency, 2006m. Initial radiological assessment methodology – part 2 methods and input data. SC030162/SR2. Environment Agency, Bristol and London.

Environment Agency, 2007a. New guidance coming on disposing of solid radioactive waste. Business and Industry, 29th May 2007. Environment Agency, Bristol and London.

Environment Agency, 2007b. Explanatory Document. Urenco (Capenhurst) Limited nuclear site at Capenhurst, Cheshire, February 2007. Environment Agency, Bristol and London.

Environment Agency, 2007c. Decision Document on the Application by HM Naval Base Devonport under the Radioactive Substances Act 1993 to Dispose of Radioactive Waste From HM Naval Base Devonport Plymouth PL2 2BG. BY9922. Environment Agency, Bristol and London.

Environment Agency, 2007d. Decision on the application by United Kingdom Atomic Energy Authority to vary its authorisation to dispose of radioactive waste from the UKAEA Winfrith site in Dorset, BW2536/CB2083, December 2007. Environment Agency, Bristol and London.

Environment Agency, 2007e. Radioactive particles in the environment around Sellafield, March 2007. Environment Agency, Bristol and London.

Environment Agency, 2008a. Radioactive substances regulation. Environmental Principles. Public consultation. Environment Agency, Bristol and London.

Environment Agency, 2008b. Assessment of Best Available Techniques (BAT). Consultation draft. Environment Agency, Bristol and London.

Environment Agency, 2008c. Nuclear Sector Plan. 2006 Environmental Performance Report. Environment Agency, Bristol and London.

Environment Agency, 2008d. Generic Design Assessment of new nuclear power plant designs summary document. Statement of findings following preliminary assessment of the submission by AREVA NP SAS and Electricite de France SA for their UK EPR design. Environment Agency, Bristol and London.

Environment Agency, 2008e. Generic Design Assessment of new Nuclear power plant designs summary document. Statement of findings following preliminary assessment of the submission by GE-Hitachi Nuclear Energy International LLC for the ESBWR design. Environment Agency, Bristol and London.

Environment Agency, 2008f. Generic Design Assessment of new Nuclear power plant designs summary document. Statement of findings following preliminary assessment of the submission by Westinghouse Electric Company LLC for their AP1000 design. Environment Agency, Bristol and London.

Environment Agency, 2008g. Briefing Note – Briefing Note – Enhanced beach monitoring and radioactive particles near Sellafield site – March 2008 update. http://www.environment-agency.gov.uk/commondata/acrobat/briefing_note_mar_08_2004834.pdf. Environment Agency, Bristol and London.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2004. Radioactivity in Food and the Environment, 2003. RIFE-9. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency. Bristol, Belfast, London and Stirling.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005. Radioactivity in Food and the Environment, 2004. RIFE-10. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, Bristol, Belfast, London and Stirling.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2006. Radioactivity in Food and the Environment, 2005. RIFE-11. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency. Bristol, Belfast, London and Stirling.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007. Radioactivity in Food and the Environment, 2006. RIFE-12. Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency. Bristol, Belfast, London and Stirling.

Environment Agency, Health and Safety Executive, Office for Civil Nuclear Security and Scottish Environment Protection Agency, 2007. Guide to regulatory processes for generic design assessment of new nuclear power stations. Environment Agency, HSE, OCNS and SEPA, Bristol and London.

Environment and Heritage Service, 2004. Report of the Chief Alkali Inspector for the years 2002 and 2003. Environment and Heritage Service, Belfast.

Environment and Heritage Service, Scottish Environment Protection Agency and Environment Agency, 2008a. Near-Surface disposal facilities on land for solid radioactive wastes : guidance on requirements for authorisation. Draft for Public Consultation. EHS, SEPA and Environment Agency, Belfast, Stirling, Bristol and London.

Environment and Heritage Service, Scottish Environment Protection Agency and Environment Agency, 2008b. Deep Geological disposal facilities on land for solid radioactive wastes : guidance on requirements for authorisation. Draft for Public Consultation. EHS and Environment Agency, Belfast, Bristol and London.

Food Standards Agency, 2001a. Consultative Exercise on Dose Assessment, 3 and 4 October 2000. FSA/0022/0501.500. Food Standards Agency, London.

Food Standards Agency, 2001b. Radiological survey of foodstuffs from the Cardiff area. Food Survey Information Sheet 18/01. www.food.gov.uk/science/surveillance/fsis-2001/radsurvcardiff.

Food Standards Agency, 2003. Analysis of farmed salmon for technetium-99 and other radionuclides. Food Survey Information Sheet Number 39/03. Food Standards Agency, London.

Food Standards Agency, 2004. Review of FSA research programmes on radiological protection. Research review report for the period 1998 – 2003. Food Standards Agency, London. http://www.food.gov.uk/science/research/researchinfo/radiologicalresearch/radioactivityenvironment/r01programme/radioprogsreview.

Food Standards Agency, 2006a. Review of Food Standards Agency radiological monitoring programmes. Food Standards Agency, London.

Food Standards Agency, 2008a. Post-Chernobyl Monitoring and Controls: Report of Cumbrian De-Restriction Surveys 2007. Food Standards Agency, London. http://www.food.gov.uk/multimedia/pdfs/derestricteng2007.pdf

Food Standards Agency, 2008b. Post-Chernobyl Monitoring and Controls: Report of Scottish De-Restriction Surveys 2007. Food Standards Agency, London. http://www.food.gov.uk/multimedia/pdfs/scotderestrict2007.pdf

Food Standards Agency and Scottish Environment Protection Agency, 2000. Radioactivity in Food and the Environment, 1999. RIFE-5. Food Standards Agency and Scottish Environment Protection Agency, London and Stirling

Food Standards Agency and Scottish Environment Protection Agency, 2002. Radioactivity in Food and the Environment, 2001. RIFE-7. Food Standards Agency and Scottish Environment Protection Agency, London and Stirling.

Ham, G. J., Wilding, D. and Wilkins, B.T., 2007. Tritium concentrations in crops fertilised with contaminated sewage sludge. R01061. RPD-EA-15-2007. HPA, Chilton.

Harrison, J.D. and Phipps, A., 2001. Invited editorial: gut transfer and doses from environmental technetium. J. Radiol. Prot., 21: (9 – 11).

Harrison, J.D., Khursheed, A and Lambert, B.E., 2002. Uncertainties in dose coefficients for intakes of tritiated water and organically bound forms of tritium by members of the public. Radiation Protection Dosimetry, 98, 299 – 311.

Harvey, M., Oatway, w., Smith, J and Simmonds, J., 2008. Implied doses to the population of the EU arising from reported discharges for EU nuclear power stations and reprocessing sites in the years 1997 to 2004. Radiation Protection No. 153. CEC, Brussels.

Harvey, M.P., Titley, J.G. and Simmonds, J.R., 2000. Generalised derived limits for radioisotopes of polonium, lead, radium and uranium. Docs. NRPB 11(2). NRPB, Chilton.

Health Protection Agency, 2007. Review of the risks from tritium. Report of the Independent Advisory Group on Ionising Radiation. RCE-4. HPA, London.

Health and Safety Executive, 2005a. HSE revokes the nuclear site licence for ICI's Triga reactor and ends the licencees' period of responsibility. http://www.hse.gov.uk/nuclear/triga.htm

Health and Safety Executive, 2007a. HSE grants consent for THORP re-start. Press releases E001:07 10 January 2007.

Health and Safety Executive, 2007b. HSE publishes THORP leak report. Press releases E006:07 23 February 2007.

Health and Safety Executive, 2007c. Purchase of DML by Babcock International Group. http://www.hse.gov.uk/nuclear/llc/2007/devonp4.html

Health and Safety Executive, 2008. Report of the Public Involvement Process associated with the Generic Design Basement of New Nuclear Reactor Designs. HSE, London.

Her Majesty's Inspectorate of Pollution, 1995. Routine measurement of gamma ray air kerma rate in the environment. Technical Guidance Note (Monitoring) M5. HMSO, London.

Hodgson, A., Scott, J.E., Fell, T.P., and Harrison, J.D., 2005. Radiation doses from the consumption of Cardiff Bay flounder containing organically bound tritium (OBT). Project SC020042/SR. Environment Agency, Bristol.

Hughes, J.S., Roberts, D, and Watson, S.J., 2006. Accidents and incidents involving the transport of radioactive materials in the UK. RPD-014. HPA, Chilton.

Hunt, G.J., 1984. Simple models for prediction of external radiation exposure from aquatic pathways. Radiat. Prot. Dosim., 8: 215 – 224.

Hunt, G.J., 1998. Transfer across the human gut of environmental plutonium, americium, cobalt, caesium and technetium: studies with cockles (Cerostoderma edule) from the Irish Sea. J. Radiol. Prot., 18(2): 101 – 109.

Hunt, G.J. and Allington, D.J., 1993. Absorption of environmental polonium-210 by the human gut. J. Radiol. Prot., 13(2):119 – 126.

Hunt, G.J. and Rumney, H.S., 2004. The human gut transfer of environmental polonium-210. Proc. Int. Conf. on widening the radiation protection world, 23 – 28 May 2004, Madrid. IRPA, Fontenay-aux-Roses.

Hunt, G.J and Rumney, H.S., 2005. The human alimentary tract transfer of environmental polonium-210. Proceedings of the Seventh International Symposium of the Society for Radiological Protection, 12th-17th June 2005, Cardiff. SRP, London.

Hunt, G.J. and Rumney, H.S., 2007. The human alimentary tract transfer and body retention of environmental polonium-210. J. Radiol. Prot., 27(4):405-26.

Hunt, G.J., Hewitt, C.J. and Shepherd, J.G., 1982. The identification of critical groups and its application to fish and shellfish consumers in the coastal area of the north-east Irish Sea. Health Physics 43 (6) 875 – 889.

Hunt, G.J., Leonard, D.R.P. and Lovett, M.B., 1986. Transfer of environmental plutonium and americium across the human gut. Sci. Total Environ., 53: 89 – 109.

Hunt, G.J., Leonard, D.R.P. and Lovett, M.B., 1990. Transfer of environmental plutonium and americium across the human gut. Sci. Total Environ., 90: 273 – 282.

Hunt, G.J., Young, A.K. and Bonfield, R.A., 2001. Transfer across the human gut of environmental technetium in lobsters (Homarus gammarus L.) from the Irish Sea. J. Radiol. Prot., 21: 21 – 29.

Hunt, G.J., Leonard, K.S., Gitzinger,C., Janssens, A., Godeanu-Metz, A. and Henrich, E., 2007. Article-35 of the Euratom Treaty: Overview of national radioactive discharge and environmental monitoring requirements in the European Union. Extended Synopsis in International Conference on Environmental Radioactivity, "From Measurement and Assessments in Regulations", 23-27 April 2007, Vienna, Austria.

Imperial College London, 2008. Reviewing the Future of the Imperial College Reactor Centre. http://www3.imperial.ac.uk/reactorcentre/aboutthecentre/futureofthereactorcentre

International Atomic Energy Agency, 1996. International basic safety standards for protection against ionising radiation and for the safety of radiation sources. Saf. Ser. No. 115. IAEA Vienna.

International Atomic Energy Agency, 1997. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. INF CIRC/546. IAEA, Vienna.

International Atomic Energy Agency, 1999. Application of radiological exclusion and exemption principles to sea disposal. IAEA-TECDOC-1068. IAEA, Vienna.

International Atomic Energy Agency, 2003. Determining the suitability of materials for disposal at sea under the London Convention 1972: a radiological assessment procedure. IAEA-TECDOC-1375. IAEA, Vienna.

International Commission on Radiological Protection, 1991. 1990 Recommendations of the International Commission on Radiological Protection. Annal. ICRP 21(1 – 3). Pergamon Press, Oxford, 201pp. (ICRP Publ. (60)).

International Commission on Radiological Protection, 1993. Principles for intervention for protection of the public in a radiological emergency. Annal. ICRP 22(4). Pergamon Press, Oxford, 30pp. (ICRP Publ. (63)).

International Commission on Radiological Protection, 1994. Age-dependent doses to members of the public from intake of radionuclides: Part 2 Ingestion dose coefficients. Annal ICRP 23(3/4). Pergamon Press, Oxford, 167pp. (ICRP Publ. (67)).

International Commission on Radiological Protection, 1996a. Age-dependent doses to members of the public from intake of radionuclides: Part 5 Compilation of ingestion and inhalation dose coefficients. Annal. ICRP 26(1). Elsevier Science, Oxford, 91pp. (ICRP Publ. (72)).

International Commission on Radiological Protection, 1996b. Conversion coefficients for use in radiological protection against external radiation. Annal ICRP 26(3/4). Elsevier Science, Oxford (ICRP Publ. (74)).

International Commission on Radiological Protection, 2001. Doses to the embryo and fetus from intakes of radionuclides by the mother. Annal ICRP 31(1 – 3). Elsevier Science, Oxford. (ICRP Publ.(88)).

International Commission on Radiological Protection, 2006. Assessing dose of the representative person for the purpose of radiation protection of the public and the optimisation of radiological protection : broadening the process. Annal ICRP 36 (3). Elsevier Science, Oxford. (ICRP Publ. (101)).

International Commission on Radiological Protection, 2007. The 2007 recommendations of the International Commission on Radiological Protection. Annal ICRP 37 (2-4). Elsevier Science, Oxford (ICRP Publ (103)).

International Organisation for Standardisation, 2005. General requirements for the competence of testing and calibration laboratories. ISO 17025.

Jobling, S., Williams, R., Johnson, A., Taylor, A., Gross-Sorokin, M., Nolan, M., Tyler, C., van Aerle, R., Santos, E., and Brighty, G., 2006. Predicted exposures to steroid estrogens in UK rivers correlate with widespread sexual disruption in wild fish populations. Environmental Health Perspective, 114 (S-1), 32 – 39.

Joint Research Centre of the European Commission, 2005. Environmental Radioactivity in the European Community 1996 – 2000. Radiation Protection No. 141. EUR. CEC, Luxembourg.

Kelly, M. and Emptage, M.,1991. Radiological assessment of the estuary at Ravenglass: Distribution of radioactivity and its relationship to sedimentary processes. Department of Environment, London.

Kershaw, P.J. and Baxter, A.J., 1995. The transfer of reprocessing wastes from north-west Europe to the Arctic. Deep-Sea Res. II, 43(6): 1413 – 1448.

Kershaw, P.J., McCubbin, D. and Leonard, K.S., 1999. Continuing contamination of north Atlantic and Arctic waters by Sellafield radionuclides. Sci. Tot. Env., 237/238: 119 – 132.

Knowles, J.F., Smith, D.L. and Winpenny K., 1998. A comparative study of the uptake, clearance and metabolism of technetium in lobster (Homarus gammarus) and edible crab (Cancer pagurus). Radiat. Prot. Dosim., 75: 125 – 129.

Kocher, D.C. and Eckerman, K.F., 1987. Electron dose-rate conversion factors for external exposure of the skin from uniformly deposited activity on the body surface. Hlth. Phys., 53: 135 – 141.

Leonard, K.S., 2007. Best practice techniques for environmental radiological monitoring. SC030308/SR. Environment Agency, Bristol and London.

Leonard, D.R.P., Camplin, W.C. and Tipple, J.R., 1990. The variability of radiocaesium concentrations in freshwater fish caught in the UK following the Chernobyl nuclear reactor accident: an assessment of potential doses to critical group consumers. pp. 247 – 256. In: 'Proc. Int. Symp. on Environmental Contamination Following a Major Nuclear Accident'. IAEA, Vienna, IAEA-SM-306/15.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997a. A summary report of the distribution of Technetium-99 in UK Coastal Waters. Radioprotection, 32: 109 – 114.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997b. Distribution of technetium-99 in UK coastal waters. Mar. Pollut. Bull., 34(8): 628 – 636.

Leonard, K.S., McCubbin, D., McMahon, C.A., Mitchell, P.I. and Bonfield, R., 1998. 137Cs/90Sr ratios in the Irish Sea and adjacent waters: a source term for the Arctic. Radiat. Prot. Dosim., 75(1 – 4): 207 – 212.

Leonard, K.S., McCubbin, D., Blowers, P. and Taylor, B.R., 1999. Dissolved plutonium and americium in surface waters of the Irish Sea, 1973 – 96. J. Environ. Rad., 44: 129 – 158.

Leonard, K.S., McCubbin, D. and Bailey, T.A., 2001. Organic forms of tritium in food chains. Project R01023/C0814. RL 6/01. Cefas, Lowestoft.

Leonard, K.S., McCubbin, D., McDonald, P., Service, M., Bonfield, R. and Conney, S., 2004. Accumulation of technetium-99 in the Irish Sea. Sci. Tot. Env., 322: 255 – 270.

Leonard, K.S., Shaw, S., Wood, N., Rowe, J.E., Runacres, S.M., McCubbin, D. and Cogan, S.M., 2007. Independent radiological monitoring; results of a recent intercomparison exercise. 10th International Symposium on Environmental Radiochemical Analysis, 13-15 September 2006, Oxford. ERA III. Royal Society of Chemistry, London.

Male, N and Jones, J, 2008. Summary of Land quality assessment of former Donibriste Airfield, Dalgety Bay, Fife. Project 12920. Defence Estates, Sutton Coldfield.

Mayall, A., Cabianca, T., Attwood, C., Fayers, C.A., Smith, J.G., Penfold, J., Steadman, D., Martin, G., Morris, T.P. and Simmonds, J.R., 1997. PC-CREAM. Installing and using the PC system for assessing the radiological impact of routine releases. EUR 17791 EN. CEC, Luxembourg.

McCubbin, D. and Vivian, C., 2006. Dose assessments in relation to disposal at sea under the London Convention 1972: judging de minimis radioactivity. Project AA005. RL5/06. Cefas, Lowestoft.

McCubbin, D., Leonard, K.S., Bailey, T.A., Williams, J. and Tossell, P., 2001. Incorporation of organic tritium (3H) by marine organisms and sediment in the Severn Estuary/Bristol Channel (UK). Mar. Pollut. Bull., 42 (10): 852 – 863.

McCubbin, D., Leonard, K.S., Brown, J., Kershaw, P.J., Bonfield, R.A. and Peak, T., 2002. Further studies of the distribution of 99Tc and 137Cs in UK and European coastal waters. Cont. Shelf. Res. 22/10: 1417 – 1445.

McCubbin, D. and Vivian, C., 2006. Dose assessments in relation to disposal at sea under the London Convention 1972: judging de minimis radioactivity. FSA Project R01062. RL5/06. Cefas, Lowestoft.

McCubbin, D., Jenkinson, S.B., Leonard, K.S., Bonfield, R.A. and McMeekan, I.T., 2008. An assessment of the availability of Tc-99 to marine foodstuffs from contaminated sediments. Project R01062. RL09/08. Cefas, Lowestoft.

McKay, W.A., Barr H.M., Halliwell C.M., Spencer D., Adsley I. and Perks C.A., 1995. Site specific background dose rates in coastal areas. DoE/HMIP/RR/94/037. Her Majesty's Inspectorate of Pollution, London.

McTaggart, K., 2003. Habits survey notebook, Unpublished. Cefas, Lowestoft.

Ministry of Agriculture, Fisheries and Food, 1994. The British Diet: Finding the facts. Food Surveillance Paper No. 40. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food, 1995. Terrestrial radioactivity monitoring programme (TRAMP) report for 1994. Radioactivity in food and agricultural products in England and Wales. MAFF, London, TRAMP/9, 223pp.

Ministry of Agriculture, Fisheries and Food, 1996. Pesticides Safety Directorate's Handbook. Appendix IC. MAFF, London.

Ministry of Agriculture, Fisheries and Food, 1998. National Food Survey 1997. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998. Radioactivity in Food and the Environment, 1997. RIFE-3. MAFF and SEPA, London and Stirling.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999. Radioactivity in Food and the Environment, 1998. RIFE-4. MAFF andSEPA, London and Stirling.

Mobbs, S., Barraclough, I., Napier, I., Casey, A., Poynter, R. and Harvey, M., 1998. A review of the use and disposal of gaseous tritium light devices. Environment Agency, Lancaster.

Mondon, K.J., and Walters, C.B., 1990. Measurements of radiocaesium, radiostrontium and plutonium in whole diets following deposition of radioactivity in the UK originating from the Chernobyl power plant accident. Food Addit. Contam., 7(6): 837 – 848.

National Dose Assessment Working Group, 2004. Radiological Assessment Exposure Pathways Checklist (Common and Unusual). NDAWG/2/2004. Environment Agency, Food Standards Agency, NRPB, NII, Chilton.

National Radiological Protection Board, 1990. Gut transfer factors. Docs. NRPB 1(2). NRPB, Chilton, 26pp.

National Radiological Protection Board, 2005. Guidance on the application of dose coefficients for the embryo and fetus from intakes of radionuclides by the mother. Docs NRPB 16(2). NRPB, Chilton, 41pp.

Northern Ireland Assembly, 2003. Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland).

Nuclear Decommissioning Authority, 2006. Strategy. NDA, Moor Row, Cumbria.

Nuclear Decommissioning Authority, 2007. Annual Plan 2007/08. NDA, Moor Row, Cumbria

Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985. Review of the continued suitability of the dumping site for radioactive waste in the North-East Atlantic. OECD, Paris, 448pp.

OSPAR, 1998. SINTRA Statement. Summary Record OSPAR 98/14/1, Annex 45. OSPAR, London.

OSPAR, 2000a. Convention for the protection of the marine environment of the North-East Atlantic. OSPAR, London.

OSPAR, 2000b. Quality Status Report 2000. OSPAR, London.

OSPAR, 2002. Discharges of radioactive substances into the maritime area by non-nuclear industry. Radioactive Substances Series. Publication 161. OSPAR, London.

OSPAR, 2006. Agreement on a monitoring programme for concentrations of radioactive substances in the marine environment. Annex 14, ref 9.8c, Malahide (Ireland): 27 June-1 July 2005. OSPAR, London.

OSPAR, 2007. Second periodic evaluation of progress towards the objective of the OSPAR Radioactive Substances Strategy. OSPAR, London.

OSPAR, 2008. Summary Record of the meeting of the Radioactive Substances Committee (RSC), Luxembourg 29 January – 1 February. RSC 08/13/1-E. OSPAR, London.

Ould-Dada, Z., 2000. Sea-to-Land transfer of radionuclides. How much do we know. Proceedings of the second RADREM-TESC Workshop held in London on 21 January 1999. DETR/RADREM/00.001 DETR, London.

Peattie, M.E., Buss, D.H., Lindsay, D.G. and Smart G.Q., 1983. Reorganisation of the British Total Diet Study for monitoring Food Constituents from 1981. Food Chem. Toxicol., 21: 503 – 507.

Povinec, P.P., Bailly Du Bois, P., Kershaw, P.J., Nies, H. and Scotto, P., 2003. Temporal and spatial trends in the distribution of 137Cs in surface waters of Northern European Seas – a record of 40 years of investigations. Deep Sea Res. II, 50: 2785 – 2801.

Preston, A., Mitchell, N.T. and Jefferies, D.F., 1974. Experience gained in applying the ICRP Critical Group concept to the assessment of public radiation exposure in control of liquid waste disposal. Proc. Symp. IAEA Portoroz, IAEA-SM-184/10, 131 – 146.

Rollo, S.F.N., Camplin, W.C., Allington, D.J. and Young, A.K., 1992. Natural radionuclides in the UK marine environment. In: 'Proceedings of the Fifth International Symposium on Natural Radiation Environment, Saltzburg, September 22 – 28, 1991'. Radiat. Prot. Dosim., 45(1/4): 203 – 210.

Rollo, S.F.N., Camplin, W.C., Duckett, L., Lovett, M.B. and Young, A.K., 1994. Airborne radioactivity in the Ribble Estuary. pp277 – 280. In: 'Proc. IRPA Regional Congress on Radiological Protection, 6 – 10 June 1994, Portsmouth, UK'. Nuclear Technology Publishing.

Rowe, J., James, A. and Allott, R., 2001. Potential for bio-accumulation of organically bound tritium in the environment: review of monitoring data. NCAS/TR/2000/026. Environment Agency, Lancaster.

Rowe, J.E., Allott, R. and Morris, C., 2005. Response to questionnaire on the implementation of Article 35 of the Euratom Treaty – Environment Agency and Food Standards Agency Monitoring Programmes. MAPG/TR/2005/003. Environment Agency and Food Standards Agency, Bristol and London.

RWE NUKEM, 2006. Investigation/hot spot removal at Dalgety Bay. TR/89191/001. RWE NUKEM, Rosyth.

Scottish Environment Protection Agency, 2006c. Aberdeen beach radioactivity declared not harmful by export team. News release 28/2/6. SEPA, Stirling.

Scottish Environment Protection Agency, 2006d. Radium contamination at Dalgety Bay, Fife. SEPA, Stirling.

Scottish Environment Protection Agency, 2007a. Consultation: Radioactive Substances Act 1993: Application by Rosyth Royal Dockyard Limited for Authorisation to Dispose of Radioactive Wastes. RSA/A/7088. SEPA, Stirling.

Scottish Environment Protection Agency, 2007b. UKAEA admit illegal Dounreay radioactive waste practices. EXT01-D01. February 2007, SEPA, Stirling.

Scottish Environment Protection Agency, 2007c. Strategy for the Assessment of the potential impact of Sellafield Radioactive Particles on Southwest Scotland, December 2007. http://www.sepa.org.uk/pdf/radioactivity/publications/Solwaymonitoring_strategy.pdf. SEPA, Stirling.

Scottish Environment Protection Agency, 2008. Assessment of radioactive discharges to sewer by the non-nuclear industry in Scotland. SEPA, Stirling.

Scottish Executive, 2000. Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000. Scottish Executive, Edinburgh.

Scottish Executive, 2005. Consultation on proposed Statutory Guidance from the Scottish Ministers to the Scottish Environment Protection Agency on the UK Strategy for Radioactive Discharges. Scottish Executive, Edinburgh.

Scottish Government, 2007. Ministers decline to endorse deep storage, http://www.scotland.gov.uk/News/Releases/2007/06/25101822. News release 25 October 2007.

Shackleton, T., 2007. Unpublished. GE Healthcare, Amersham.

Shaw, S., 2006. Analysis of fish and water samples from the River Cam for phosphorus-32. Project HSL-013. Scientifics Ltd., Didcot.

Simmonds, J.R., Lawson, G. and Mayall, A., 1995. Radiation Protection 72; Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. Report EUR 15760 EN. Office for Official Publications of the European Community, Luxembourg.

Smith, B.D. and Jeffs, T.M., 1999. Transfer of radioactivity from fishmeal in animal feeding stuffs to man. RL 8/99. Cefas, Lowestoft.

Smith, K.R. and Jones, A.L. 2003. Generalised habit data for radiological assessments. NRPB-W41. NRPB, Chilton.

Smith, J.T., Comans, R.N.J., Beresford, N.A., Wright, S.M., Howard, B.J. and Camplin, W.C., 2000. Chernobyl's legacy in food and water. Nature, 405: 7141.

Smith, D.L., Smith, B.D., Joyce, A.E. and McMeekan, I.T., 2002. An assessment of aquatic radiation exposure pathways in Northern Ireland. SR(02)14. RL 20/02. Scotland and Northern Ireland Forum for Environmental Research, Edinburgh.

Smith, B.D., Hunt, G.J. and Camplin, W.C., 2004. The impact of liquid radioactive waste discharges from Sellafield to the Irish Sea in recent years. Proc. Int. Conf. on Widening the radiation protection world, 23 – 28 May 2004, Madrid. IRPA, Fontenay-aux-Roses.

Smith, K.R., Mobbs, S.F. and Cooper, J.R., 2006. Dose criteria for the designation of radioactivity contaminated land. RCE-2. HPA, Chilton.

Stephen, P., 2006. Personal communication. July 2006. Health and Safety Executive, Bootle.

Swift, D.J., 2001. Cardiff radiological survey of selected foodstuffs. Project C1003. RL 11/01. Cefas, Lowestoft.

Swift, D.J. and Nicholson, M.D., 2001. Variability in the edible fraction content of ^{60}Co, ^{99}Tc, ^{110m}Ag, ^{137}Cs and ^{241}Am between individual crabs and lobsters from Sellafield (north eastern Irish Sea). J. Environ. Radioact., 54, 311 – 326.

United Kingdom – Parliament, 1965. Nuclear Installations Act, 1965. HMSO, London.

United Kingdom – Parliament, 1985. Food and Environment Protection Act, 1985. HMSO, London.

United Kingdom – Parliament, 1993. Radioactive Substances Act, 1993. HMSO, London.

United Kingdom – Parliament, 1995a. Environment Act, 1995. HMSO, London.

United Kingdom – Parliament, 1995b. Review of Radioactive Waste Management Policy. HMSO, London, 55pp. (Cm 2919).

United Kingdom – Parliament, 1999. The Ionising Radiations Regulations 1999. Stat. Inst. 1999/3232. HMSO, London, 67pp.

United Kingdom – Parliament, 2003. Water resources, England and Wales. The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003. Stat. Inst. 2003 No 3242. HMSO, London.

United Kingdom – Parliament, 2008. Draft Marine Bill. Cm 7351. HMSO , London.

Watson, S.J., Jones, A.L., Oatway, W.B. and Hughes, J.S., 2005. Ionising radiation exposure of the UK population: 2005 Review. HPA-RPD-001. HPA, Chilton.

Welsh Assembly Government, 2006. Publication of report on radiation and North Wales Coastal Land. Welsh Assembly Government, Cardiff.

Wood, M.D., Hall, P.J., Wittrick, S., Copplestone, D. and Leah, R.T., (*in preparation)*. Survey of gamma dose rates in air around the Esk Estuary. Environment Agency, Bristol and London.

World Health Organisation, 2004. Guidelines for drinking water quality. 3rd Edition. WHO, Geneva.

Williams. J.L., Russ, R.M., McCubbin, D. and Knowles, J.F., 2001. An overview of tritium behaviour in the Severn estuary (UK). J. Rad. Prot., 21: 337 – 344.

Young, A.K., McCubbin, D. and Camplin, W.C., 2002. Natural radionuclides in seafood. Project R03010/C0808. RL 17/02. Cefas, Lowestoft.

APPENDIX 1. 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, 2007

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Sellafield Limited)	Tritium	1600	$5.20\ 10^{-6}$	<1
	Uranium[c]	BPM	$4.00\ 10^{-7}$	NA
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$3.00\ 10^{-7}$	12
Sellafield[d]	Alpha	$8.8\ 10^{-4}$	$1.39\ 10^{-4}$	16
	Beta	0.042	0.00207	4.9
	Tritium	1100	82.9	7.5
	Carbon-14	3.3	0.36	11
	Krypton-85	$4.4\ 10^{5}$	$1.41\ 10^{4}$	3.2
	Strontium-90	$7.1\ 10^{-4}$	$3.64\ 10^{-5}$	5.1
	Ruthenium-106	0.028	0.00131	4.7
	Antimony-125	0.0023	$7.07\ 10^{-4}$	31
	Iodine-129	0.07	0.00482	6.9
	Iodine-131	0.055	$5.65\ 10^{-4}$	1.0
	Caesium-137	0.0058	$1.73\ 10^{-4}$	3.0
	Plutonium alpha	$1.9\ 10^{-4}$	$2.72\ 10^{-5}$	14
	Plutonium-241	0.003	$2.79\ 10^{-4}$	9.3
	Americium-241 and curium-242	$1.2\ 10^{-4}$	$2.10\ 10^{-5}$	18
Springfields	Uranium	0.0053	$5.20\ 10^{-4}$	9.8
Springfields (Nexia Solutions)	Tritium	10^{-4}	$3.20\ 10^{-7}$	<1
	Carbon-14	10^{-5}	$4.20\ 10^{-8}$	<1
	Other alpha radionuclides	10^{-6}	Nil	Nil
	Other beta radionuclides	10^{-5}	$5.90\ 10^{-10}$	<1
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$8.99\ 10^{-6}$	<1
	Beta[f,g]	0.045	$1.53\ 10^{-4}$	<1
	Tritium	2	0.184	9.2
	Krypton-85	3000	Nil	Nil
	Strontium-90	0.0042	$3.50\ 10^{-5}$	<1
	Ruthenium-106	0.0039	$6.32\ 10^{-6}$	<1
	Iodine-129	0.0011	$1.06\ 10^{-4}$	9.6
	Iodine-131	$1.5\ 10^{-4}$	$6.62\ 10^{-5}$	44
	Caesium-134	$8.4\ 10^{-4}$	$8.23\ 10^{-7}$	<1
	Caesium-137	0.007	$5.92\ 10^{-6}$	<1
	Cerium-144	0.007	$4.85\ 10^{-6}$	<1
	Plutonium-241	0.0033	$2.78\ 10^{-6}$	<1
	Curium-242	$2.7\ 10^{-4}$	$5.51\ 10^{-8}$	<1
	Curium-244[h]	$5.4\ 10^{-5}$	$4.55\ 10^{-9}$	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	$8.86\ 10^{-9}$	<1
	Beta	0.0015	$3.30\ 10^{-8}$	<1
	Tritium	4.5	0.0014	<1
	Krypton-85	$4\ 10^{-4}$	$1.72\ 10^{-6}$	<1
Dounreay (Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$3.16\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$5.20\ 10^{-7}$	1.0
	Tritium	10.5	0.135	1.3
	Krypton-85	4	Nil	Nil
Dounreay (PFR minor sources)	Alpha[i]	$6\ 10^{-8}$	$4.11\ 10^{-10}$	<1
	Beta[f]	$5\ 10^{-7}$	$1.62\ 10^{-9}$	<1
	Tritium	0.2	$7.75\ 10^{-4}$	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq	% of annual limit[b]
Dounreay				
(East minor sources)	Alpha[i]	$1.37\ 10^{-5}$	$7.88\ 10^{-8}$	<1
	Beta[f,g]	$3.71\ 10^{-4}$	$4.63\ 10^{-7}$	<1
	Krypton-85[j]	1	Nil	Nil
Dounreay				
(West minor sources)	Alpha[i]	$3\ 10^{-7}$	$2.03\ 10^{-9}$	<1
	Beta[f,g]	$7.5\ 10^{-5}$	$1.01\ 10^{-8}$	<1
	Tritium	0.01	$2.43\ 10^{-4}$	2.4
Harwell				
(AEA Technology)	Alpha	$7\ 10^{-7}$	Nil	Nil
	Beta	$3\ 10^{-5}$	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
Harwell				
(UKAEA)	Alpha	$8\ 10^{-7}$	$5.01\ 10^{-8}$	6.3
	Beta	$2\ 10^{-5}$	$7.60\ 10^{-7}$	3.8
	Tritium	15	0.3	2.0
	Krypton-85	2	0.214	11
	Radon-220	100	10.1	10
	Radon-222	3	0.37	12
	Iodines	0.01	Nil	Nil
	Other radionuclides	0.1	Nil	Nil
Harwell				
(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}	$2.57\ 10^{-9}$	2.6
	Beta/gamma	$3\ 10^{-5}$	$1.88\ 10^{-7}$	<1
	Radon-222	1	0.0102	1.0
	Tritium	2	Nil	Nil
	Krypton-85	0.06	Nil	Nil
Windscale	Alpha	$1.0\ 10^{-6}$	$1.10\ 10^{-7}$	11
	Beta	$5\ 10^{-5}$	$1.67\ 10^{-6}$	3.3
	Tritium	0.01	Nil	Nil
	Carbon-14	BPM	$1.85\ 10^{-5}$	NA
	Krypton-85	9	0.003	<1
	Iodine-131	$9.0\ 10^{-6}$	$7.00\ 10^{-7}$	7.8
	Radon-222	0.5	0.04	8.0
Winfrith				
(WMT Ltd)	Alpha	10^{-7}	Nil	Nil
	Tritium	19.5	8.85	45
	Carbon -14	0.03	$9.11\ 10^{-6}$	<1
	Other	10^{-7}	Nil	Nil
Winfrith				
(UKAEA)	Alpha	$2\ 10^{-6}$	$3.30\ 10^{-10}$	<1
	Tritium	4	0.76	19
	Carbon-14	0.006	0.00137	23
	Other	$5\ 10^{-6}$	$1.66\ 10^{-8}$	<1
Minor sites				
Imperial College Reactor Centre				
Ascot	Tritium	$3\ 10^{-4}$	$4.22\ 10^{-5}$	14
	Argon-41	1.7	0.154	9.1
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 2007	
			TBq	% of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	$2\ 10^{-5}$	$2.53\ 10^{-7}$	1.3
	Tritium	0.02	0.00421	2.1
	Carbon-14	0.005	$2.50\ 10^{-4}$	5.0
Bradwell	Beta	$6\ 10^{-4}$	$4.13\ 10^{-6}$	<1
	Tritium	1.5	0.0226	1.5
	Carbon-14	0.6	0.00111	<1
Chapelcross	Tritium	5000	85.1	1.7
	Sulphur-35	0.05	$2.7\ 10^{-5}$	<1
	Argon-41	4500	Nil	Nil
Dungeness				
'A' Station	Beta[q]	$5.5\ 10^{-4}$	$6.41\ 10^{-5}$	12
	Tritium	2.6	0.219	8.4
	Carbon-14	5	0.243	4.9
	Sulphur-35	0.15	0.00165	1.1
	Argon-41	1700	Nil	Nil
Dungeness[s]				
'B' Station	Particulate beta[v]	0.001	$1.34\ 10^{-6}$	<1
	Tritium	12	4.46	37
	Carbon-14	3.7	0.797	22
	Sulphur-35	0.3	0.0366	12
	Argon-41	75	20.9	28
	Cobalt-60[q,w]	10^{-4}	$3.67\ 10^{-7}$	<1
	Iodine-131	0.0015	$1.03\ 10^{-5}$	<1
Hartlepool[s]	Particulate beta[v]	0.001	$9.42\ 10^{-7}$	<1
	Tritium	10	0.843	8.4
	Carbon-14	4.5	1.66	37
	Sulphur-35	0.23	0.0187	8.1
	Argon-41	150	6.83	4.6
	Cobalt-60[q,w]	10^{-4}	$1.95\ 10^{-6}$	1.9
	Iodine-131	0.0015	$4.76\ 10^{-5}$	3.2
Heysham[s]				
Station 1	Particulate beta[v]	0.001	$1.91\ 10^{-6}$	<1
	Tritium	10	1.18	12
	Carbon-14	4.5	1.48	33
	Sulphur-35	0.2	0.021	11
	Argon-41	150	8.01	5.3
	Cobalt-60[q,w]	10^{-4}	$4.42\ 10^{-6}$	4.4
	Iodine-131	0.0015	$8.99\ 10^{-5}$	6.0
Heysham[s]				
Station 2	Particulate beta[v]	0.001	$2.76\ 10^{-6}$	<1
	Tritium	10	1.17	12
	Carbon-14	3.7	1.52	41
	Sulphur-35	0.23	0.01	4.3
	Argon-41	75	8.84	12
	Cobalt-60[q,w]	10^{-4}	$6.94\ 10^{-6}$	6.9
	Iodine-131	0.0015	$3.82\ 10^{-5}$	2.5
Hinkley Point				
'A' Station	Beta	$1.5\ 10^{-4}$	$4.37\ 10^{-7}$	<1
	Tritium	1.5	0.103	6.9
	Carbon-14	0.6	$7.12\ 10^{-4}$	<1
Hinkley Point[s]				
'B' Station	Particulate beta[v]	0.001	$6.24\ 10^{-6}$	<1
	Tritium	12	0.902	7.5
	Carbon-14	3.7	0.472	13
	Sulphur-35	0.35	0.0670	19
	Argon-41	100	3.76	3.8
	Cobalt-60[q,w]	10^{-4}	$5.23\ 10^{-6}$	5.2
	Iodine-131	0.0015	$5.91\ 10^{-6}$	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq	% of annual limit[b]
Hunterston 'A' Station	Beta[q]	$6\ 10^{-5}$	$3.8\ 10^{-7}$	<1
	Tritium	0.02	0.00161	8.1
	Carbon-14	0.002	$1.81\ 10^{-4}$	9.1
Hunterston[t] 'B' Station	Particulate beta	$5\ 10^{-4}$	$4.47\ 10^{-5}$	8.9
	Tritium	15	1.60	11
	Carbon-14	4.5	0.540	12
	Sulphur-35	0.5	0.0182	3.6
	Argon-41	150	5.9	3.9
	Iodine-131[x]	0.002	$8.13\ 10^{-5}$	4.1
Oldbury	Beta	10^{-4}	$1.56\ 10^{-5}$	16
	Tritium	9	1.31	15
	Carbon-14	4	0.325	8.1
	Sulphur-35	0.45	0.0133	3.0
	Argon-41	500	5.2	1.0
Sizewell 'A' Station	Beta	$8.5\ 10^{-4}$	$3.80\ 10^{-6}$	<1
	Tritium	3.5	1.18	34
	Carbon-14	2	0.11	5.5
	Sulphur-35	0.35	0.015	4.3
	Argon-41	3000	Nil	
Sizewell[s] 'B' Station	Halogens[v]	0.0027	$3.75\ 10^{-6}$	<1
	Particulate Beta	10^{-4}	$5.00\ 10^{-6}$	5.0
	Tritium	3	1.18	39
	Carbon-14	0.5	0.295	59
	Iodine-131[w]	$5\ 10^{-4}$	$1.90\ 10^{-5}$	3.8
Torness[t]	Particulate beta	$4\ 10^{-4}$	$3.34\ 10^{-6}$	<1
	Tritium	11	2.62	24
	Carbon-14	4.5	0.880	20
	Sulphur-35	0.3	0.00873	2.9
	Argon-41	75	5.45	7.3
	Iodine-131	0.002	$2.21\ 10^{-6}$	<1
Trawsfynydd	Beta	$5\ 10^{-5}$	$3.94\ 10^{-7}$	<1
	Tritium	0.75	0.12	16
	Carbon-14	0.01	0.00274	27
Wylfa	Beta	$7\ 10^{-4}$	$4.84\ 10^{-5}$	6.9
	Tritium	18	2.78	15
	Carbon-14	2.3	1	43
	Sulphur-35	0.45	0.13	29
	Argon-41	100	14.4	14
Defence establishments				
Aldermaston[a,m,u]	Alpha	$1.65\ 10^{-7}$	$4.59\ 10^{-8}$	28
	Particulate Beta	$6\ 10^{-7}$	$1.1\ 10^{-7}$	18
	Tritium	39	0.580	1.5
	Carbon-14	$6\ 10^{-6}$	$4.00\ 10^{-8}$	<1
	Argon-41	0.001	Nil	Nil
	Krypton-85	0.075	0.0125	17
	Volatile beta	$4.4\ 10^{-6}$	$3.8\ 10^{-7}$	9
Barrow[l]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.048	Nil	Nil
Burghfield[a,m]	Tritium	10^{-8}	Nil	Nil
	Alpha	$6\ 10^{-9}$	$3.4\ 10^{-10}$	5.7
Coulport	Tritium	0.05	0.00295	5.9

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq	% of annual limit[b]
Derby[n,r]	Uranium	$4\ 10^{-6}$	$6.25\ 10^{-7}$	16
	Alpha[q]	$2.4\ 10^{-8}$	$2.04\ 10^{-10}$	<1
	Beta[q]	$1.8\ 10^{-6}$	$4.35\ 10^{-8}$	2.4
Devonport[o]	Beta/gamma[q]	$3\ 10^{-7}$	$4.24\ 10^{-8}$	14
	Tritium	0.004	$3.63\ 10^{-4}$	9.1
	Carbon-14	0.043	$6.55\ 10^{-4}$	1.5
	Argon-41	0.015	$3.01\ 10^{-5}$	<1
Dounreay				
(Vulcan)	Alpha[q]	10^{-6}	$4.77\ 10^{-8}$	4.8
	Beta[q]	10^{-4}	$1.2\ 10^{-6}$	1.2
	Noble gases	0.027	$3.40\ 10^{-4}$	1.3
	Iodine-131	$3.7\ 10^{-4}$	$2.65\ 10^{-5}$	7.2
Rosyth[p]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$2.25\ 10^{-6}$	$1.68\ 10^{-7}$	7.5
	Beta>0.4 MeV	0.02	$6.35\ 10^{-6}$	<1
	Radionuclides T1/2<2hr	0.75	0.0425	5.7
	Tritium	2	$1.08\ 10^{-6}$	<1
	Sulphur-35	0.035	0.0105	30
	Selenium-75	0.001	$2.89\ 10^{-4}$	19
	Iodine-125	0.02	$9.05\ 10^{-4}$	4.5
	Iodine-131	0.001	$4.70\ 10^{-4}$	47
	Radon-222	10	4.48	45
	Other noble gases	50	0.464	<1
	Other	0.01	$3.15\ 10^{-4}$	2.0
Cardiff (GE Healthcare)	Soluble tritium	156	76.0	49
	Insoluble tritium	600	293	49
	Carbon-14	2.38	1.98	83
	Phosphorus-32/33	$5\ 10^{-6}$	$8.30\ 10^{-7}$	17
	Iodine-125	$1.8\ 10^{-4}$	$2.63\ 10^{-5}$	15
	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] *There are no numerical limits for this discharge. However, the authorisation stipulates that the Best Practicable Means should be used to control the discharge*

[d] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*

[e] *Excluding curium-242 and 244*

[f] *Excluding tritium*

[g] *Excluding krypton-85*

[h] *Data 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 April 2007*

[t] *Discharge authorisation revised with effect from 1 June 2007*

[u] *Discharge authorisation revised with effect from 1 March 2007*

[v] *Not reported after 31 March 2007*

[w] *Not reported prior to 1 April 2007*

[x] *Not reported prior to 1 June 2007*

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, 2007

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Tritium[c]	78	0.031	<1
	Uranium	0.02	$8.60\ 10^{-5}$	<1
	Uranium daughters	0.02	$6.60\ 10^{-5}$	<1
	Non-uranic alpha	0.003	$2.90\ 10^{-5}$	<1
	Technetium-99	0.1	$3.90\ 10^{-5}$	<1
Sellafield[d] (sea pipelines)	Alpha	1	0.125	13
	Beta	220	24.8	11
	Tritium	$2\ 10^{4}$	628	3.1
	Carbon-14	21	4.65	22
	Cobalt-60	3.6	0.05	1.4
	Strontium-90	48	5	10
	Zirconium-95 + Niobium-95	3.8	0.12	3.2
	Technetium-99	10	4.89	49
	Ruthenium-106	63	1.49	2.4
	Iodine-129	2.0	0.104	5.2
	Caesium-134	1.6	0.137	8.6
	Caesium-137	34	6.98	21
	Cerium-144	4.0	0.419	10
	Neptunium-237	1.0	0.038	3.8
	Plutonium alpha	0.7	0.105	15
	Plutonium-241	25	2.83	11
	Americium-241	0.3	0.0224	7.5
	Curium-243+244	0.069	0.00311	4.5
	Uranium[i]	2000	302	15
Sellafield (factory sewer)	Alpha	$3\ 10^{-4}$	$5.70\ 10^{-5}$	19
	Beta	0.0061	$6.81\ 10^{-4}$	11
	Tritium	0.068	0.0112	16
Springfields	Alpha	0.55	0.026	4.7
	Beta	140	2.99	2.1
	Technetium-99	0.6	0.051	8.5
	Thorium-230	0.4	0.0014	<1
	Thorium-232	0.015	$3.47\ 10^{-4}$	2.3
	Neptunium-237	0.04	0.00169	4.2
	Other transuranic radionuclides	0.02	0.00313	16
	Uranium	0.1	0.018	18
Research establishments				
Dounreay	Alpha[4]	0.02	$8.68\ 10^{-5}$	<1
PFR liquid metal disposal plant	Beta[1]	0.11	0.00106	<1
	Tritium	1.4	0.00914	<1
	Sodium-22	1.8	0.0681	3.8
	Caesium-137	0.066	$7.63\ 10^{-5}$	<1
Dounreay Other facilities	Alpha	0.09	$2.25\ 10^{-4}$	<1
	Beta	0.62	0.00189	<1
	Tritium	5.5	0.109	2.0
	Strontium-90	0.77	0.0457	5.9
	Caesium-137	1	0.0103	1.0
Harwell (pipeline)				
	Alpha	$5\ 10^{-5}$	$4.65\ 10^{-6}$	9.3
	Beta	0.0033	$3.13\ 10^{-4}$	9.5
	Tritium	0.3	0.00386	1.3
	Cobalt-60	$1.2\ 10^{-4}$	$1.61\ 10^{-6}$	1.3
	Caesium-137	$5.4\ 10^{-4}$	$3.63\ 10^{-5}$	6.7
Harwell (Lydebank Brook)	Alpha	10^{-4}	$1.11\ 10^{-5}$	11
	Beta	$6\ 10^{-4}$	$4.73\ 10^{-5}$	7.9
	Tritium	0.08	0.00664	8.3

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq[a]	% of annual limit[b]
Winfrith (inner pipeline)[7]	Alpha	0.02	$1.34\ 10^{-4}$	<1
	Tritium	220	23.4	11
	Caesium-137	2	0.0817	4.1
	Other radionuclides	1	0.0146	1.5
Winfrith (outer pipeline)[7]	Alpha	0.002	$3.96\ 10^{-5}$	2.0
	Tritium	0.15	0.0066	4.4
	Other radionuclides	0.001	$6.27\ 10^{-5}$	6.3
Winfrith (River Frome)[7]	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	2	$2.11\ 10^{-5}$	<1
	Caesium-137	0.2	$4.87\ 10^{-5}$	<1
	Other radionuclides	0.4	$7.07\ 10^{-5}$	<1
Bradwell	Tritium	7	0.0281	<1
	Caesium-137	0.7	0.0151	2.1
	Other radionuclides	0.7	0.0248	3.6
Chapelcross	Alpha	0.1	$1.66\ 10^{-5}$	<1
	Beta[1]	25	0.0010	<1
	Tritium	5.5	0.0082	<1
Dungeness 'A' Station	Tritium	8	3.54	44
	Caesium-137	1.1	0.0699	6.4
	Other radionuclides	0.8	0.0222	2.8
Dungeness[9] 'B' Station	Tritium	650	339	52
	Sulphur-35	2	0.470	24
	Cobalt-60	0.01	0.00147	15
	Caesium-137[9]	0.1	0.00494	4.9
	Other radionuclides[10]	0.08	0.00822	10
Hartlepool[9]	Tritium	650	335	52
	Sulphur-35	3	0.676	23
	Cobalt-60	0.01	$9.05\ 10^{-5}$	<1
	Caesium-137[9]	0.1	0.00130	1.3
	Other radionuclides[10]	0.08	0.00379	4.7
Heysham[9] Station 1	Tritium	650	272	42
	Sulphur-35	2	0.304	15
	Cobalt-60	0.01	$8.11\ 10^{-4}$	8.1
	Caesium-137[9]	0.1	0.00290	2.9
	Other radionuclides[10]	0.08	0.0109	14
Heysham[9] Station 2	Tritium	650	325	50
	Sulphur-35	2	0.0826	4.2
	Cobalt-60	0.01	$7.30\ 10^{-5}$	<1
	Caesium-137[9]	0.1	0.00147	1.5
	Other radionuclides[10]	0.08	0.0122	15
Hinkley Point 'A' Station	Tritium	1.8	0.326	18
	Caesium-137	1	0.18	18
	Other radionuclides	0.7	0.14	20

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq[a]	% of annual limit[b]
Hinkley Point[g]				
'B' Station	Tritium	650	47.5	7.3
	Sulphur-35	2	0.0540	2.7
	Cobalt-60	0.01	$6.40\ 10^{-5}$	<1
	Caesium-137[9]	0.1	0.00274	2.7
	Other radionuclides[10]	0.08	0.00441	5.5
Hunterston				
'A' Station	Alpha	0.04	$6.93\ 10^{-5}$	<1
	Beta	0.6	0.0367	6.1
	Tritium	0.7	$3.90\ 10^{-4}$	<1
	Plutonium-241	1	$5.40\ 10^{-5}$	<1
Hunterston[p]				
'B' Station	Alpha	0.001	$4.85\ 10^{-5}$	4.9
	All other non-alpha	0.2	0.00611	4.1
	Tritium	700	35.4	5.1
	Sulphur-35	6	0.399	6.7
	Cobalt-60	0.01	$2.80\ 10^{-4}$	2.8
Oldbury	Tritium	1	0.178	18
	Caesium-137	0.7	0.376	54
	Other radionuclides	0.7	0.17	24
Sizewell				
'A' Station	Tritium	11	2.07	19
	Caesium-137	1	0.262	26
	Other radionuclides	0.7	0.157	22
Sizewell[g]				
'B' Station	Tritium	80	29.2	36
	Caesium-137[9]	0.02	0.006	30
	Other radionuclides[10]	0.13	0.0130	10
Torness[p]	Alpha	$5\ 10^{-4}$	$4.43\ 10^{-6}$	<1
	All other non-alpha	0.15	0.00255	1.7
	Tritium	700	320	46
	Sulphur-35	3	0.0277	<1
	Cobalt-60	0.01	$1.58\ 10^{-4}$	1.6
Trawsfynydd	Tritium	0.5	0.003	<1
	Strontium-90	0.05	$1.45\ 10^{-4}$	<1
	Caesium-137	0.03	0.00119	4.0
	Other radionuclides[5]	0.17	0.00127	<1
Wylfa	Tritium	15	6.19	41
	Other radionuclides	0.11	0.0115	10
Defence establishments				
Aldermaston (Silchester)[q]	Alpha	0.01	$3.89\ 10^{-6}$	<1
	Beta/gamma	0.02	$1.49\ 10^{-5}$	<1
	Tritium	0.025	0.00106	4.2
Aldermaston (to Stream)	Tritium	0.010	$3.00\ 10^{-12}$	<1
Barrow[l]	Tritium	0.012	Nil	Nil
	Other gamma emitting radionuclides	$3.5\ 10^{-6}$	Nil	Nil
Derby[m]	Alpha[n]	0.002	$7.86\ 10^{-5}$	3.9
	Alpha[o]	$3\ 10^{-7}$	$1.80\ 10^{-8}$	6.0
	Beta[o]	$3\ 10^{-4}$	$9.97\ 10^{-7}$	<1
Devonport[k] (sewer)	Tritium	0.002	$1.28\ 10^{-4}$	6.4
	Cobalt-60	$3.5\ 10^{-4}$	$1.23\ 10^{-5}$	3.5
	Other radionuclides	$6.5\ 10^{-4}$	$3.05\ 10^{-4}$	47

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq[a]	% of annual limit[b]
Devonport[k] (estuary)	Tritium	0.7	0.132	19
	Carbon-14	0.0017	$4.12\ 10^{-4}$	24
	Cobalt-60	$8\ 10^{-4}$	$5.90\ 10^{-5}$	7.4
	Other radionuclides	$3\ 10^{-4}$	$3.86\ 10^{-5}$	13
Faslane	Alpha	$2\ 10^{-4}$	$2.95\ 10^{-7}$	<1
	Beta[3,6]	$5\ 10^{-4}$	$1.34\ 10^{-5}$	2.7
	Tritium	1	0.0664	6.6
	Cobalt-60	$5\ 10^{-4}$	$3.45\ 10^{-6}$	<1
Rosyth[j]	Alpha	$5\ 10^{-7}$	$2.1\ 10^{-8}$	4.2
	Beta[3,6]	$4.8\ 10^{-4}$	$2.29\ 10^{-5}$	4.8
	Tritium	0.012	$4.6\ 10^{-4}$	3.8
	Cobalt-60	0.0025	$5.4\ 10^{-5}$	2.2
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$3\ 10^{-4}$	$1.25\ 10^{-5}$	4.2
	Beta>0.4 MeV	0.06	$3.05\ 10^{-4}$	<1
	Tritium	0.141	$5.34\ 10^{-4}$	<1
	Iodine-125	0.004	$3.67\ 10^{-5}$	<1
	Caesium-137	0.005	$1.23\ 10^{-5}$	<1
	Other radionuclides	0.215	0.00402	1.9
Cardiff (GE Healthcare)	Tritium	130	28.1	22
	Carbon-14	0.91	0.143	16
	Phosphorus-32/33	$8.5\ 10^{-5}$	$7.40\ 10^{-8}$	<1
	Iodine-125	$3\ 10^{-4}$	$1.26\ 10^{-6}$	<1
	Others	$1.2\ 10^{-4}$	Nil	Nil
Industrial and landfill sites				
Drigg (sea pipeline)[e,8]	Alpha	BPM	$1.30\ 10^{-4}$	NA
	Beta	BPM	0.00127	NA
	Tritium	BPM	0.18	NA
Drigg (stream)[h,8]	Alpha	NA	NA	NA
	Beta	NA	NA	NA
	Tritium	NA	NA	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] *The limit for tritium is derived from a limit on activity concentration in Rivacre Brook of 111 Bq ml^{-1} and a flow rate of 90 m^3 h^{-1}*
[d] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[e] *Discharge authorisations at Drigg were revised with effect from 1 May 2006*
[f] *New authorisation 1 April 2006*
[g] *Discharge authorisation revised with effect from 1 April 2007*
[h] *Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)*
[i] *The limit and discharge data are expressed in kg*
[j] *Discharges were made by Rosyth Royal Dockyard Ltd*
[k] *Discharges were made by Devonport Royal Dockyard Ltd*
[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[n] *Discharge limit is for Nuclear Fuel Production Plant*
[o] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[p] *Discharge authorisation revised with effect from 1 June 2007*
[q] *Discharge authorisation revised with effect from 1 March 2007*
[1] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[2] *Excluding sulphur-35*
[3] *Excluding cobalt-60*
[4] *All alpha emitting radionuclides taken together*
[5] *Including strontium*
[6] *Excluding tritium*
[7] *New authorisation March 2006*
[8] *New authorisation from May 2006 - limits revoked*
[9] *Not reported prior to 1 April 2007*
[10] *Includes Caesium-137 prior to 1 April 2007*
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, 2007

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2007	
			TBq	% of limit[a]
Drigg[b]	Tritium	10	0.256	2.6
	Carbon-14	0.05	0.0280	56
	Cobalt-60	2	0.295	15
	Iodine-129	0.05	$1.80\ 10^{-4}$	<1
	Radium-226 plus			
	thorium-232	0.03	0.00117	3.9
	Uranium	0.3	0.0159	5.3
	Other alpha[d]	0.3	0.179	60
	Others[d,e]	15	1.76	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 disposed, 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 2007

Site	Month	Summary of incident	Consequences and action taken
Dounreay	June	SEPA was notified by UKAEA of the detection of radioactive contamination (including plutonium) in a surface water drain near to the Dounreay foreshore.	UKAEA devised a programme of work to intercept the contaminated liquor and divert it to an authorised route and then to identify options to remediate the contaminated land that was believed to be the source of the contamination. The European Commission requested information about this event under the terms of Euratom Treaty Article 35 which requires each Member State to establish facilities necessary to carry out continuous monitoring of the levels of radioactivity in air, water and soil and to ensure compliance with the EU Basic Safety Standards Directive. SEPA provided its regulatory overview of this incident to the Scottish Government, which was included with the response sent to the EC.
Sellafield	September 2006 – August 2007	In February 2008 we issued a warning letter to Sellafield Limited in response to elevated aerial discharges of caesium-137 from the Fuel Handling Plant, which breached the annual plant limit during the period September 2006 – August 2007 (as reported in RIFE 12).	The work carried out by Sellafield Limited to address the root cause of the elevated discharge has led to a better understanding of the processes which generate the radioactive contamination in air at the plant, and how to control them. This has led to a significant reduction in caesium-137 discharges from November 2006, which has been sustained over the last year. The radiation doses to the public were assessed to be very low.
Sellafield	August – October 2006	In RIFE 12, we reported that aerial discharges of antimony-125(Sb-125) exceeded the site Quarterly Notification Level during the period August-October 2006.	The precise source of the elevated discharges has still not been confirmed. Investigations suggest there might be a correlation between Sb-125 discharges and the fuel de-canning rates. There is also a suggestion that the elevated discharges could be linked to the de-canning of fuel from Wylfa power station; Wylfa spent fuel tends to be of a higher burn-up than fuel from other Magnox stations. Wylfa is also progressively contributing to a greater share of the total amount of Magnox fuel de-canned as the other Magnox stations close down. Sellafield Limited has also not ruled out that there may be some connections between the elevated Sb-125 discharges and the elevated Cs-137 discharges which also occurred in 2006. Consequently it is not certain whether such elevated discharges of Sb-125 will recur and whether any measures could be taken to avoid such discharges. The Environment Agency continue to monitor this issue. The radiation doses to the public were assessed to be very low.
Sellafield	May – December 2007	Routine large area monitoring of local beaches began in May 2007, following trials of specially designed vehicle-mounted survey equipment in November 2006 and February 2007. 261 radioactive items were found using this equipment during 2007, comprising stones, pebbles and particles.	The HPA has advised that no special precautions are necessary regarding use of the beaches. However, monitoring and assessment will continue into 2008 and beyond. The finds are likely to be associated with past incidents and events at Sellafield. However, as a precaution an Enforcement Notice was issued to Sellafield Limited with the aim of further improving, as far as practicable, the current systems for excluding solids from liquid waste streams before discharge (an authorisation requirement).
Sizewell A Nuclear Site	January 2007	Substantial leak of water from Site fuel pond.	Participated in Site response, carried out investigation and took action. Followed up Site response and progressed case for enforcement action.

APPENDIX 3. Abbreviations and glossary

AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques
BE	British Energy
BNFL	British Nuclear Fuels plc
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Limited
BSS	Basic Safety Standards
CAC	Codex Alimentarius Commission
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
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DH	Department of Health
DML	Devonport Management Limited
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
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
FMD	Foot and Mouth Disease
FSA	Food Standards Agency
GDA	Generic Design Assessments
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
IC	Imperial College
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
ISO	International Standards Organisation
LGC	Laboratory of the Government Chemist
LLETP	Low Level Effluent Treatment Plant
LLW	Low level Waste
LLWR	Low level Waste Repository
LoD	Limit of Detection
MAFF	Ministry of Agriculture, Fisheries & Food
MoD	Ministry of Defence
MRL	Minimum reporting level
ND	Not detected
NDA	Nuclear Decommissioning Authority
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
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
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
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	Tetrophenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UKAEA	United Kingdom Atomic Energy Authority
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UOC	Uranium Ore Concentrate
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WMTL	Waste Management Technology Limited
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}.
Becquerel	One radioactive transformation per second.
Committed effective	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 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.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the 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 gathers data on people's occupancy close to each site and local food intake rates. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Berkeley and Oldbury, Bradwell, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Faslane, Hartlepool, Harwell, Heysham, Hinkley Point, Hunterston, Rosyth, Sellafield, Sizewell, Springfields, Torness, Trawsfynydd, Winfrith and Wylfa. 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) (Stephen, 2006 and Bunker, 2007).

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 2007 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). A similar approach is used for the routine assessments and is described in Appendix 1.

A4.4 Results of the assessment of total dose

The results of the assessment are summarized 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

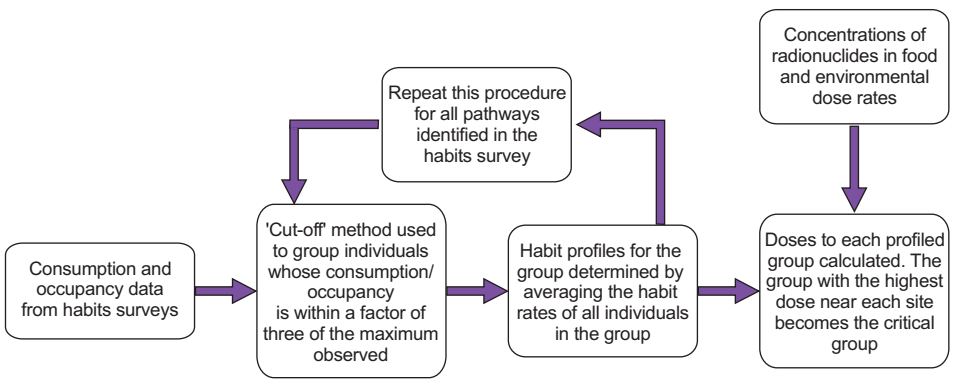


Figure A4.1. Steps in the total dose methodology

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 2007 were less than the limit of 1mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most important groups for liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose was to seafood consumers at Sellafield and Whitehaven, though approximately half of this was due to the legacy of discharges of naturally-occurring radionuclides from a phosphate processing works in Whitehaven. The cessation of energy production at Dungeness A and Sizewell A has seen the *total dose* received by local inhabitants drop sharply, primarily due to the reduction in direct radiation from these sites. 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* doubled in response to a relatively high concentration of caesium-137 in venison, which was not sampled in 2006. This contributes 94 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 23. The *total doses* calculated for nuclear sites since 2003 are presented in Table A4.3. The steady decrease in *total dose* at Cardiff has continued, with the dose in 2007 less than a quarter of the *total dose* in 2003. This is due to 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 has also 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. There have been no other significant trends in *total dose* identified from the assessments undertaken.

Table A4.1. Individual radiation exposures - direct radiation pathway, 2007

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.12
Sellafield	Bgd[a]
Springfields	<0.030
Research establishments	
Dounreay	<0.010
Harwell	0.026[b]
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	<0.060
Bradwell	<0.070
Chapelcross	Bgd[a]
Dungeness	0.28
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	0.004
Hunterston	<0.090
Oldbury	Bgd[a]
Sizewell	0.004
Torness	<0.020
Trawsfynydd	0.016
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	0.085

[a] *Doses not significantly different from natural background*
[b] *2006 data used due to unavailability of 2007 data*

Table A4.2. Individual radiation exposures integrated across pathways, 2007

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, ^{234}U
Amersham	Local adult inhabitants (0 - 0.25km)	0.23	Direct radiation
Berkeley and Oldbury	Local inhabitants aged 1y (0 - 0.25km)	0.061	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.070	Direct radiation
Cardiff	Milk consumers aged 1y	<0.005	Milk, ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{137}Cs
Chapelcross	Milk consumers aged 1y	0.019	Milk, ^{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	0.059	Game meat, ^{137}Cs
Dungeness	Local adult inhabitants (0 - 0.25km)	0.28	Direct radiation
Faslane	-	-	
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.026	Direct radiation
Heysham	Local adult inhabitants (0.25 - 0.5km)	0.021	Direct radiation
Hinkley Point	Prenatal children of local inhabitants (0.5 - 1km)	<0.005	Direct radiation
Hunterston	Prenatal children of local inhabitants (0.5 - 1km)	0.090	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Milk consumers aged 1y	0.011	Milk, ^{90}Sr, ^{137}Cs
Sizewell	Prenatal children of wild fruit and nut consumers	<0.005	Direct radiation
Springfields	Adult mushroom consumers	0.031	Direct radiation
Torness	Prenatal children of root vegetable consumers	0.022	Direct radiation
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.018	Direct radiation, milk
Winfrith	Adult green vegetable consumers	<0.005	Milk, fruit, green vegetables, potatoes, ^{14}C, ^{137}Cs
Wylfa	Local adult inhabitants (0 - 0.25km)	0.011	Direct radiation
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of river bank	<0.005	External dose from riverbank
Amersham	Adult occupants over sediment	<0.005	Gamma dose rate over sand/stone
Berkeley and Oldbury	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Bradwell	Adult occupants over sediment	0.016	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	0.008	Gamma dose rate over sediment, fish, ^{3}H, ^{14}C
Chapelcross	Adult occupants over sediment	0.017	Gamma dose rate over sediment
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult occupants over sediment	0.010	Gamma dose rate over sediment, milk, potatoes, ^{129}I, ^{241}Am
Dungeness	Fish consumers aged 1y	0.028	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish
Hartlepool	Prenatal children of mollusc consumers	<0.005	Direct radiation, molluscs, ^{14}C
Harwell	Adult occupants of riverbank	0.006	External dose from riverbank
Heysham	Adult occupants over sediment	0.038	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.035	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 and Whitehaven	Adult mollusc consumers	0.37[c]	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Adult crustacea consumers	<0.005	Fish, crustacea, ^{14}C, ^{137}Cs, ^{241}Am
Springfields	Adult occupants on houseboats	0.11	Gamma dose rate over sediment
Torness	Adult fish consumers	<0.005	Direct radiation, fish, ^{241}Am
Trawsfynydd	Adult occupants over sediment	0.007	Gamma dose rate over sediment, direct radiation, fish
Winfrith	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Wylfa	Adult occupants over sediment	0.006	Gamma dose rate over sediment

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 river bank	<0.005	External dose from riverbank
Amersham	Local adult inhabitants (0 - 0.25km)	0.23	Direct radiation
Berkeley and Oldbury	Local inhabitants aged 1y (0 - 0.25km)	0.061	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.070	Direct radiation
Cardiff	Prenatal children of occupants over sediment	0.008	Gamma dose rate over sediment, fish, ^{3}H, ^{14}C
Chapelcross	Milk consumers aged 1y	0.019	Milk, ^{90}Sr, ^{241}Am
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult consumers of game meat	0.059	Game meat, ^{137}Cs
Dungeness	Local adult inhabitants (0.5 - 1km)	0.28	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.026	Direct radiation
Heysham	Adult occupants over sediment	0.038	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.035	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.5 - 1km)	0.090	Direct radiation
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield and Whitehaven	Adult mollusc consumers	0.37[c]	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of wild fruit and nut consumers	<0.005	Direct radiation
Springfields	Adult occupants on houseboats	0.11	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)	0.018	Direct radiation, milk
Winfrith	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Wylfa	Local adult 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 0.19 mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven*

Table A4.3. Trends in total dose from all sources[a]

Site	2003	2004	2005	2006	2007
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005	<0.005
Amersham		0.24	0.24	0.22	0.23
Berkeley and Oldbury					0.061
Bradwell					0.070
Cardiff	0.038	0.023	0.023	0.011	0.008
Chapelcross			0.023	0.024	0.019
Devonport		<0.005	<0.005	<0.005	<0.005
Dounreay	0.012	0.011	0.043	0.029	0.059
Dungeness			0.55	0.55	0.28
Faslane				<0.005	<0.005
Hartlepool	0.021	0.021	0.021	0.021	0.021
Harwell					0.026
Heysham				0.037	0.038
Hinkley Point				0.048	0.035
Hunterston		0.10	0.090	0.097	0.090
Rosyth			<0.005	<0.005	<0.005
Sellafield and Whitehaven	0.66	0.58	0.40	0.43	0.37
Sizewell			0.086	0.091	<0.005
Springfields				0.13	0.11
Torness				0.024	0.022
Trawsfynydd			0.021	0.022	0.018
Winfrith	<0.005	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.009	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 2007 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 Protection 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.

Tritium in Sewage Sludge – R01061

Authorised discharges of radionuclides into sewers result in contamination of sewage sludge, which can be used as a soil conditioner. A review of published information, conducted by the Health Protection Agency (HPA) indicated that specific data on the uptake of radionuclides from sludge-amended land into crops was scarce (Ham e*t al.*, 2007). Discharges from the radiochemical plant in Cardiff are routed to a waste water treatment works, and have resulted in elevated concentration in sewage sludge pellets. This provided the opportunity to generate specific data on crop uptake.

The project made use of the contractor's existing lysimeter facility to generate realistic uptake data for selected crops grown in three soil types. This was augmented by smaller scale studies on a wider range of crops that generated relative values for uptake parameter values applicable to the Agency's predictive models. Losses via transportation are an important area of uncertainty, and experiments to measure the extent of these losses were also undertaken. Losses from transpiration were also estimated using an activity balance approach.

Concentrations of tritium in treated soil decreased throughout the period of the experiment, and measured values in the soil itself displayed considerable variability, although this variability decreased with time. It was not possible to quantify individual soil to crop transfer in terms of conventional concentration ratios. However, the results showed that it would be reasonable to assume in risk assessments that the proportion of tritium transferred into crops from soil treated with sewage sludge would be small.

Sampling at Drigg sand dunes – SC070019

This project used radionuclide concentrations in biota in sand dunes near the LLWR site, which is near Drigg in Cumbria, to study the validity of computer models used to predict the impact of radiation on wildlife. Samples were collected for five amphibian species, two bird species, two mammal species, three reptile species, one vegetation species and one invertebrate species (Beresford *et al.*, 2008). All samples were analysed to determine whole-body activity concentrations of gamma-emitting radionuclides. The only anthropogenic radionuclides detected were caesium-137 and americium-241. A subset of samples were also analysed to determine

concentrations of technetium-99, strontium-90, plutonium-239/240 and americium-241 (by alpha analysis). The results indicated that it was likely there would be an adverse impact on wildlife in the sand dunes. They also contributed to the refinement of existing computer models.

Technetium-99 from sediments in seafood – R01062

A proportion of technetium-99 discharges from Sellafield are held in marine sediments. The aim of the project was to investigate the seabed accumulation of technetium-99 and to consider the potential for its effect on seafood contamination (McCubbin *et al*., 2008). This was achieved via (i) a programme of sediment core sampling to estimate the inventory of technetium-99 currently residing in the sub-tidal sediments of the Irish Sea and (ii) tuning, validating and applying a multi-compartmental model to estimate the rate and extent of re-dissolution of technetium-99 into the overlying seawater and hence the availability to seafood.

The inventory of technetium-99 in sub-tidal sediments was of the order of 37 TBq. The modelling suggested that the impact of remobilization from sediments upon concentrations in the water column is predicted to be small in the short to medium term (up to 2012) relative to current discharges from Sellafield.

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 the animal feed pathway has a particular prevalence. The first phase of the project was conducted in 2006. This involved a survey to determine the extent of seaweed usage, 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 they are given in Table 8.20. The analysis of foodstuffs will take place in 2008 and an assessment of the pathways will be summarized in next year's report.

Radioactive discharges to sewer by the non-nuclear industry in Scotland – SEPA

This project is now complete and is summarized in Section 7.6

Table A5.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Discharges to sewer by non-nuclear industry in Scotland	SEPA	S	Completed
Tritium transfer from sewage sludge to plants	R01061	F	Completed
Availability of technetium-99 to seafood from contaminated sediments	R01062	F	Completed
Sampling at Drigg sand dunes	SCO70019	E	Completed
Total diet studies	R03024	F	Completed
Freshwater concentration factors for phosphorus-32	SCO60080	E	Oct-08
Soil and herbage survey	UKRSR01 and SC000027	E, S	Dec-08
Transfer from seaweed to terrestrial foods	R04003	F	Mar-09
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-09
Total diet studies	ERI015	F	Mar-10

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

Table A5.2. Concentrations of radionuclides in seaweed and soil in Scotland measured to investigate the transfer of radionuclides from sea to land, 2007

Area	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			^{90}Sr	^{99}Tc	^{137}Cs
Outer Hebrides	Seaweed	1		100	0.23
Northern Inner Hebrides	Seaweed	1		140	0.76
Southern Inner Hebrides	Seaweed	1			1.2
N and NW coast	Seaweed	1			0.18
Outer Hebrides	Soil	1		43	21
Northern Inner Hebrides	Soil	1	5.8	73	21
Southern Inner Hebrides	Soil	1	2.1	300	17
N and NW coast	Soil	1	4.7	32	15

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

APPENDIX 6. Disposal of dredge material from Heysham, 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 2007, a specific assessment was conducted for the disposal of dredge material in the vicinity of the Port of Heysham (outside the harbour).

The outer 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.

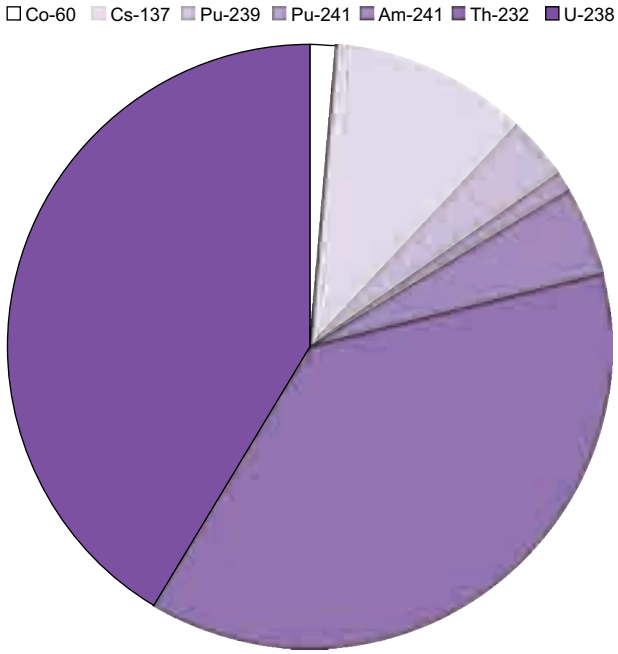


Figure A6.1. Radionuclide contribution to dose to individual crew members due to dredging at Heysham

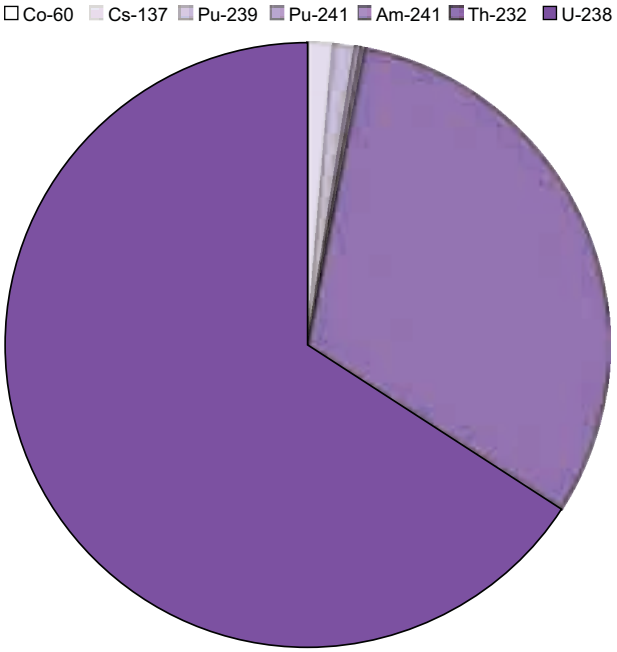


Figure A6.2. Radionuclide contribution to dose to individual members of the public due to dredging at Heysham

Table A6.1. Concentrations of radionuclides in sediment from Lancashire, 2007

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	0.30	16	7.0	7.0	9.0	17
2	0.30	15	8.0	7.0	10	23
3	0.30	22	8.0	8.0	12	41
4	0.60	24	8.0	8.0	12	47
5	0.30	23	8.0	9.0	8.0	39
6	0.70	50	16	17	22	62
Mean	0.42	25	9.2	9.3	12	38

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

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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 2006 unchanged. The main changes are:

Sampling and measurement

- Sellafield particles - additional discussion of monitoring for radioactive particles on beaches at Sellafield is provided
- Ports - analyses of samples of food in consignments being imported through Dover and Felixstowe Ports were undertaken because screening equipment detected unusually high results
- Small users in Scotland - monitoring to determine the effects of discharges to sewers by the non-nuclear industry in Scotland was introduced
- Aberdeen landfills - monitoring leachate from landfill sites in Aberdeen was extended
- Chapelcross - enhanced sampling of freshwater and measurement of dose rates at Chapelcross was completed in 2006. Sampling of cooling towers was instigated
- Sea-to-land transfer - sea-to-land transfer of radionuclides site in Scotland and at Hinkley Point was investigated
- River Thames fish - sampling of freshwater fish in the River Thames catchment was dropped because of increased field work costs
- Faslane - monitoring of mussels at Faslane to investigate the impact of using shells as fertiliser was introduced. The natural variability of radioactivity in groundwater in Scotland was investigated
- Special sampling at nuclear sites – this was continued where there were unusual short-term increases in discharges and inadvertent releases
- Litvinenko - the study of the environmental effects of contamination from the Litvinenko incident was completed in 2006 and is not discussed further in this report
- Landfills in England and Wales - monitoring of leachate from landfill sites in England and Wales has much reduced because of the low radiological significance of the findings

Assessment and presentation

- *Total Dose* - a further three sites have been assessed using a *Total Dose* assessment methodology. This brings together information on all sources of exposure at nuclear sites, including direct radiation
- New charts - are provided of trends in dose for sites in the middle of the UK and from natural radionuclides at Whitehaven
- Site maps - maps of sites and sampling locations have been revised and updated. New maps are provided for Dounreay and Winfrith
- Atmospheric dispersion modelling - use of atmospheric dispersion modelling is substantially revised and extended to ensure adequate coverage of all significant pathways
- New habits data - consumption and occupancy rates for critical groups have been updated with the benefit of recent habit survey results at Dumfries and Galloway, Bradwell, Berkeley, Oldbury, Harwell and Hunterston
- New dose assessments are undertaken to represent groups affected in coastal areas around the Irish Sea through typical, as opposed to high-rate, occupancy of intertidal areas. The assessment effects of radioactivity from the marine environment on a typical tourist visiting Cumbria is also introduced
- Dose coefficients - the most recent information on dose coefficients has been reviewed and changes to the values used for intakes of polonium-210 have been included
- Dredge spoil disposal - an assessment of the impact of dredge spoil disposal from Heysham Harbour is provided
- Research related to the monitoring programmes has been reviewed and results relevant to (i) Drigg sand dunes (near Sellafield), (ii) technetium-99 in sub-tidal sediments in the Irish Sea and (iii) food chain transfer of tritium have been included.

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 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 Article 35 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 in 2007 - Whitehaven. 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 were also small programmes that considered the effects of discharges from non-nuclear sites such as hospitals.

About thirty landfill sites were monitored in England and Scotland. The programme in Wales finished in 2006. The distribution of landfill sites considered in 2006 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 2007 to investigate the effects of disposal of dredged spoil from Heysham 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*. The EC compile data into a report of results from all Member States. At the time of writing, the last report covered data for 1996 – 2000 (Joint Research Centre, 2005). The TDS was supplemented with a study of canteen meals in 2006. Together they account for the 'dense' and 'sparse' networks for mixed diet (Commission of the European Communities, 2000a) required by the EC.

Specific foods, freshwater, rain and airborne particulates

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

Milk sampling took place at dairies throughout the UK in 2006. 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).

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

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 2007, 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.

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
- IC Imperial College, University of London, total uranium analysis of terrestrial samples in England, Wales and the Channel Islands
- 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 the Scottish Environment Protection Agency. 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

* *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.*

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.

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 when (i) either the radionuclide is one which is in the relevant authorisation, (ii) or it has been analysed by radiochemistry, (iii) or it has been reported as being a positive value in that table in the previous 5 years, (iv) or a positive result is detected in any other sample presented in the table in 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 the Scottish Environment Protection Agency with Directions concerning radiation doses to the public and their methods of estimation and regulation for all pathways (Department of the Environment, Transport and the Regions, 2000 and Scottish Executive, 2000). In Northern Ireland, regulations were made to implement the requirements of the BSS Directive in the Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland) 2003 (Northern Ireland Assembly, 2003). The methods and data used in this report are consistent with the Directions.

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

The mean dose received by the 'critical group' is compared with the dose limit. The critical group represents those who are most exposed to radiation and in this report are generally people who eat large quantities of locally grown food (high-rate consumers) or who spend long periods of time in areas where radioactive contamination may exist. The limits apply to all age groups. Children may receive higher doses than adults because of their physiology, anatomy and dietary habits. The embryo/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'. The approach used in this report is consistent with their guidance. The ICRP has recently revised its recommendations (International Commission on Radiological Protection, 2007) and the new recommendations do not significantly affect the analysis in this report. The detailed implications concerning EU and UK radiation protection standards are being considered by the relevant authorities and their findings will be taken into account in future issues of this report.

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

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

As discussed in last year's RIFE report, the Codex Alimentarius Commission (CAC) has been producing revised guideline levels for radionuclides in foods following accidental radiological contamination for use in international trade. The proposals were the subject of a consultation in the UK led by the Food Standards Agency. Subsequently, a drafting group led by the IAEA and the EC was set up to revise the draft guidelines. The new guidelines have now been published (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. Further research is being undertaken to provide methods and data to enable more complete and systematic assessments to be made in the UK (Commission of the European Communities, 2004). SEPA undertook a Pressures and Impacts Assessment on Scotland's Water Environment from radioactive substances. The report concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data from some locations to support this conclusion. The report is available from http://www.sepa.org.uk/pdf/publications/technical/wfd_Assessment_pressures_impacts.pdf

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 three 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, Aldermaston and 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 fishermens' nets, and
- The time spent near the source.

In both cases, the assessment estimates exposures from these pathways for potential critical groups, that is the groups of people who are likely to be most exposed.

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

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 Berkeley, Bradwell, Dumfries and Galloway, Harwell, Hunterston, Oldbury and Sellafield in 2007. 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 ^{99}Tc, ^{106}Ru, ^{144}Ce, ^{147}Pm and ^{241}Pu 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.

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 given in Environment Agency (2006l). 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 for 2006. 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	$1.61\ 10^{-4}$	b	$6.81\ 10^{-6}$
	Ravenglass	a	$2.75\ 10^{-4}$	$2.75\ 10^{-3}$	$5.20\ 10^{-6}$
	Drigg	a	$4.33\ 10^{-4}$	$3.90\ 10^{-3}$	$1.43\ 10^{-5}$
	Isle of Man	a	$2.25\ 10^{-4}$	$2.08\ 10^{-3}$	$1.30\ 10^{-5}$
Beef	Sellafield	a	$1.61\ 10^{-1}$	b	$6.81\ 10^{-4}$
	Ravenglass	a	$2.75\ 10^{-1}$	$1.38\ 10^{-1}$	$5.20\ 10^{-4}$
	Drigg	$8.02\ 10^{-2}$	$4.33\ 10^{-1}$	$1.95\ 10^{-1}$	$1.43\ 10^{-3}$
	Isle of Man	$1.73\ 10^{-2}$	$2.25\ 10^{-1}$	$1.04\ 10^{-1}$	$1.30\ 10^{-3}$
Sheep	Sellafield	a	$1.86\ 10^{-1}$	b	a
	Ravenglass	a	$3.18\ 10^{-1}$	$1.59\ 10^{-1}$	$2.40\ 10^{-4}$
	Drigg	a	$5.00\ 10^{-1}$	$2.25\ 10^{-1}$	$6.60\ 10^{-4}$
	Isle of Man	$2.00\ 10^{-2}$	$2.60\ 10^{-1}$	$1.20\ 10^{-1}$	$6.00\ 10^{-4}$
Beef offal	Sellafield	a	$1.61\ 10^{-1}$	b	a
	Ravenglass	a	$2.75\ 10^{-1}$	a	a
	Drigg	$3.21\ 10^{-1}$	$4.33\ 10^{-1}$	$3.90\ 10^{1}$	$2.86\ 10^{-1}$
	Isle of Man	$6.93\ 10^{-2}$	$2.25\ 10^{-1}$	$2.08\ 10^{1}$	$2.60\ 10^{-1}$
Sheep offal	Sellafield	a	$1.86\ 10^{-1}$	b	$2.36\ 10^{-2}$
	Ravenglass	a	$3.18\ 10^{-1}$	a	a
	Drigg	a	$5.00\ 10^{-1}$	a	$4.95\ 10^{-2}$
	Isle of Man	$8.00\ 10^{-2}$	$2.60\ 10^{-1}$	$2.40\ 10^{1}$	$4.50\ 10^{-2}$

[a] *Positive result used, or LoD result used because modelling result greater than LoD*
[b] *No grass, Leafy Green Vegetable or 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
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^3s^{-1} (Jobling et al., 2006)*
[b] *Based on an average flow rate of 0.3 m^3s^{-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 (2006m) methodology*

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. 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 (NA)	10 year old children	500 h y^{-1} over sediment
		5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		20 l y^{-1} water by inadvertent ingestion
Cardiff	A (2003)	24 kg y^{-1} fish
		3.8 kg y^{-1} prawns and lobster
		500 h y^{-1} over mud
	B (NA)	500 h y^{-1} over bank of River Taff
		2.5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		34 l y^{-1} water by inadvertent ingestion
	C (2003)	5.6 kg y^{-1} wildfowl
Channel Islands (1997)		62 kg y^{-1} fish
		30 kg y^{-1} crabs, spider crabs and lobsters
		30 kg y^{-1} scallops and whelks
		1400 h y^{-1} over mud and sand
Chapelcross (2005)	A	31 kg y^{-1} salmonids
		950 h y^{-1} over mud
	B	450 h y^{-1} over salt marsh
		19 kg y^{-1} wildfowl
	C	390 h y^{-1} handling nets
		610 h y^{-1} handling sediment
Culham (NA)		600 l y^{-1} water
Derby (NA)		600 l y^{-1} water
Devonport (2004)	A	32 kg y^{-1} fish
		3.5 kg y^{-1} crabs, prawns and shrimps
		1.7 kg y^{-1} scallops
		980 h y^{-1} over sediment and shale
	B	2000 h y^{-1} over mud
Dounreay (2003)	A	1500 h y^{-1} handling fishing gear
	B	30 kg y^{-1} fish
		8.9 kg y^{-1} crab and lobster
		0.5 kg y^{-1} mussels and winkles
	C	410 h y^{-1} over rock and sand
	D	8 h y^{-1} in a Geo
Drigg (NA)		35 l y^{-1} water
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (2005)	A	51 kg y^{-1} fish
		9.3 kg y^{-1} crabs and shrimps
		17 kg y^{-1} king scallops
		1500 h y^{-1} over mud and sand
	B (Rye Harbour houseboats)	2000 h y^{-1} over mud

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 (2002)		32 kg y^{-1} fish 15 kg y^{-1} crab and lobster 12 kg y^{-1} winkles and whelks 910 h y^{-1} over mud
Harwell (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) (2007)	41 kg y^{-1} cod (60%) and other fish (40%) 20 kg y^{-1} crab (50%), lobster (30%) and *Nephrops* (20%) 29 kg y^{-1} winkles (60%) and other molluscs (40%) 830 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (2003)	730 h y^{-1} handling nets and pots
	C (Bait digging and mollusc collecting) (2003)	1000 h y^{-1} handling sediment
	D (Whitehaven commercial) (1998)	40 kg y^{-1} plaice and cod 9.7 kg y^{-1} *Nephrops* 15 kg y^{-1} whelks
	E (Morecambe Bay)	see Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod 29 kg y^{-1} shrimps 23 kg y^{-1} whelks
	G (Dumfries and Galloway) (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 670 h y^{-1} over saltmarsh
	I (Dumfries and Galloway (wildfowling) (2007)	22 kg y^{-1} wildfowl 15 kg y^{-1} cod and plaice
	J (Typical fish consumer) (NA)	100 kg y^{-1} fish 20 kg y^{-1} crustaceans 20 kg y^{-1} molluscs
	K (Isle of Man) (NA)	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
	L (Northern Ireland) (2000)	

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	41 kg y^{-1} fish
	2003-2007) (NA)	13 kg y^{-1} crabs
		5.3 kg y^{-1} lobsters
		3.8 kg y^{-1} *Nephrops*
		18 kg y^{-1} winkles
		16 kg y^{-1} other molluscs
		810 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)	400 h y^{-1} over salt marsh
	(2003)	2.0 10^{-3} kg y^{-1} mud by inadvertent ingestion
		3.7 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) (2003-2007) (NA)	2600 h y^{-1} over mud
	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*
Data sources include Environment Agency (2002a) and Smith and Jones (2003)

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 age groups 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 (AGIR) concerning relative biological effectiveness and radiation weighting (Health Protection Agency, 2007).

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	0.02	0.24	0.080	1.2	1.5	1.6	0.94	0.39	1.5
	(0.0030-0.55)	(0.013-2.4)	(0.043-0.76)	(0.02-0.79)	(0.18-6.8)	(0.69-2.6)	(0.68-6.8)	(0.59-1.3)	(0.18-0.61)	(0.68-4.9)
Polonium-210	0.82	9.1	19	5.3	17	13	42	18	6.5	8.4
	(0.18-4.4)	(1.1-35)	(4.1-35)	(1.9-10)	(1.2-69)	(6.1-25)	(19-69)	(11-36)	(1.2-11)	(5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

[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