RIFE - 12

Radioactivity in Food and the Environment, 2006

Environment Agency

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November 2007

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

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Preface

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

This is the twelfth report in the series and the fifth publication that all four organisations have produced in partnership.

Our report aims to provide 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, Environment and Heritage Service 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 carried out by each of our organisations during 2006, providing one overall detailed set of information. It also means that we can assess 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, and 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.

Operators of nuclear sites are required to monitor their discharges and the effects on the environment. The Food Standards Agency and the Environment Agencies carry out their own monitoring programmes. These are important because they provide an independent assessment and act as an additional check on the monitoring programmes carried out by site operators.

Our monitoring programmes are the primary way of checking whether radiation exposure conforms to legal limits. Our monitoring:

- allows us to check that any radioactivity in food and the environment from authorised releases and discharges does not affect people's health or the environment
- establishes long-term information on concentrations and trends so that we can identify any changes and take action if we need to
- allows the assessment of the public's total exposure to radiation around nuclear sites

The results from the report show that the public's exposure to radiation around each nuclear site in 2006 was below, and in many cases well below, the legal limit. Concentrations of radionuclides in food and the environment around nuclear sites were very similar to previous years. At many sites, radionuclide levels were low and, in some cases, so low they could not be detected.

At some places, levels of radioactivity were lower than in the past and these appear to be falling year on year. For example, levels of tritium in seafood around Cardiff continued to fall in 2006 from the highest levels seen in 2001. Technetium-99 levels around Sellafield and polonium-210 concentrations in seafood near Whitehaven continued to decrease.

As older power stations have closed down and treatment plants opened, this has had an important effect on reducing radionuclide discharges and levels in the environment. Before 2006, seven of the 11 Magnox power stations (the first generation of nuclear power stations in the UK) had been closed permanently. The Magnox power stations at Dungeness and Sizewell were closed at the end of 2006, leaving only Oldbury and Wylfa, and the British Energy nuclear power stations, operating at the start of 2007.

Technetium-99 discharges from Sellafield are now substantially reduced and met the 2006 target in the UK National Discharges Strategy.

We have carried out detailed investigations in a number of specific places. We investigated localised areas of radioactive contamination at Dalgety Bay in Fife and near Dounreay. At the end of 2006, we requested enhanced monitoring of the beaches around Sellafield for radioactive particles. This continues in 2007.

The Chernobyl accident happened in 1986, with radioactive fallout affecting parts of the UK. Radiocaesium levels in upland areas and in grazing sheep exceeded recommended levels. In 1986, there were controls placed on approximately 9,700 farms and 4,225,000 sheep across the UK. In 2006, 20 years on, 374 farms (reducing further to 371 at the start of 2007) and 200,000 sheep in some upland areas of England, Scotland and Wales were still affected by post-Chernobyl controls.

This report summarises the results from several large-scale radiological monitoring programmes run by the UK

Government and Devolved Administrations. The results clearly show that discharges from nuclear sites do not compromise environmental or public health and all doses are within the 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 levels at other UK locations not associated with nuclear sites

Radiation exposures 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 food consumption.

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 sites in the UK. In 2006, radiation doses to adults and children living around nuclear sites remained well below national and European limits.

A group of people in Cumbria that consumed a large quantity of fish and shellfish received the highest dose of radiation due to discharges. Their dose was estimated to be 0.47 millisieverts (mSv, a measure of dose) in 2006. This was due to the effects of current and past liquid discharges from Sellafield and from past liquid discharges from the phosphate processing plant at Whitehaven. Sellafield discharges were estimated to have contributed 0.23 mSv to this dose in 2006, similar to the contribution to dose in 2005 of 0.22 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 0.006 mSv (about 3%) to the 0.23 mSv dose, a reduction from 0.013 mSv (about 6%) of 0.22 mSv in 2005. Doses from technetium-99 have been falling for several years as a result of decreasing discharges.

Although liquid radioactive discharges from Sellafield have fallen in recent years, in some cases people who have eaten seafood have received higher doses with some groups having seen an increase of 75% since 2000. This upward trend in doses is mainly due to the fact that people living near Sellafield have been consuming more seafood rather than because of any increase in concentrations of radionuclides in seafood. This trend now appears to be reducing.

As well as the radiation from Sellafield discharges, the seafood consumer group also received 0.24 mSv from what is known as Technologically enhanced Naturally-Occurring Radioactive Material. Some radionuclides that occur naturally can have their levels in the environment increased due to previous industrial operations in this case discharges from a phosphate processing works at Whitehaven. The dose of 0.24 mSv in 2006 is similar to the value of 0.23 mSv in 2005. Altogether, the group who consumed the seafood received a dose from radiation exposure of 0.47 mSv in 2006, 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 0.029 mSv in 2006 and compared with the dose of 0.034 mSv in 2005. Doses were also assessed to people who had consumed crops grown on land fertilised by seaweed from around Sellafield. Their estimated dose for 2006 was 0.013 mSv (0.069 mSv in 2005).

In terms of radiation exposure from waste discharges, the second most significant group of people were those living near the nuclear power stations at Dungeness. In 2006, their dose was 0.13 mSv (similar to the dose in 2005). Most of this dose was due to the gaseous plume of argon-41, mainly discharged from the Dungeness A station. The next most significant dose in terms of radiation exposure from waste discharges was for a group near Sizewell nuclear power stations. The group received a dose of 0.059 mSv, mostly caused by argon-41 from the 'A' station.

Other sites, significant in terms of doses to the public, included Springfields in Lancashire, where people living in houseboats in the Ribble estuary were estimated to receive 0.075 mSv in 2006. Most of this exposure was due to external dose due to radionuclides from Sellafield in intertidal sediments. This was an increase from the dose of 0.037 mSv seen in 2005. The change was due to the introduction of specific dose rate measurements on a boat.

The next most significant site in terms of public dose was at Hinkley Point. Liquid discharges gave a group of seafood consumers a dose of 0.040 mSv or 4% of the public dose limit. Some of the dose from seafood consumption was due to past tritium discharges from the GE Healthcare plant at Cardiff.

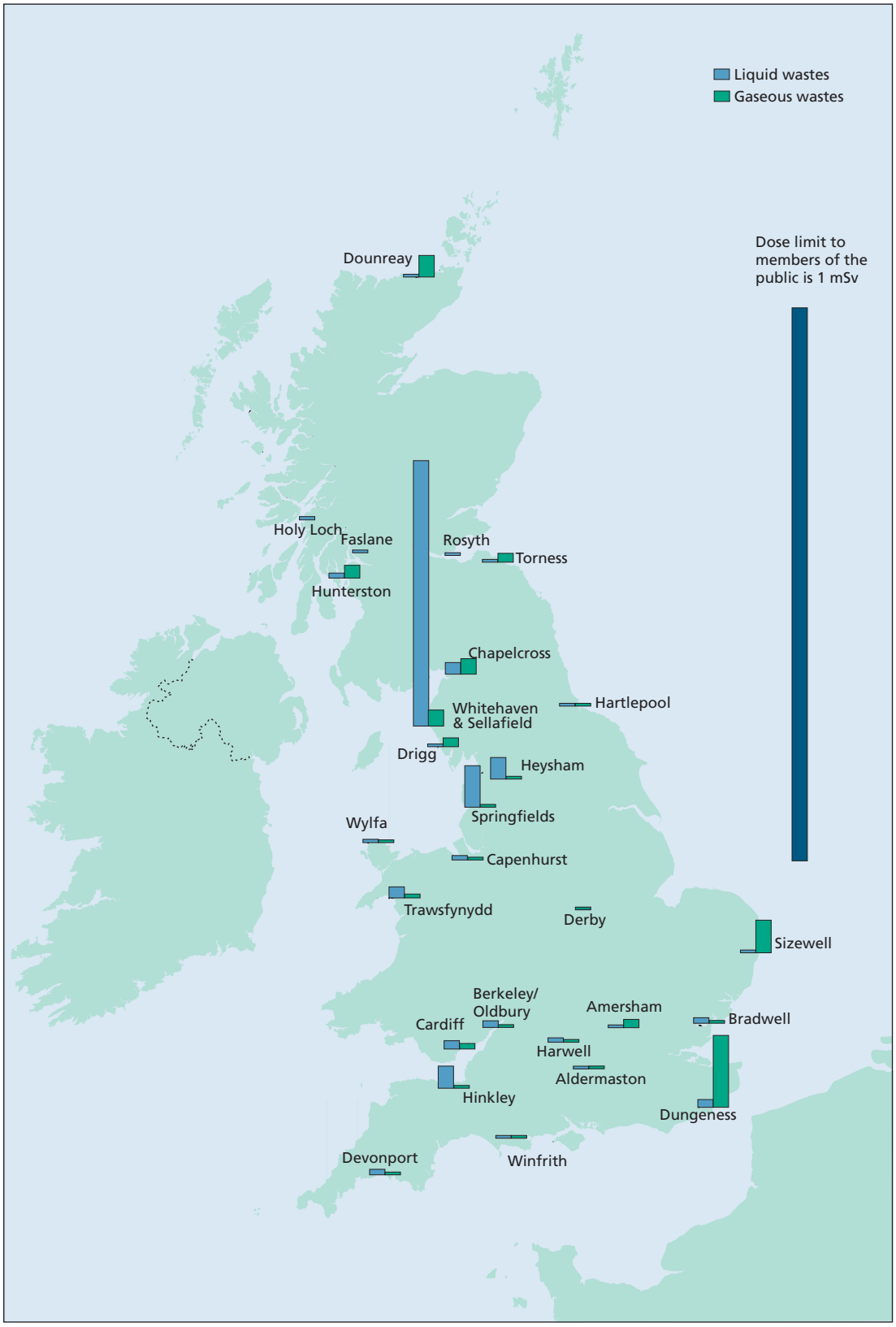


Figure S1. Radiation exposures in the UK due to radioactive waste discharges, 2006 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S1. Radiation doses due to discharges of radioactive waste in the United Kingdom, 2006

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	0.008	Ext ^{237}Np
	Terrestrial foods[i]	G	<0.005	
Springfields	External (skin) to fishermen	L	0.075[f]	Beta
	Fish and shellfish consumption	L	0.022	Ext ^{137}Cs
	Terrestrial foods	G	<0.005[h]	^{129}I ^{234}U
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	0.075	Ext
	External in intertidal areas (farmers and wildfowlers)	L	0.033	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2002-2006 surveys) (excluding naturally occurring radionuclides)[k]	L	0.23	$^{239/240}$Pu ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2002-2006 surveys) (including naturally occurring radionuclides)[l]	L	0.47	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2006 surveys) (excluding naturally occurring radionuclides)[k]	L	0.24	$^{239/240}$Pu ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.029	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.013	
	External in intertidal areas (Ravenglass)[a]	L	0.042	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)	L	0.075	Ext
	External (skin) to bait diggers	L	0.19[f]	Beta
	Handling of fishing gear	L	0.068[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield	L	0.013	^{99}Tc
Research establishments				
Culham	Water consumption[n]	L	<0.005	
Dounreay	Fish and shellfish consumption	L	<0.005	^{241}Am
	External in intertidal areas	L	<0.005	Ext
	Terrestrial foods[i]	G	0.039	
Harwell	Fish consumption and external to anglers	L	0.008	Ext ^{137}Cs
	Terrestrial foods[i]	G	<0.005	
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods	G	<0.005	^{14}C ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{14}C
Chapelcross	Fish and shellfish consumption and external in intertidal areas	L	0.021	Ext
	Terrestrial foods[i]	G	0.028	^{90}Sr
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.013	Ext ^{241}Am
	Occupancy of houseboats	L	0.014	Ext
	Terrestrial foods, external and inhalation near site	G	0.13	^{14}C ^{41}Ar
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{14}C
	Terrestrial foods[i]	G	<0.005	^{14}C ^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.038	Ext ^{241}Am
	Terrestrial foods[i]	G	<0.005	^{35}S
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.040	Ext
	Terrestrial foods[i]	G	<0.005	^{35}S
Hunterston	Fish and shellfish consumption	L	<0.005	^{137}Cs ^{241}Am
	External in intertidal areas	L	0.009	Ext
	Terrestrial foods[i]	G	0.023	^{90}Sr

Summary Table S1. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear power production *continued*				
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	0.059	^{14}C ^{41}Ar
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{99}Tc ^{241}Am
	Terrestrial foods[i]	G	0.016	^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.008	Ext ^{137}Cs
	Terrestrial foods[i]	G	0.007	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.006	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
	Terrestrial foods	G	<0.005[h]	
Derby	Water consumption[n]	L	<0.005	
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods[o]	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	L	0.006	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	0.015	^{75}Se ^{222}Rn
Cardiff	Fish and shellfish consumption[o] and external in intertidal areas	L	0.015	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.010	^{3}H
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	
Industrial and landfill				
Drigg	Terrestrial foods[i]	G	0.016	^{90}Sr
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.24	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.47	^{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*

Relatively high concentrations of tritium were found in food and the environment near GE Healthcare at Cardiff, where radiochemicals for life sciences are produced. In 2006, the most exposed group, with an estimated dose of 0.015 mSv, was prenatal children. Most of the dose was due to the consumption of fish from the Severn Estuary that contained tritium and carbon-14. The dose to the prenatal children was similar to that to adults at 0.012 mSv. The reduction in dose from 2005 (0.027 mSv) was due to lower concentrations of tritium in these fish.

The group most exposed to radiation in Scotland consisted of people who ate food grown on the land near Dounreay. They received an annual dose of 0.039 mSv in 2006. In 2005, this group was estimated to have received a dose of 0.040 mSv.

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 exposure pathway may be significant around some of the Magnox power stations that are still operating. The Health and Safety Executive (which is the relevant regulatory authority) has provided estimates of direct radiation doses at sites in the UK, using information from the site operators.

In 2003, a 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 2006, *total doses* to the public were assessed at twenty nuclear site locations. The results are shown in Figure S.2 and Table S.2. In 2006, *the total doses* at these twenty sites were all less than the annual EU and UK limit of 1 mSv. We will extend these types of site assessments to the remaining major nuclear sites in future *Radioactivity in Food and the Environment* reports, as the necessary information becomes available.

Radioactivity levels in samples collected around nuclear sites

The previous section highlighted changes in doses in 2006, but these were not necessarily due to variations in concentrations of radioactivity in samples with some due to changes in people's diets. This section summarises any changes in concentrations of radioactivity in food or the environment.

The UK Radioactive Discharge Strategy was published in 2002. It describes how the UK will implement the agreements of the 1998 and later meetings of the Oslo and Paris Convention 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 future years. In 2006, the Environment Agency and the Scottish Environment Protection Agency issued new permits with more stringent conditions and limits on disposing of radioactive waste for Winfrith in Dorset, Windscale in Cumbria and Hunterston 'B' and Torness in Scotland. During 2006, the Environment Agency continued determining the permits for defence sites at Aldermaston and Burghfield, the Sellafield Ltd.-operated site at Capenhurst and all the power stations operated by British Energy in England. In addition, during 2006, the Department for Environment, Food and Rural Affairs (Defra), the Department of Health (DoH) and the National Assembly for Wales (NAW) completed a joint review of the Environment Agency's decisions and recommendations made in 2002 with respect to radioactive wastes from Magnox sites. Defra, the DoH and the NAW concluded that there was no need to exercise their powers to direct the Environment Agency to change any of the decisions it made and thus the discharge limits imposed were agreed to.

Reductions in discharges, either through reductions in discharge limits or operator initiatives, can lead to reductions in concentrations in food and environmental samples in the vicinity of the site. In December 2006, the Environment Agency reported that GE Healthcare had announced that their major recycling initiative (Project Paragon) had been successful in developing a process to recycle tritium but had been less successful in developing a process for the recycling of liquid and gaseous carbon-14 wastes. The overall effect of the project is lower discharges of tritium.

The reductions in discharges from GE Healthcare at Cardiff have led to reductions in concentrations of tritium in fish, which have continued to decline since their peak level of 2000. Similarly, reductions in discharges of technetium-99 from the Sellafield site has 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 2006 compared with 2005. This was due to significant reductions in discharges from the Springfields site. Apart from these, there were no major changes in levels of radioactivity in 2006 compared to those in 2005.

In 2006, the highest concentrations of tritium in seafood from near Cardiff were in the range 4,400 to 4,600 Bq kg^{-1} in sole and flounder, down from the range of 6,000 to 11,000 Bq kg^{-1} in 2005. The 2006 levels are less than 10% of the levels seen in 2000, when tritium in flounder concentrations was 54,000 Bq kg^{-1}. Tritium concentrations in seafood at some other coastal locations around the UK ranged up to 210 Bq kg^{-1} above the expected background tritium concentration of 1 Bq kg^{-1}. The enhancement was a result of 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 levels found near Cardiff.

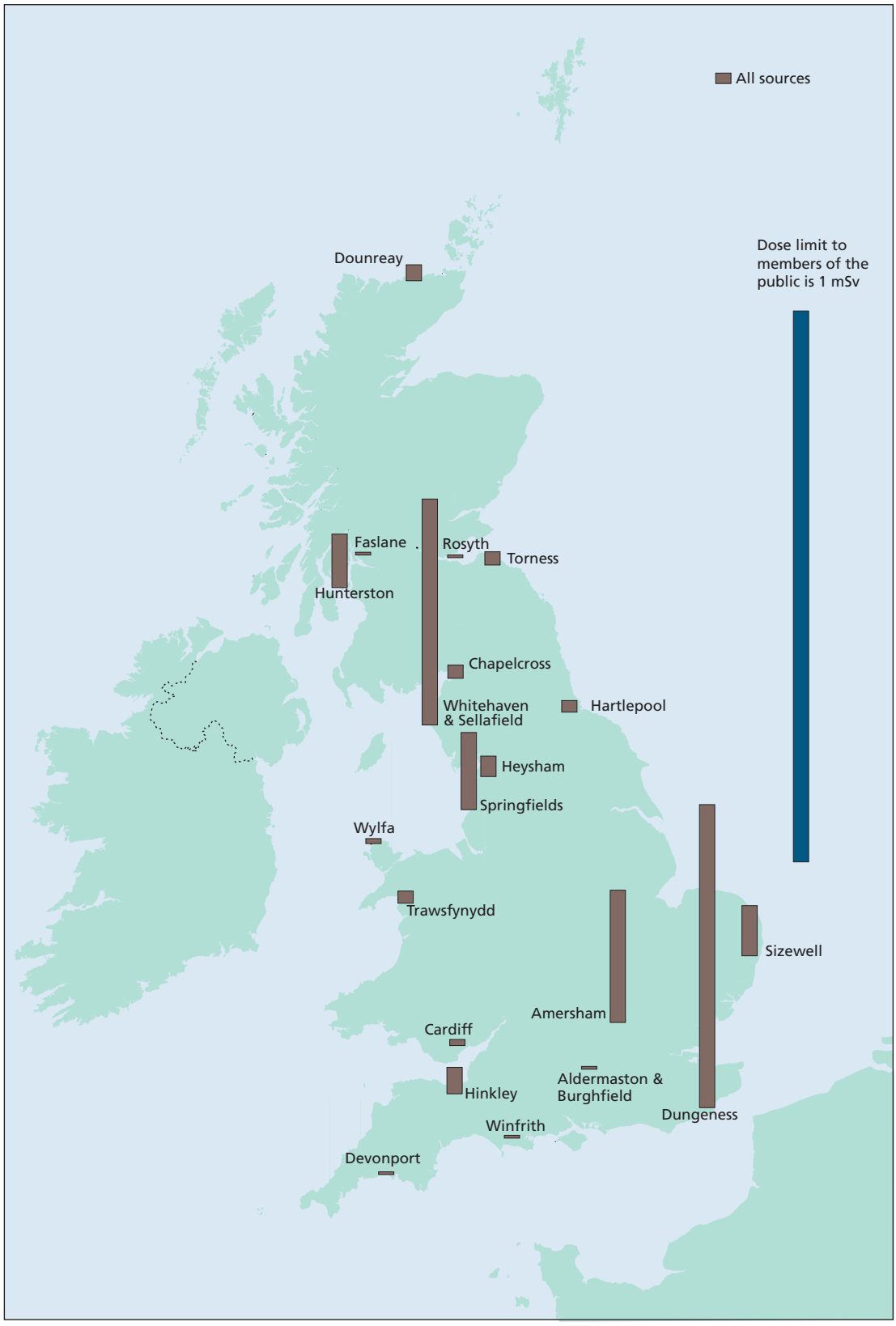


Figure S2. Total radiation exposures in the UK due to radioactive waste discharges and direct radiation, 2006 (Exposures at Whitehaven and Sellafield are mostly due to technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S2. Radiation doses due to all sources at major UK sites, 2006[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	Not assessed	
Springfields	0.13	Gamma dose rate over sediment
Sellafield[d]	0.44	Molluscs, ^{210}Po, ^{241}Am
Research establishments		
Culham	Not assessed	
Dounreay	0.029	Milk, ^{90}Sr, ^{106}Ru, ^{129}I, ^{144}Ce, ^{241}Am
Harwell	Not assessed	
Winfrith	<0.005	Gamma dose rate over sediment
Nuclear power stations		
Berkeley and Oldbury	Not assessed	
Bradwell	Not assessed	
Chapelcross	0.024	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Dungeness	0.55	Direct radiation
Hartlepool	0.021	Direct radiation
Heysham	0.037	Gamma dose rate over sediment
Hinkley Point	0.048	Gamma dose rate over sediment
Hunterston	0.097	Direct radiation
Sizewell	0.091	Direct radiation
Torness	0.024	Direct radiation
Trawsfynydd	0.022	Direct radiation, milk
Wylfa	0.009	Direct radiation
Defence establishment		
Aldermaston and Burghfield	<0.005	Milk, ^{3}H, ^{137}Cs, ^{234}U
Derby	Not assessed	
Devonport	<0.005	Fish, ^{137}Cs, ^{241}Am
Faslane	<0.005	Gamma dose rate over mud
Holy Loch	Not assessed	
Rosyth	<0.005	Fish, crustaceans, ^{241}Am
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.011	Fish, ^{3}H, ^{14}C
Industrial and landfill		
Drigg	Not assessed	
Whitehaven[d]	0.44	Molluscs, ^{210}Po, ^{241}Am

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

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

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

[d] The doses from man-made and naturally occurring radionuclides were 0.21 and 0.22 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven.

During 2006, discharges of technetium-99 from Sellafield continued at the low level achieved since new abatement technology was successfully introduced. Discharges are expected to remain low in future years. 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 2005. 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. However, there was no evidence that humans would be affected by this transfer, which would result from animals feeding on the seaweed.

Marine sediment samples are a useful indicator of trends in the environment. People who spend time on beaches can also 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. The trend is not associated with changes in discharges. Concentrations of americium-241 have increased due to 'in-growth' from plutonium-241 in the environment. Remobilisation of historical sediments containing higher activity concentrations or the increased presence of finer-grained sediments with high activity concentrations will also play a part in this trend. The increases are small and are not easy to detect in fish and shellfish samples from Cumbria.

Releases of argon-41 gas from Dungeness 'A' and Sizewell 'A' Magnox power stations in 2006 continued to have a significant local effect on concentrations in the air near the station. As it is not practicable to monitor for argon-41, concentrations in air are predicted using dispersion models. These stations stopped generating electricity at the end of 2006, and the discharges of argon-41 have now ceased.

At some nuclear sites concentrations of radionuclides in food and the environment are 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 elevated relative to background levels.

There were no major changes in external dose rates in intertidal areas in 2006 compared with 2005. At most locations the external dose rates were close to background. Levels were enhanced 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 2005 and 2006 due to reduced discharges from the Springfields site. New measurements of dose rates on board a houseboat in the Ribble estuary were carried out as part of a survey of occupancy habits. They suggested an increase in the dose estimate for people living on houseboats.

Nuclear site incidents and non-routine surveys

Additional sampling was needed on eight occasions in 2006 as a result of nuclear site operations.

During 2006, further fragments of irradiated nuclear fuel were recovered near Dounreay. Nineteen fragments were recovered from Sandside Bay and four from the Dounreay foreshore. As the particles to which the fuel fragments are attached can be resuspended and pass into fish the fishing restrictions under the Food and Environment Protection Act 1985 are still in force. Normal levels were detected at all of the sites except at Sellafield where radioactive particles and contaminated pebbles/stones were removed from the beaches and at Chapelcross where particles/flakes of scale were removed from beaches. In both of these cases, the increases were small and had negligible effects on local public radiation doses.

At the end of 2006, BNGSL began monitoring the beaches close to Sellafield for particles using equipment developed for the purpose and used widely at Dounreay. A number of active particles were found on the foreshore. These ranged from pebbles to small mineral grains. These particles are thought to be related to past discharges made before the current treatment and filtration equipment were installed. Further survey work will be carried out by BNGSL in 2007.

There were six other occasions 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. Most cases involved higher than normal gaseous releases of radioactivity. These cases occurred at Amersham, Chapelcross, Oldbury, Sellafield, Sizewell 'A' and Wylfa. Generally, for reassurance purposes, for the extra analyses required samples from the routine monitoring programmes were collected earlier, and analysed more quickly than scheduled.

Ad hoc sampling was also needed at Hartlepool. Some radionuclides that occur naturally in the environment are suspected of having their concentration elevated above background levels. Increases in levels of gamma dose rates have been observed for some time on the south bank of the Tees near Hartlepool. The sampling was conducted to confirm the proportion of the concentrations that were from sources other than the nuclear power industry. This year's results confirmed earlier findings of a local increase in gamma dose rates. Polonium-210 concentrations in shellfish from a small area of the south bank were also found to be higher than expected for the UK environment. Concentrations of carbon-14 were considerably higher than expected from natural sources. These levels are likely to be due to non-nuclear site discharges.

In 2006, the diets and occupancy habits of people near nuclear sites at Faslane, Hinkley Point, Sellafield, Heysham, Springfields and Torness 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 living in areas that were not near to nuclear sites were mostly exposed to radioactivity from naturally-occurring sources. Man-made radionuclides only contributed a small proportion of the total public radiation dose in people's general diet.

Monitoring of artificial radioactivity on the Isle of Man and in Northern Ireland showed that consumer doses were all less than 2% 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% of the limit.

Concentrations of naturally-occurring radionuclides in fish and shellfish near the site of past phosphate processing in Whitehaven have previously been found to be higher than expected ranges. This year the increase above background was lower 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 the phosphogypsum plant, 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 level of these radionuclides in UK seafood. People consuming large quantities of seafood were estimated to receive a dose of 0.24 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 and Technologically enhanced Naturally-Occurring Radioactive Material radionuclides was estimated to be 0.47 mSv.

To understand the effects of enhanced concentrations of radioactivity at other non-nuclear sites a programme of monitoring and assessment was carried out at Dalgety Bay in Fife. At Dalgety Bay, environmental monitoring of intertidal areas has found items that contain radium-226. These items were removed when found and it has been recommended that public notice signs be erected in the area by the local authority to inform people of the potential hazard on the beach. The source of these items is not certain but it is likely to be due to wastes generated from past military operations at the Royal Naval Air Station Donibristle, which closed in 1959. The data from the most recent monitoring exercise in 2006 related to seafood samples and a contamination survey. No significant increase above the normal background levels was detected.

Monitoring of the potential environmental effects of the incident involving Mr. Litvinenko was carried out in the London area. The Environment Agency sampled from river catchments in the affected area. No high concentrations of polonium-210 were found in these river environments. The HPA and others carried out monitoring at a significant number of premises in London and a programme of decontamination was undertaken as necessary. This was largely complete at the time of writing.

Raised 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 2006. 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 374 farms in 2006 compared with 9700 farms in 1986 when the accident happened. At the start of 2007 the number of farms under restriction was further reduced to 371.

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.

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 Environment and Heritage Service, the Food Standards Agency and the Scottish Environment Protection Agency 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 15,000 analyses and dose rate measurements were completed in 2006.

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 inside front cover and 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 and 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 contains the results of programmes for the monitoring of food and environmental materials for radioactivity in the UK during 2006. Food monitoring in England and Wales is carried out by the Food Standards Agency. Environmental and dose rates monitoring in England and Wales is carried out by the Environment Agency. Food and environmental monitoring in Scotland is carried out by Scottish Environment Protection Agency (SEPA) and in Northern Ireland by the Environment and Heritage Service (EHS). The Food Standards Agency and SEPA are still monitoring some upland areas in England, Wales and Scotland for caesium-137 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 also carries out nationwide monitoring of whole diet, milk and crops well away 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 EHS 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. They act as regulators of radioactive waste disposal under the Radioactive Substances Act 1993 (United Kingdom - Parliament, 1993). The Environment Agency and SEPA also have a broad responsibility (under the Environment Act 1995 (United Kingdom - Parliament, 1995a)) for protecting (and determining general concentrations of pollution in) the environment.

There are several purposes for the monitoring programmes. Ongoing monitoring helps to establish the long term levels in foods and the environment and to confirm whether levels are rising or falling or are unchanged with time and distance from the sites. The results are also used to check the safety of the foodchain. 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 for comparison with the UK dose limits. The monitoring is independent of that carried out by the operators and therefore augments the operator monitoring and where there is overlap acts as a check. Most of the monitoring carried out and presented in the report concerns the local effects of discharges from nuclear sites in the UK. Other work carried out includes the Chernobyl monitoring, which provides the authorities with information on levels in affected areas and whether restrictions are still required. Monitoring is also carried out in food and the environment remote from nuclear sites providing information on background levels 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. 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 seven UK laboratories, given below. These laboratories also undertook most of the sample collection for the programmes.

Key points

- UK collaboration between Government authorities
- Results from monitoring programmes in 2006 used to calculate dose. Dose assessed against standards for the public
- Independent of industry
- Harmonisation with Europe is planned
- Considers nuclear and non-nuclear sites
- National and international policy and regulation context described

- 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 carried out in order to check on the fate in the environment of discharges from nuclear establishments. The results are also used to make an assessment of doses to the public that are compared with dose limits. The dose assessments are retrospective in that they apply to 2006, using monitoring results for that year. The radioactivity levels found in 2006 are the accumulation of all past discharges made up to 2006.

In this report, two main types of dose assessment are made. One type is a retrospective assessment to groups of people 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 20 nuclear sites and *total dose* assessments have been made at all these. In 2007 habit data will become available at three more sites to enable *total dose* to be calculated at these sites.

The doses are compared with the UK 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 European skin dose limit. All dose limits are based on recommendations made by the International Commission on Radiological Protection (ICRP).

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.

Collective doses are beyond the scope of this report and as such are presented elsewhere. They are derived using modelling techniques.

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 to 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

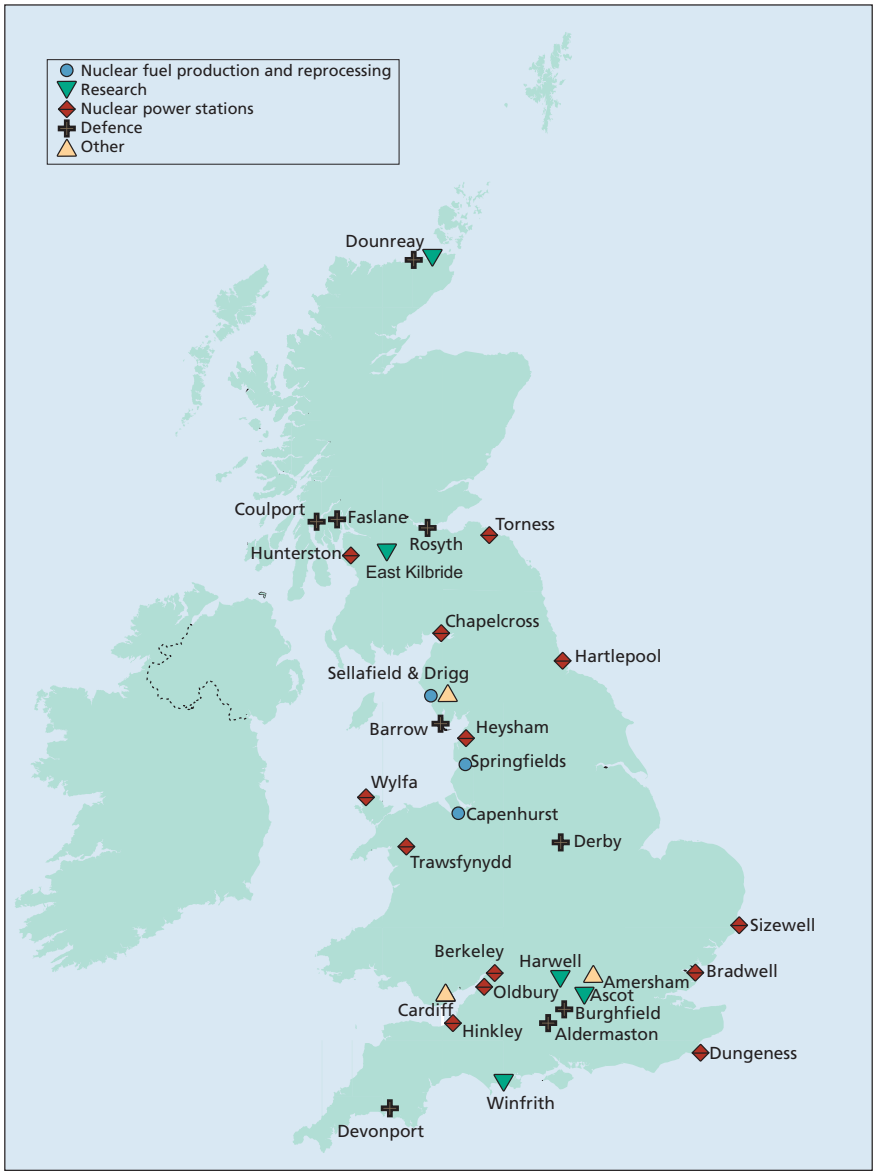
1.2.1 Radioactive waste disposal from nuclear sites

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 licenced sites that are sources of waste containing man-made radionuclides are shown in Figure 1.1. Nuclear licenced sites are authorised to dispose of radioactive wastes (United Kingdom - Parliament, 1993). Nuclear sites are also subject to the Nuclear Installations Act (United Kingdom - Parliament, 1965). The programmes reported here include monitoring at each of these sites. For completeness, it should be noted that discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also 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 monitoring is therefore undertaken near this site. Discharges from other non-nuclear sites are generally considered insignificant and as such environmental monitoring of their effects is usually not required. However, this situation is reviewed from time to time and where appropriate surveys are included in the programme. Discharges of radioactive substances by the non-nuclear industry into the sea have been reviewed by the members of the Oslo and Paris (OSPAR) Convention (OSPAR, 2002).

Appendix 2 presents a summary of the discharges of liquid and gaseous radioactive waste and disposals of solid radioactive

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



waste from nuclear establishments in the UK during 2006. 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 summarised in a single table: in particular, periods shorter than one year are specified at some sites. In 2006, all discharges and disposals were below the authorised limits, and in many cases well below. The tables show the percentage of the limit actually discharged in 2006.

The authorised limits are set through a permit determination process, initiated either by the operator or by the Environment Agencies. In support of the permit determinations prospective assessments of doses to the public are made assuming discharges at the permit limits. Authorisations are set so that doses to the public from the site will be well below the dose limit of 1 mSv per year if discharges occurred at the permit limits. The implications of the authorisation for the foodchain are also considered. In 2006, and in other years, discharges were below the specified limits. Therefore, provided the limits are complied with, the public and the foodchain are expected to be protected. During the permit determination, consideration is also taken of the effect of the planned authorised discharges on the environment. In addition, the authorisations require the use of Best Practicable Means to minimise discharges still further.

The discharges and disposals made by sites are in general fairly regular and consistent in each year. However, from time to time there may be unplanned events that cause unintended leakages, spillages or other emissions that are different to the normal or expected pattern of discharges. Such events are reported to the Environment Agencies and may lead to follow up action, including reactive monitoring by the site, the Environment Agencies or the Food Standards Agency. In cases where there has been a breach of authorisations, regulatory action may be taken. The events of this type in 2006 are summarised in Table 1.1. Where monitoring was initiated as a consequence of these events, the results are presented and discussed in the relevant site text later in this report.

1.2.2 International agreements and the UK discharge strategy

This subsection presents information on the context of UK radioactive discharges as they relate to international agreements. The UK has ratified the 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, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). This provided a description of how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the strategy relate to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes. They are:

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

The strategy stated that due to the diverse nature of other minor sources of radioactive discharges, no discharge profile or target would be set for this industrial sector, presuming that these discharges would continue to be tightly controlled and reduced wherever practicable (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. A new draft is expected to be out to public consultation during the winter 2007/8.

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, 2007). 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, 2006a). An agreement has been reached on the basis for future monitoring of relevance to OSPAR by Contracting Parties (OSPAR, 2006b). The programme includes sampling in fifteen divisions of the OSPAR maritime area and is supported by procedures for ensuring quality control. The European Commission (EC) has considered various options for a new policy instrument concerning the protection and conservation of the marine environment and has proposed that a binding legal commitment is required - a Marine Strategy Directive (Commission of the European Communities, 2006 a, b). Member states and the Commission are considering how best to take this initiative forward.

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).

1.2.3 Managing radioactive liabilities in the UK

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

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up by the introduction of legislation. The Energy Act 2004, which was enacted on 22nd July 2004, has enabled the establishment of the Nuclear Decommissioning Authority (NDA) which began operation in April 2005. The NDA has taken responsibility for nuclear sites currently operated by British Nuclear Fuels 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.

The Government have recently issued a new UK policy for managing these wastes which includes the following priorities (Department for Environment, Food and Rural Affairs, 2007b):

- An emphasis on community involvement
- Initiating a UK wide strategy for the management of LLW
- from non-nuclear industries
- Consideration of a replacement of the national disposal facility near Drigg in Cumbria
- Waste minimisation

At the same time, and following the recommendations of the Committee on Radioactive Waste management (CoRWM), the Government announced its plans for higher activity wastes (Department for Environment, Food and Rural Affairs, 2007c). Geological disposal was affirmed as being the solution in the long term with maintenance of safe and secure storage in the interim.

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 (Section 7). There is still a considerable amount of solid low level radioactive wastes which will require disposal. Some will be sent to the LLWR near Drigg, but alternative disposal options are being considered. With the increasing momentum for decommissioning and clean-up of nuclear sites, the Environment Agencies are 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 are aiming to have the documents ready for public consultation in 2008.

1.2.4 Regulator strategies and reviews

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

The Environment Agency has issued its strategy for radioactive substances regulation for 2006-11 (Environment Agency, 2006a) and plans for improvement in the performance of the nuclear industry sector (Environment Agency, 2006b, c). Following the Government's Energy Review in 2006 which stated that nuclear power should have a role in the future UK generating mix, the Environment Agencies, with HSE and the Office for Civil Nuclear Security*, published their guide to potential providers of nuclear power stations. The guide specifies the process whereby the regulators will consider generic designs, and the information that sector vendors, potential operators and other interested parties will be expected to provide so their proposals can be assessed (Environment Agency, Health and Safety Executive, Office for Civil Nuclear Security and Scottish Environment Protection Agency, 2007).

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

* *As from 1st April 2007 the Office for Civil Nuclear Security is part of HSE.*

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.

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 2006 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, assessment are undertaken when appropriate for assurance that there is no significant foodchain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA has recently 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). No specific assessments were carried out in 2006. However, assessments carried out in previous years have shown that the impact of the radioactivity associated with the disposal operations is very low and that exposures are below 0.010 mSv.

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, 2006). 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 2006. 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 Cap de la Hague in France.

The Environment Protection Act 1990 provides the basis, through the Environment Act 1995, for a regulatory regime for the identification and remediation of contaminated land. Implementation of the regime has initially focused on non-radioactive contamination. However, Defra has now issued the statutory guidance which sets out the regime 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 (Department for Environment, Food and Rural Affairs, 2006b). The regime does not currently apply to radioactive contamination from nuclear licenced sites but a second phase of regulation will be implemented in due course. A profile of industries which may have given rise to land contamination has been published (Department for Environment, Food and Rural Affairs, 2006c). Dose criteria for the designation of radioactively contaminated land have been determined for England and Wales (Smith *et al.*, 2006).

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

conversely the effects of aquatic discharges are detected in the terrestrial environment. Where this is found, appropriate comments are made in this report.

All sources of ionising radiation exposure to the UK population have been reviewed every few years, the most recent being in 2005 (Watson *et al.*, 2005). Sources of naturally-occurring radiation and man-made radiation produced for medical usage predominate. The average annual dose from naturally-occurring radiation was found to be 2.2 mSv and about half of this was from radon exposure indoors. The average annual dose from artificial radiation was 0.42 mSv, mainly derived from 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% 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 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 licenced 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

Table 1.1. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2006

Site	Month	Summary of incident	Consequences and actions taken
Chapelcross		Radioactive limescale particles were found on the beach near the discharge point to the Solway Firth.	See Section 4. Monitoring on beaches enhanced. Removal of particles by Operator. Remedial action on plant commenced.
Heysham 1	February	Fuelling machine plug ejected leading to release of about 1 MBq of unfiltered particulate activity via the reactor building vents and louvres.	No detectable activity in the environment as a result of the event. Considered to be a failure to use Best Practicable Means. Warning letter issued.
Sellafield reprocessing plant	February	Leakage of pond water from the side of one of the walls at the pond used to store spent AGR fuel.The pond water did not overflow the confines of the pond but escaped through a thin gap in an expansion joint between abutting concrete blocks. Under normal operating conditions pond water would not travel via this route (as the pond water level is maintained below this level), however, at the time of the incident the pond level had been raised in order to test the response of specific equipment.There was no spillage beyond the pond wall and the leaked water was all collected in the sub-pond drainage system.	The collected pond water was discharged to sea via a different discharge route from that normally taken by the pond discharge. The radioactivity involved was estimated to contribute only a small fraction of the radioactivity normally discharged by this discharge route. In response, the Environment Agency issued an Enforcement Notice in July requiring improvements in the way this, and other ponds across the site, are managed and controlled.
Hunterston B Power Station	March	Boiler tube leak which resulted in small radioactive gaseous release via the Low Pressure Vents.	The consequences were very low – the release was accommodated within the site's existing authorised gaseous discharge limit.
Sizewell B Power Station	April	A four day interruption to monitoring of carbon-14 on gaseous discharge stack occurred due to operator error. There was no evidence from other station indicators of any unusual or elevated discharge during this time. Some environmental samples were kept separate and analysed more quickly, no unusual results were found.	Enforcement Notice issued requiring review and improvement of equipment and working arrangements.
Sizewell A Power Station	April	The Site Operator of the 'A' station reported that levels for carbon-14 in gaseous discharges were close to exceeding weekly advisory levels.	The Food Standards Agency analysed extra samples of local milk for carbon-14 but found no elevated concentrations. The Environment Agency carried out ad hoc sampling and analysis of soil and grass. Three suitable sampling locations were identified, plus a sample was also taken from the Visitor Centre for background purposes. Subsequent analysis showed that all carbon-14 analyses were below the analytical detection limit apart from one grass sample. This was marginally above the limit of detection, but the concentration was of no radiological significance.
Devonport Royal Dockyard Limited	June	Small amount of radioactive contamination found in bunded area within dock bottom, bund had overflowed at one location. Monitoring indicated no radioactivity had been released to the environment.	Site warning issued as the event represented a breach of the authorisation.
Wylfa Power Station	June	The Site Operator reported that the weekly advisory levels in gaseous discharges had been exceeded.	The Food Standards Agency undertook extra analyses of tritium and carbon-14 in samples of local milk but found no elevated concentrations of either radionuclide.
Dounreay	July	Operations in the Prototype Fast Reactor resulted in an unintended discharge of krypton-85 to atmosphere.	The quantity discharged over one day was close to the annual discharge limit. Dose implications were assessed to be low.

Table 1.1. continued

Site	Month	Summary of incident	Consequences and actions taken
Sellafield reprocessing plant	August	Sea Line 3 (the main pipeline used to carry authorised disposals of radioactive waste into the Irish Sea) is co-axial on the pipe bridge over the River Ehen and railway line. During work to prepare for the pipe bridge refurbishment, corrosion holes were found in the secondary containment pipe. These were repaired. Inspection of the primary pipe showed no holes or evidence of leakage from it.	There was no environmental impact associated with this event as there was no leakage of liquid from the primary pipe. An Enforcement Notice under the Radioactive Substances Act 1993 was served requiring a review of the inspection, maintenance and testing of the sea lines; expanding the outcome of the review to cover the other authorised discharge routes; and the review of the routing of drainage from the pipe bridge. The recommendations of these reviews are to be implemented as agreed with the Environment Agency.
Sellafield reprocessing plant	August +	Gradual unexplained increase in discharges to air from the Fuel Handling Plant (FHP) at Sellafield over several months. By the end of October 2006 the 12-month caesium-137 discharge had reached about 120% of the plant limit. Following investigation, the cause of the increased discharges was identified and changes were made to the way the plant was operated. Discharges returned to their normal levels in November 2006 and are now lower than they have been for a number of years.	The maximum radiation dose that could occur as a result of a discharge made at the plant limit for the FHP for 12 months is less than 0.0002 mSv. Whilst the increase in aerial discharges has been accompanied by some localised increases in levels of caesium-137 being detected in air, grass and deposition samples on Site (through BNGSL environmental monitoring programme), no discernable impact in milk has been detected through the RIFE monitoring programme. BNGSL has investigated the cause and has reported their findings. The Environment Agency is currently considering enforcement response.
Sellafield reprocessing plant	August +	Increase in antimony-125 discharges to air from FHP. In October 2006, the Environment Agency was notified that the Quarterly Notification Level for aerial discharges of antimony-125 from the site had been exceeded for the period June-August 2006. Discharges remained above the quarterly notification level in September and October but then declined. Originally, it was thought that the cause of the increase in antimony-125 discharges might be connected to the rise in caesium-137 discharges (see above). However, this is now being questioned and investigated further. The progress of this investigation has been hampered as FHP has not been processing fuel because the Magnox reprocessing plant has been shutdown, and discharges of antimony-125 have declined. Over the past two years the Environment Agency has been requiring BNGSL to assess their method for monitoring antimony-125 discharges to air in order to ensure that the best practicable means are being used. This work has been delayed due to operational reasons (i.e. prolonged shutdowns of Magnox reprocessing have occurred during this period). Early results have suggested that there is breakthrough of sample i.e. failure to capture a complete sample, and that discharges may therefore be above the authorised limit (which was set on the basis of the measurements from the existing sampling arrangements).	The environmental and health impact associated with any under-reporting and the elevated discharges is calculated as low (much less than 1 mSv per year to the most exposed group) on account of the quantity involved and that antimony-125 is a relatively low impact radionuclide. The outcome of this work is now due to be reported during 2007. There may be a need to revise the current sampling arrangements and the limits for antimony-125 discharges to air once this matter is fully understood. Whilst the increase in aerial discharges has been accompanied by some localised increases in levels of antimony-125 being detected in air, grass and deposition samples on Site (through BNGSL environmental monitoring programme), no discernable impact in milk has been detected through the RIFE monitoring programme.
Maynard Centre (GE Healthcare, Cardiff)	September/ October	The operator breached monthly limits (by ~20% and 0.1%) for the disposal of radioactive waste to the Fawley Incinerator.	No environmental impact beyond those already assessed by the authorised discharges from the incinerator. The incinerator operator continued to operate the incinerator in accordance with their authorisation.Warning letter issued to GE Healthcare Ltd.
Oldbury Power Station	September	The Site Operator at Oldbury reported that weekly advisory levels for carbon-14 in gaseous discharges had been exceeded.	The Food Standards Agency undertook extra analyses of carbon-14 in samples of local milk. No elevated concentrations of this radiouclide were found.

Table 1.1. continued

Site	Month	Summary of incident	Consequences and actions taken
Grove Centre (GE Healthcare, Amersham)	November	Maintenance work on the site radioactive liquid effluent management system resulted in 20-30 litres of radioactive liquid effluent leaking from the system into a surface water duct.	There was no environmental impact as the radionuclides in question had a very short half-life. Warning Letter issued to GE Healthcare Ltd.
Sellafield reprocessing plant	November	Nine items (including pebbles and sand grain sized particles) with elevated radioactivity were identified and removed from the beach. These were found during the initial trial of a new large area beach monitoring technique (Groundhog Evolution).	The contaminated items were taken onto the Sellafield site where they were subject to further analysis to establish their characteristics and to determine their likely age and source. Based upon the information at the time of writing we consider that the health risks to the public, in the unlikely event of contact with items with the levels of radioactivity concerned, are likely to be very low. Further monitoring is taking place in 2007 and new studies into the origin and fate of particles near Sellafield have commenced.
Sizewell B	November	Valve misalignment during liquid effluent processing caused slight increase in discharged radioactivity. Discharges remained at about 12% of the relevant limit and were increased as a result of the error by 0.1%.	Warning letter issued regarding failure to use Best Practicable Means for minimising discharges in this instance.

2. Nuclear fuel production and reprocessing

There are four sites in the UK associated with nuclear fuel production and reprocessing. The sites are at: Capenhurst, where there are two licenced nuclear sites (one carrying out uranium enrichment, the other undergoing decommissioning); Springfields, where fuel for nuclear power stations is fabricated; and Sellafield, where irradiated fuel from nuclear power stations is reprocessed. The Windscale nuclear site, owned by the NDA, is adjacent to the Sellafield

Key points

Capenhurst, Cheshire

- Consultation documents issued by Environment Agency for changes in authorisations (Sellafield Ltd. and Urenco)
- Discharges, concentrations and dose rates were generally similar to 2005
- Doses (Table 2.1) were less than 1% of dose limit

Springfields, Lancashire

- Discharges were similar to 2005, except reduction in total beta in liquid discharge
- New surveys of local diet and occupancy habits occupancy rates undertaken (including estimation for wildfowlers and anglers over saltmarsh)
- Concentrations and gamma dose rates were generally similar to those in 2005; decreases in beta dose rates and thorium-234 concentrations detected
- Dose to wildfowlers and anglers over saltmarsh was less than 4% of dose limit
- Dose to houseboat dwellers has been assessed using new measurements of dose rate on a boat. The dose increased but to less than 8% of the dose limit
- Other doses from discharges (Table 2.1) were less than 3% of dose limit and similar to 2005
- The *total dose* from all sources was 13% of the dose limit

Sellafield, Cumbria

- Discharges were similar to 2005, except increase in antimony-125 in gaseous discharge
- New authorisation limit (April 2006) for technetium-99 liquid discharge (10 TBq)
- New surveys of local diet and occupancy rates
- Restart of full THORP reprocessing delayed
- Gaseous discharges of caesium-137 and antimony-125 from the Fuel Handling Plant exceeded quarterly notification level for several months before returning to normal levels (and now lower than recent years)
- Environment Agency served an enforcement notice requiring improvements in the way pond water is managed and controlled across the site
- Concentrations and dose rates were generally similar in 2005. Technetium-99 continued to decline in shellfish; some increases in radionuclide concentrations in coastal sediment
- Large area beach monitoring technique trialled by operators to establish any localised 'hot spots' on beaches. Some particles found and removed
- Dose to seafood consumers (0.23 mSv) from artificial radionuclides was similar to 2005. Dose from gaseous discharges (0.029 mSv) was reduced in 2006 (from 0.034 mSv, 2005) (Table 2.17)
- The *total dose* from all sources, including the legacy of phosphate processing, was 44% of the dose limit

site and is currently operated by UKAEA. 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 2006, gaseous and liquid discharges were below limits for each of the sites (see Appendix 2). Independent monitoring of the environment around each of the sites is carried out by the Food Standards Agency and the Environment Agency.

2.1 Capenhurst, Cheshire

There are two nuclear licenced sites at Capenhurst, one owned by the NDA and one by Urenco (Capenhurst) Limited. Sellafield Limited operated the NDA site, involving the dismantling and decommissioning of redundant facilities. Urenco operated a facility involving centrifuge enrichment of uranium.

After reviewing the radioactive waste authorisation held by both BNGSL 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 Ltd. (then BNGSL) (Environment Agency, 2006d) and in February 2007 for Urenco (Environment Agency, 2007b).

The Food Standards Agency has assessed the potential impact of radioactive waste discharges from both sites at Capenhurst, in response to the operators' application to the Environment Agency for revised discharge authorisation (Food Standards Agency, 2006a). The report concluded that that the proposed limits are acceptable on the grounds of food safety.

Gaseous discharges and terrestrial monitoring

The authorisations held by Sellafield Ltd. and Urenco limit gaseous discharges of tritium and uranium via stacks. 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 2006 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.

Liquid waste discharges and aquatic monitoring

The authorisation held by Sellafield Ltd. places limits on liquid waste discharges to the Rivacre Brook of tritium, uranium and daughters, technetium-99 and non uranium alpha (mainly neptunium-237).

The effects of liquid discharges were monitored by collecting samples of Brook water and sediments for analysis of tritium,

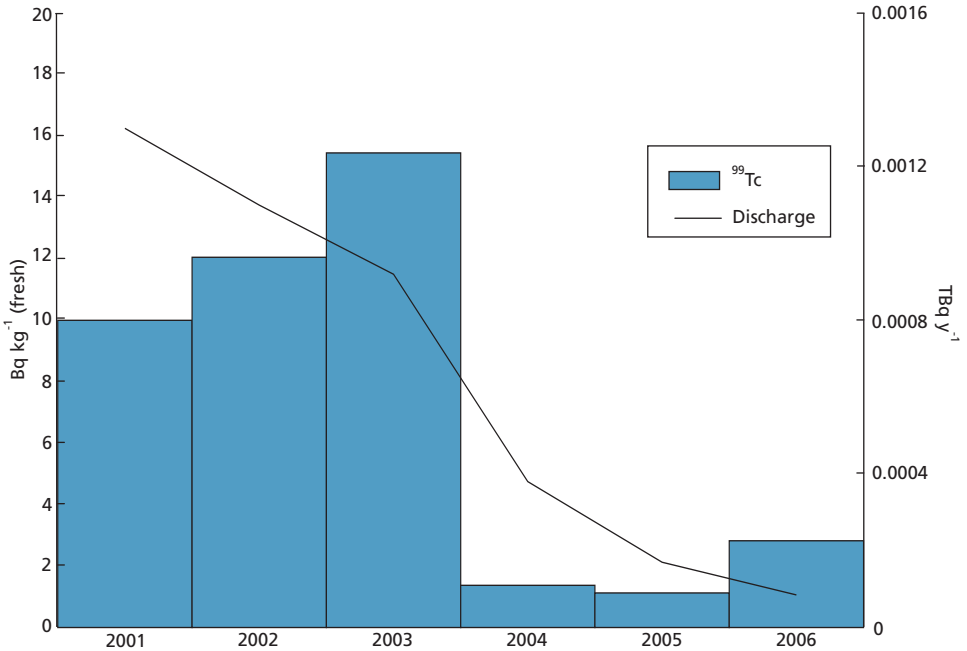


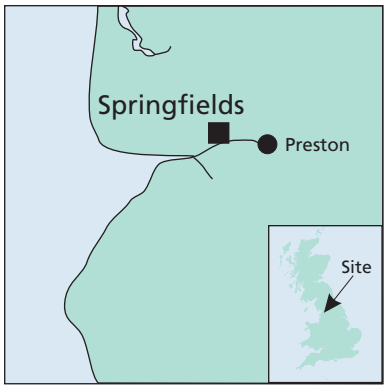
Figure 2.1. Technetium-99 annual discharges from, and concentrations in grass at, Capenhurst, 2001–2006

technetium-99, gamma emitting radionuclides, uranium, neptunium-237, total alpha and total beta. Fish and shellfish from the local marine environment were sampled and measured for a range of radionuclides. Results for 2006 are presented in Table 2.2(a). Dose rate measurements were taken on the banks on the Rivacre Brook. Results for 2006 are presented in Table 2.2(b). Concentrations of radionuclides and dose rates were very low and similar to those in 2005. Sediment samples from the Rivacre Brook contained very low but measurable concentrations of technetium-99; also of uranium, which was enhanced above natural levels close to the discharge point. Variations in concentrations in sediment from the Brook are to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in waters were also very low. Measured dose rates were slightly enhanced relative to natural background near to the discharge point. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides; these reflected the distant effects of discharges from Sellafield.

Doses to the public

The measured concentrations of radionuclides and dose rates were used to assess doses to the public due to the Capenhurst sites' operations. Doses were assessed for children playing in and around Rivacre Brook and consumers of local milk and vegetables. The highest dose was assessed as 0.008 mSv to children who play near the Brook and may also inadvertently ingest water and sediment (Table 2.1). The dose was estimated assuming a high occupancy of the bank of the Brook, relatively high inadvertent ingestion rates of water and sediment and the slightly enhanced gamma dose rates near the discharge point. Doses to consumers of locally grown food were less than 0.005 mSv in 2006.

2.2 Springfields, Lancashire



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

In November 2004, the Environment Agency issued a new authorisation with revised discharge limits to BNFL at Springfields. The authorisation permits the discharge of radioactivity in gaseous wastes via stacks on site; liquid wastes by pipelines to the Ribble Estuary; and solid waste disposals to a nearby landfill site and to the LLWR near Drigg. In April 2005, the authorisation held by BNFL was transferred to SFL.

A habits survey was undertaken June 2006. Increases in consumption (fish and shellfish) and houseboat dwellers occupancy rates, and a decrease in net handling rates have been observed. Previous observations of mollusc consumption were not noted in 2006. In addition, occupancy rates for wildfowlers and anglers over saltmarsh have been estimated. Revised figures for consumption rates, together with inhalation, handling and occupancy rates, are provided in Appendix 1.

The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.2.

Gaseous discharges and terrestrial monitoring

For many years the site has been authorised to discharge small amounts of uranium to atmosphere. The most recent discharge authorisations, which came into force in November 2004, placed lower limits on discharges of uranium from the fuel manufacturing and decommissioning operations. The most recent authorisations also set limits on discharges of tritium, carbon-14, total alpha and total beta from NSL.

Monitoring of foods around the site, included sampling of milk, fruit and vegetables and these were analysed for uranium, tritium, carbon-14, strontium-90, iodine-129, and isotopes of thorium, plutonium and americium. Gamma-ray spectrometry was also carried out and the results are reported for cobalt-60, ruthenium-106 and caesium-137. Grass and soil samples were collected and analysed for isotopes of uranium. The concentrations of radionuclides found in 2006 are shown in Table 2.3(a). 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 for liquid wastes that came into force in November 2004 sets limits on total alpha, total beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides. The revised limits are lower for all the radionuclides except technetium-99 and neptunium-237, which stayed the same. The largest discharge was of short half-life beta-emitting radionuclides, mostly thorium-234.

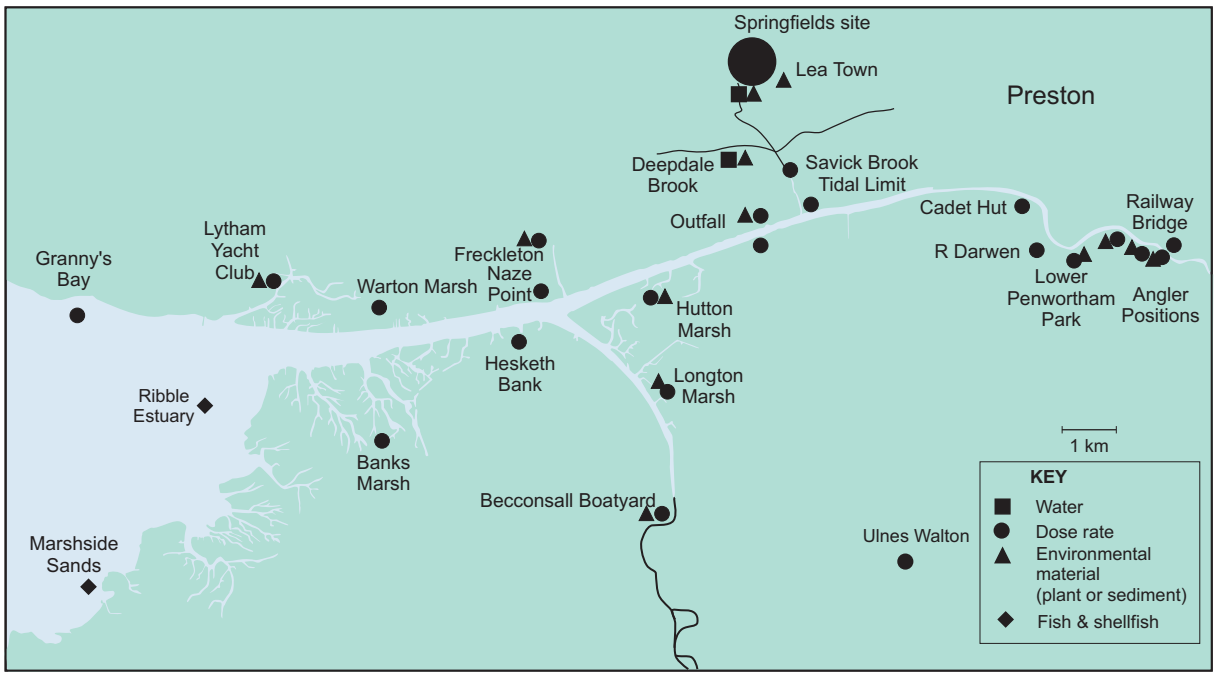


Figure 2.2. Monitoring locations at Springfields (excluding farms)

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 (including cobalt-60, caesium-137, ruthenium-106, antimony-125 and amercium-241) and radiochemically for isotopes of uranium, thorium and plutonium.

Results for 2006 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 detected, which were partly or wholly due to Springfields discharges, were isotopes of thorium, uranium and their decay products. Total beta measurements were dominated by the presence of thorium-234. This radionuclide has a relatively short half life of 24 days; observed concentrations are closely linked to recent discharges from Springfields, tidal movements and river flow. In 2006, thorium-234 concentrations were lower in comparison with recent years, following a reduction in total beta in liquid discharge from 117 TBq (2005) to 21 TBq (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.

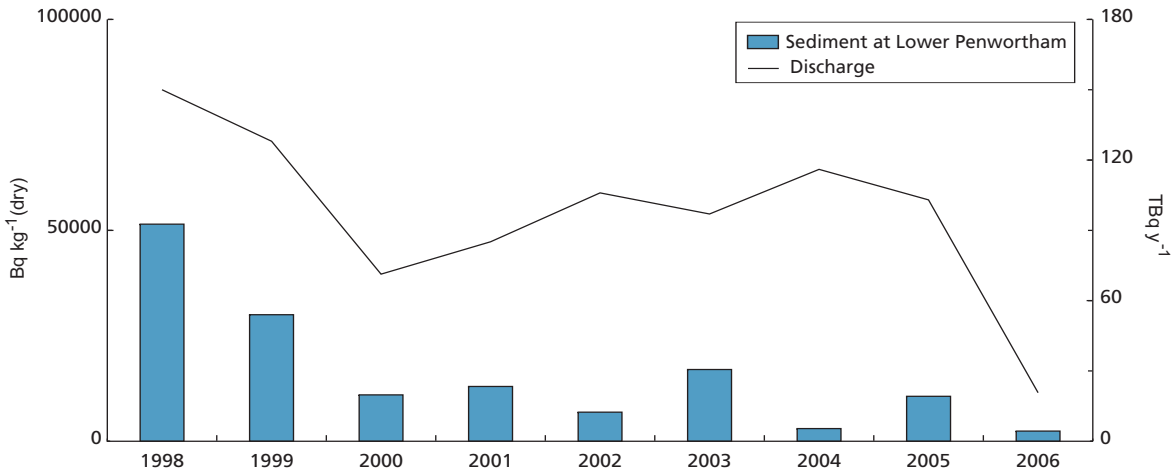


Figure 2.3. Total beta in liquid discharges from Springfields and concentrations in sediment at Lower Penwortham

Gamma dose rates in the estuary were generally elevated above those to be expected due to natural background (the UK average for muddy estuaries is 0.07 μGy h^{-1}). The elevated dose rates are due to the presence of gamma emitting radionuclides, partly from Springfields (mainly thorium-234 and protactinium-234m) and partly from Sellafield (mainly caesium-137, americium-241 and cobalt-60). Gamma dose rates in the estuary were broadly similar in 2006 to those in 2005. In addition to the routine monitoring, measurements were also taken on a houseboat where significant occupancy takes place and these have been used as the basis for the radiological assessment (see Table 2.3(b)). Beta dose rates on fishing nets were also enhanced above those expected due to natural background. This was due to the concentrations of beta emitting radionuclides such as thorium-234 and protactinium-234m from Springfields. Beta dose rates in 2006 were generally lower than those in 2005 due to the reduction in discharges.

Solid waste disposals and related monitoring

The Springfields authorisations also permit disposal of solid LLW to Clifton Marsh landfill site. Until 1983, BNFL had also disposed of LLW to the Ulnes Walton landfill site. The Environment Agency monitors waters from near the landfill sites at Ulnes Walton and Clifton Marsh. The results are shown in Section 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 data (from the habits survey 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: those consuming foods such as fruit and vegetables grown around the site; fish and shellfish consumers; people living on houseboats in the Ribble estuary; 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 2006, the dose to high-occupancy houseboat dwellers in the Ribble Estuary was 0.075 mSv, less than 8% of the dose limit for members of the public of 1 mSv. The assessed dose to houseboat dwellers in 2006 was higher than in 2005 (0.037 mSv). This was because updated information was available from additional measurements on board a houseboat. 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 carried out by Rollo *et al.* (1994) showed that exposures due to airborne radionuclides that may have come from discharges to the estuary were very small.

The dose to high-rate seafood consumers in 2006, including a contribution from external exposure, was 0.022 mSv, which was approximately 2% of the dose limit for members of the public of 1mSv. The majority of this dose was attributable to americium-241 and caesium-137 from Sellafield discharges. The exposure from seafood consumption reduced from 0.023 mSv (2005) to 0.007 mSv due to no observed mollusc consumption in 2006. Doses 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 0.075 mSv, much less than the skin dose limit of 50 mSv. In 2006, the dose to the critical group of wildfowlers and farmers over saltmarsh was assessed. The dose from external exposure was 0.033 mSv, which was approximately 3% of the dose limit for members of the public of 1mSv. The dose to the group consuming terrestrial foods grown around the site 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 0.13 mSv or 13% of the dose limit.

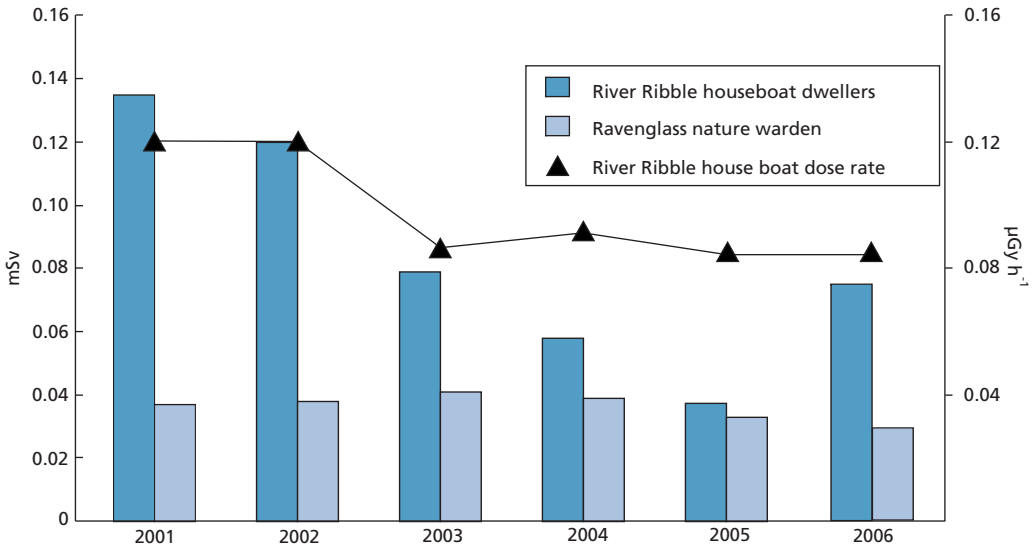


Figure 2.4. Individual radiation exposures to groups affected by external gamma dose, 2001-2006

2.3 Sellafield, Cumbria

This site was operated in 2006 by BNGSL (now Sellafield Ltd.) and is now owned by the NDA. The main operations on the Sellafield Ltd. Sellafield site are: fuel reprocessing at the Magnox Reprocessing Plant and the Thermal Oxide Reprocessing Plant (THORP); decommissioning and clean-up of redundant nuclear facilities; the manufacture of mixed oxide fuel and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in March 2003 and is now being decommissioned. The UKAEA Windscale site adjoins 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. The reprocessing of spent Magnox fuel continued during 2006 with a total of 720 tonnes of fuel reprocessed. This was an increase from the 348 tonnes reprocessed in 2005.

A number of minor occurrences are recorded for 2006 at Sellafield in Table 1.1 and where relevant these are referred to later in this section.

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.

The new gaseous discharge authorisation for the Sellafield site came into force on 1 October 2004. This authorisation placed limits on discharges to atmosphere of total alpha, total beta and 12 named radionuclides. In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site. Three radionuclides in the previous authorisation, which were produced in the Calder Hall power station, are no longer discharged from the station following shutdown, and are not now specified: namely argon-41, sulphur-35 and cobalt-60. Discharges of gaseous wastes from Sellafield in 2006 are summarised in Appendix 2. Discharges were much less than the authorised limits.

As reported in Table 1.1, there was a gradual increase, over several months, in the gaseous discharges of caesium-137 from the Fuel Handling Plant (FHP). Following investigation, the cause was identified and plant operational changes were made which resulted in discharges returning to normal levels (and now lower than recent years). Also discharges of antimony-125 from FHP exceeded the quarterly notification level from June to October 2006 but then declined.

Monitoring around the site related to gaseous discharges

There is a substantial programme of monitoring of terrestrial foods in the vicinity of Sellafield carried out by the Food Standards Agency. This programme is the most extensive of those for the nuclear sites in the UK in order to reflect the scale of the discharges from the site. A wide range of foodstuffs was sampled in 2006 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 2006 are presented in Table 2.4. The concentrations of all radionuclides were low and there was no indication of widespread contamination from the site. Concentrations in terrestrial foodstuffs were generally similar to those in 2005.

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

A wide range of fruit and vegetables was sampled in 2006 including apples, blackberries, broccoli, cabbage, carrots, cauliflower, elderberries, potatoes, runner beans, swede and turnips. The results were similar to those found in previous years. In common with meat and offal samples, only limited evidence was found in some of these foods arising from the atmospheric discharges from Sellafield. Concentrations of transuranic radionuclides, when detectable in these foods, were very low.

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 which terminate 2.1 km beyond low water mark. Liquid wastes are also discharged from the factory sewer and interceptor sewer. Discharges from the Sellafield pipelines during 2006 are summarised in Appendix 2. The new authorisation from 1 October 2004 sets limits on total alpha and total beta and 15 named 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 Exchange Effluent Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP). The new overall site limits are lower than before for: total beta, tritium, cobalt-60, zirconium- and niobium-95, technetium-99, caesium-134, caesium-137 and cerium-144. Lower limits have also been set for the factory sewer. All of the discharges in 2006 were well below the limits in the authorisation. Discharges of tritium, carbon-14, ruthenium-106 and iodine-129 were similar in 2006 to those in 2005. 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 2006 to those in 2005, but continued their long-term downward trend, from their peak of 192 TBq in 1995, to 85 TBq in 2002, 37 TBq in 2003, 14 TBq in 2004 and 6.7 TBq in 2005. The reduction of technetium-99 discharges was due to the diversion of the Medium Active Concentrate waste stream to vitrification and use of a new chemical precipitant (TetroPhenylPhosphonium bromide - TPP) to remove technetium-99 from the waste stream at the EARP plant.

The Environment Agency served an enforcement notice on the site, in July 2006, requiring improvements in the way pond water is managed and controlled across the site, following a leak from one of the storage ponds (Environment Agency, 2006e). The volume of water lost was a small fraction (~0.1%) of the total volume of water in the pond and the amount of radioactivity was estimated to contribute to a very small fraction of the radioactivity routinely discharged to sea.

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was carried out during 2006. 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 carried out in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

Concentrations of caesium-137 in fish were generally similar in 2006 to those in 2005. 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 is not due to Sellafield discharges but is substantially from the Chernobyl accident. Concentrations of caesium-137 in fish (known to have been caught in Icelandic waters) remained typical of those from weapons test fallout, at a value of about 0.1 - 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 of about 25 Bq kg^{-1}, the data suggest there is a local enhancement of carbon-14 due to discharges from Sellafield. Tritium, which is of low radiotoxicity, gives the highest concentrations of radioactivity in marine fish at about 100 – 150 Bq kg^{-1}, with similar concentrations of organically associated tritium. Concentrations of tritium in local seawater at St Bees are less than 10 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 is detectable owing to generally greater uptake of radioactivity than by fish. Beta/gamma radioactivity data (excluding plutonium-241) for 2006 are provided in Table 2.6. In addition to sampling by Cefas, supplies of winkles, mussels and limpets were obtained from consumers who collected them 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). However, generally, molluscs tend to contain higher concentrations of radionuclides than crustaceans, and both contain more than fish. The highest concentrations due to Sellafield discharges are found for tritium, carbon-14 and

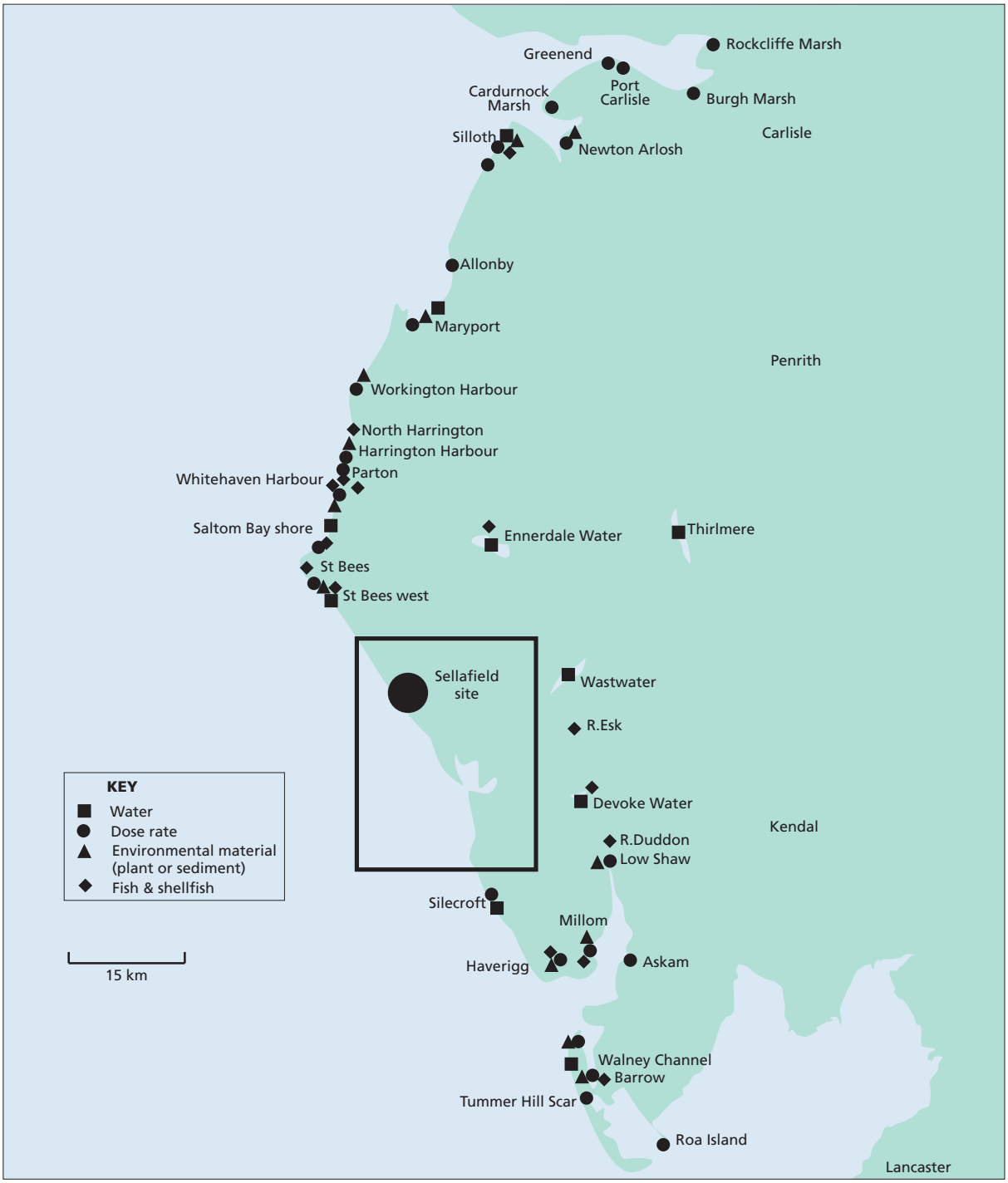


Figure 2.5. Monitoring locations in Cumbria (excluding farms)

technetium-99. When comparing 2006 and 2005 data across a wide range of sampling locations and shellfish species, concentrations of radionuclides for 2006 were broadly similar to those in 2005 except for technetium-99, which showed a systematic decrease. This is due to the recent progressive reductions in discharges. A similar pattern of concentrations for the relatively short-lived ruthenium-106 was observed in 2006, as in 2005, following reduced rates of reprocessing and discharges in both years.

The data for the analysis of fish and shellfish samples (chosen on the basis of potential radiological significance) for transuranic radionuclides in 2006 are presented in Table 2.7. Transuranics are less mobile than radiocaesium in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish. Concentrations in shellfish in 2006 were generally similar to those in 2005; those from the north-eastern Irish Sea were the highest concentrations of transuranics found in foodstuffs in the UK.

Figure 2.6. Monitoring locations at Sellafield (excluding farms)

Trends in concentrations of radionuclides in seafood near Sellafield are shown in Figures 2.7 – 2.12 with the corresponding discharge profiles. Concentrations have generally reflected changes in discharges, over time periods characteristic of radionuclide mobility and organism uptake. There is variability from year to year, particularly for the more mobile species. For the transuranics (Figures 2.11 – 2.12), the long-term trend in reductions of concentrations appears to be slowing.

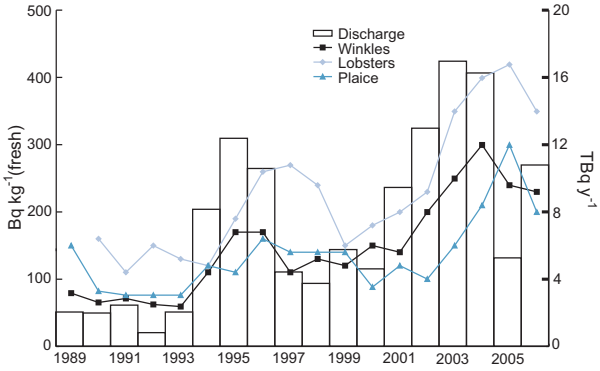


Figure 2.7. Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

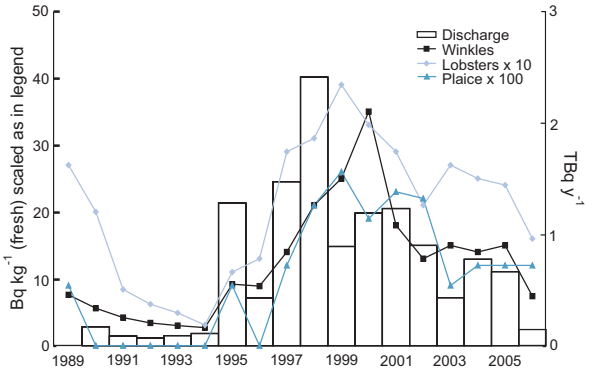


Figure 2.8. Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

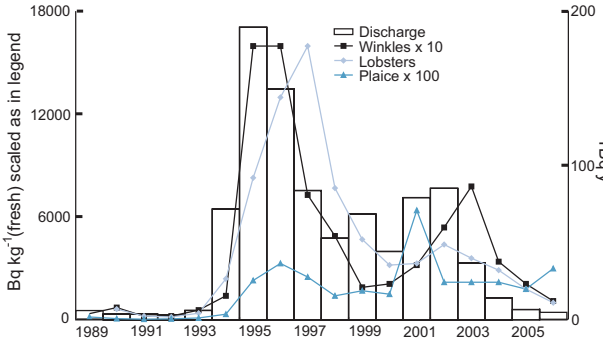


Figure 2.9. Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

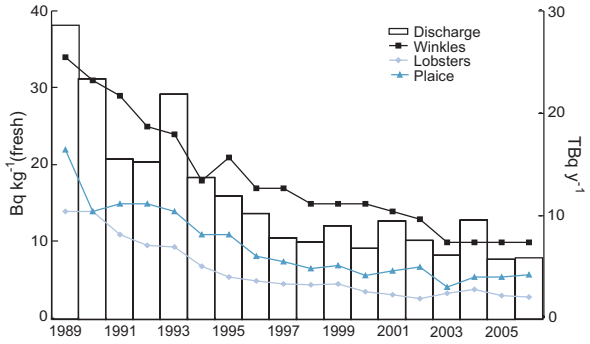


Figure 2.10. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

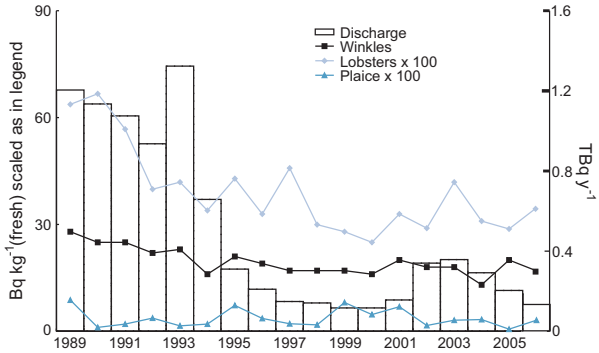


Figure 2.11. Plutonium-239/240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

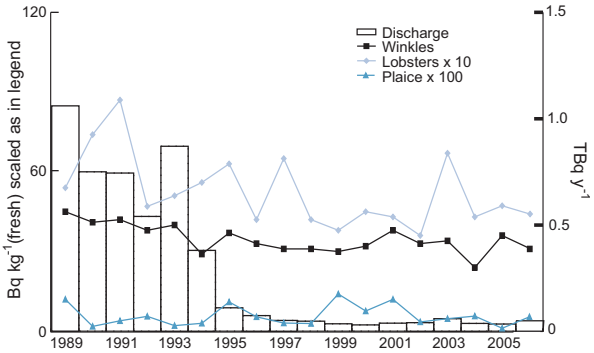


Figure 2.12. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield

Monitoring of sediments

A further important pathway leading to radiation exposure as a result of Sellafield liquid discharges arises from uptake of radionuclides by intertidal sediments in areas frequented by the public. Sediments are regularly monitored, both because of relevance to exposures and in order to keep distributions of adsorbed radioactivity under review. The results for 2006 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 2006 were generally similar to those in recent years.

The trends over the last two decades 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. In particular there have been sustained reductions in discharges of caesium-137 and transuranics; these reductions are reflected in the decreases in concentrations of these radionuclides at Ravenglass. Discharges of cobalt-60 have been variable in recent years, as reflected in the sediment concentrations at Ravenglass (Figure 2.15). Since the mid 1990s, discharges of caesium-137,

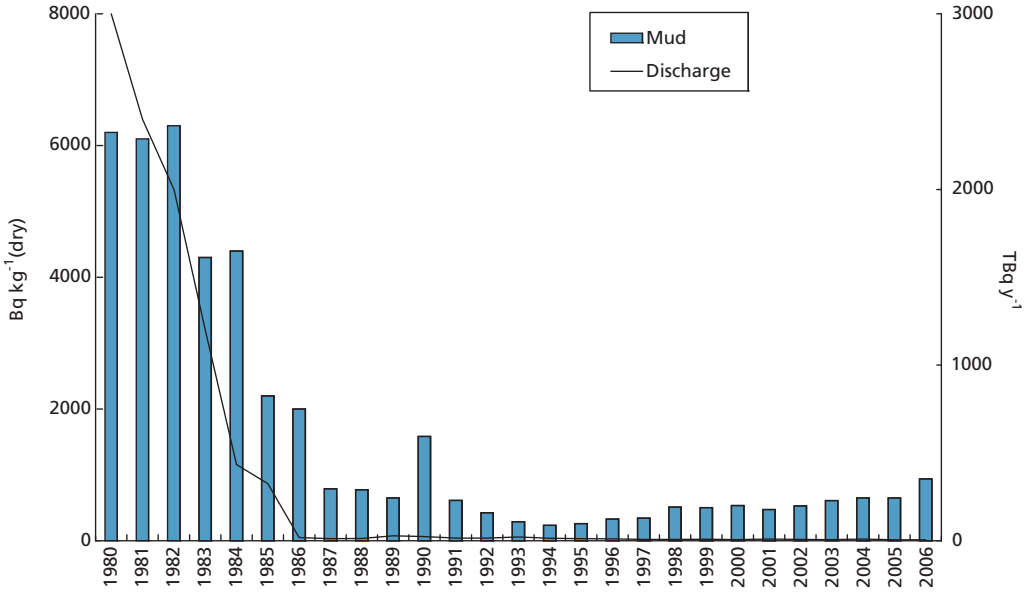


Figure 2.13. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

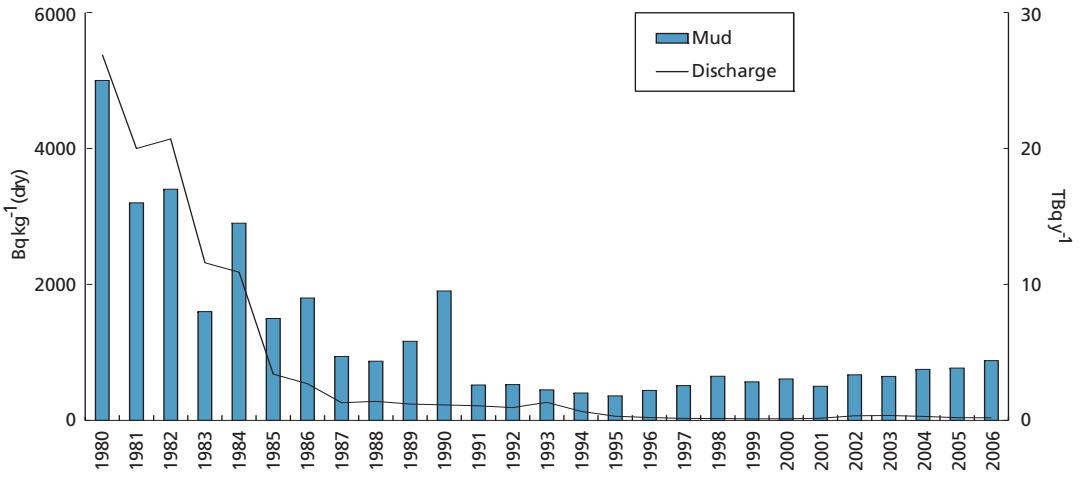


Figure 2.14. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

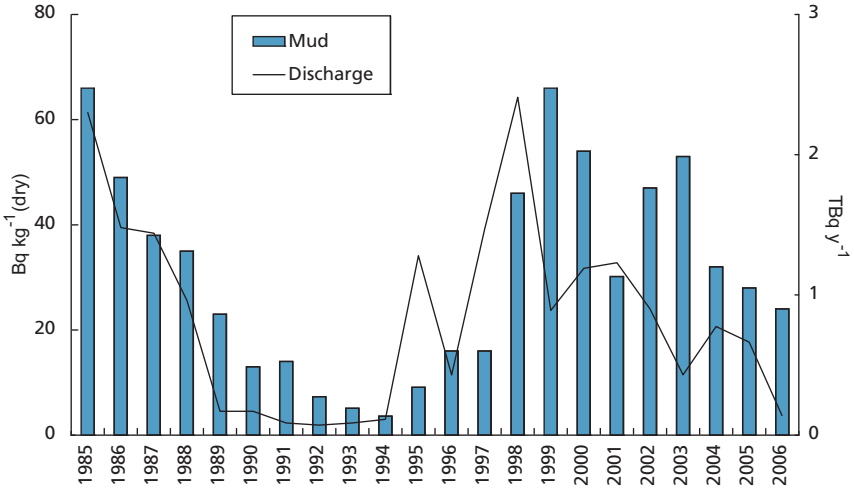


Figure 2.15. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys).

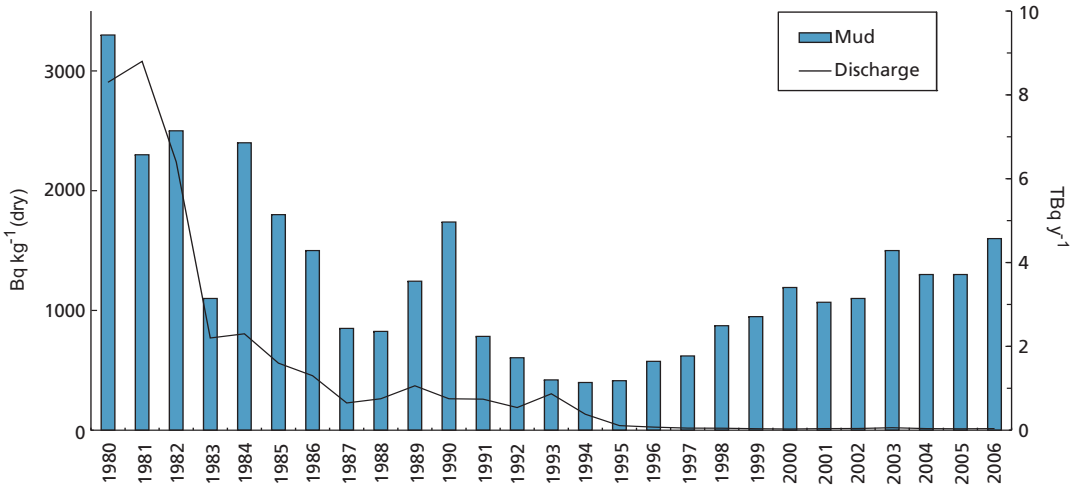


Figure 2.16. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass (data prior to 1988 are from BNFL surveys)

plutonium isotopes and americium-241 have been maintained at low levels, but there has been some variability and even a suggestion of progressive increases in the concentrations in sediments. This result could be due to remobilisation and subsequent accretion of fine-grained sediments containing higher activity concentrations. For americium-241, there is also an additional contribution due to radioactive 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.

Monitoring of dose rates

Dose rates are regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation dosemeters. Table 2.9 lists the locations monitored by the Environment Agencies and the Food Standards Agency together with the gamma dose rates in air at 1 m above ground. Dose rates near other nuclear establishments that reflect Sellafield discharges are given in the relevant sections of this report. The general decrease in dose rates with increasing distance from Sellafield, which was apparent under conditions of higher discharges several decades ago, is no longer so apparent, but there is variability depending on ground type, generally higher dose rates being recorded over areas with finely divided sediments. Dose rates measured above mud and salt marsh, shown in Figure 2.18, fluctuate quite markedly with ground type, and illustrate the current low dependence on distance from Sellafield within the Irish Sea. Dose rates over intertidal areas throughout the Irish Sea

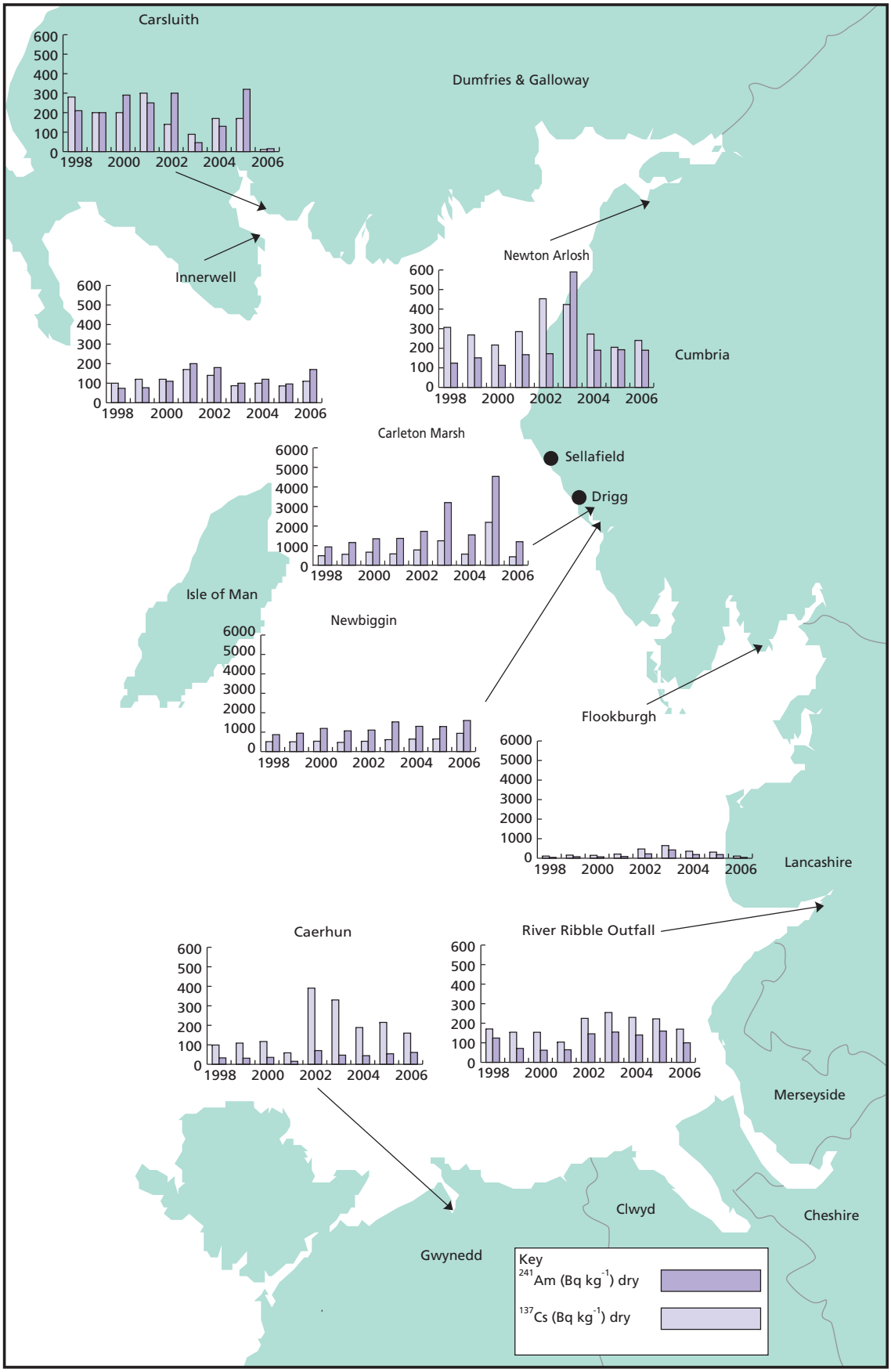


Figure 2.17. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 1998–2006

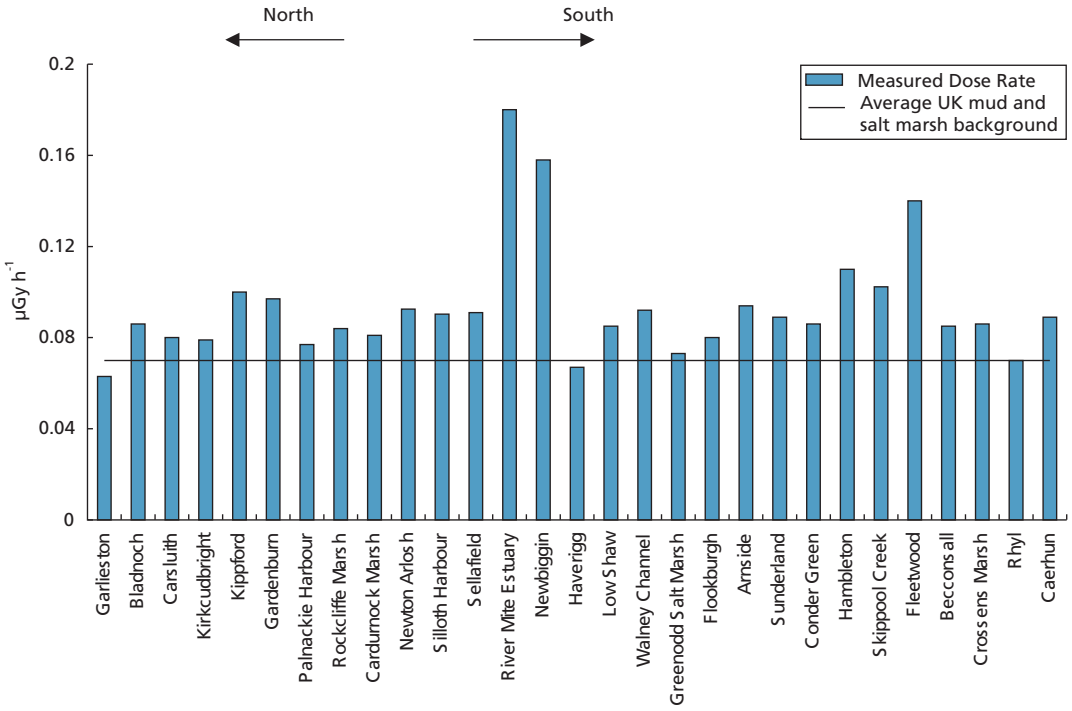


Figure 2.18. Gamma dose rate above mud and salt marsh with distance from Sellafield

in 2006 were similar to those data for the same locations in 2005. Slightly higher gamma dose rates from the Ravenglass estuary (River Mite) were measured in 2006 in comparison to values reported in 2005. This is likely to have been due to normal variability in the environment.

Gamma dose rates above mud and salt marshes, from a range of coastal locations in the vicinity of Sellafield, are shown in Figure 2.19. Over the period considered, the rates are reasonably similar with time for each location. Locations that are further afield from Sellafield show dose rate values that only marginally exceed average UK natural background rates.

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

Monitoring of fishing gear

During immersion in seawater, 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 2006 are presented in Table 2.10. Measured dose rates were generally similar to those in recent years.

Contact dose-rate monitoring of intertidal areas

A programme of measurements of beta dose rates on shoreline sediments using contamination monitors continued in 2006 to allow the exposure to be estimated for people who handle sediments regularly and the results are presented in Table 2.11. Dose rates were similar to those observed in recent years, although dose rates at Ravenglass (Salmon Garth) were reduced from 0.46 µSv h^{-1} (2005) to 0.20 µSv h^{-1} (2006).

More general beta/gamma monitoring of contamination on beaches using portable probes continued in 2006 to establish whether there are any localised 'hot spots' of activity, particularly in strand lines and beach debris. In 2006, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

Some increased monitoring of public beaches by the operators commenced on a trial basis in 2006. This made use of a vehicle mounted detection system which offered a greater efficiency in covering large areas and a greater effectiveness in detecting radioactive particles and other objects. Nine items (including pebbles and sand grain sized particles) with elevated radioactivity were identified and removed from the beach. The contaminated items are being subjected to further analysis (on the Sellafield site) to establish their characteristics and to determine their likely age and source. The large area monitoring is continuing in 2007 and more information will be available in the next RIFE report.

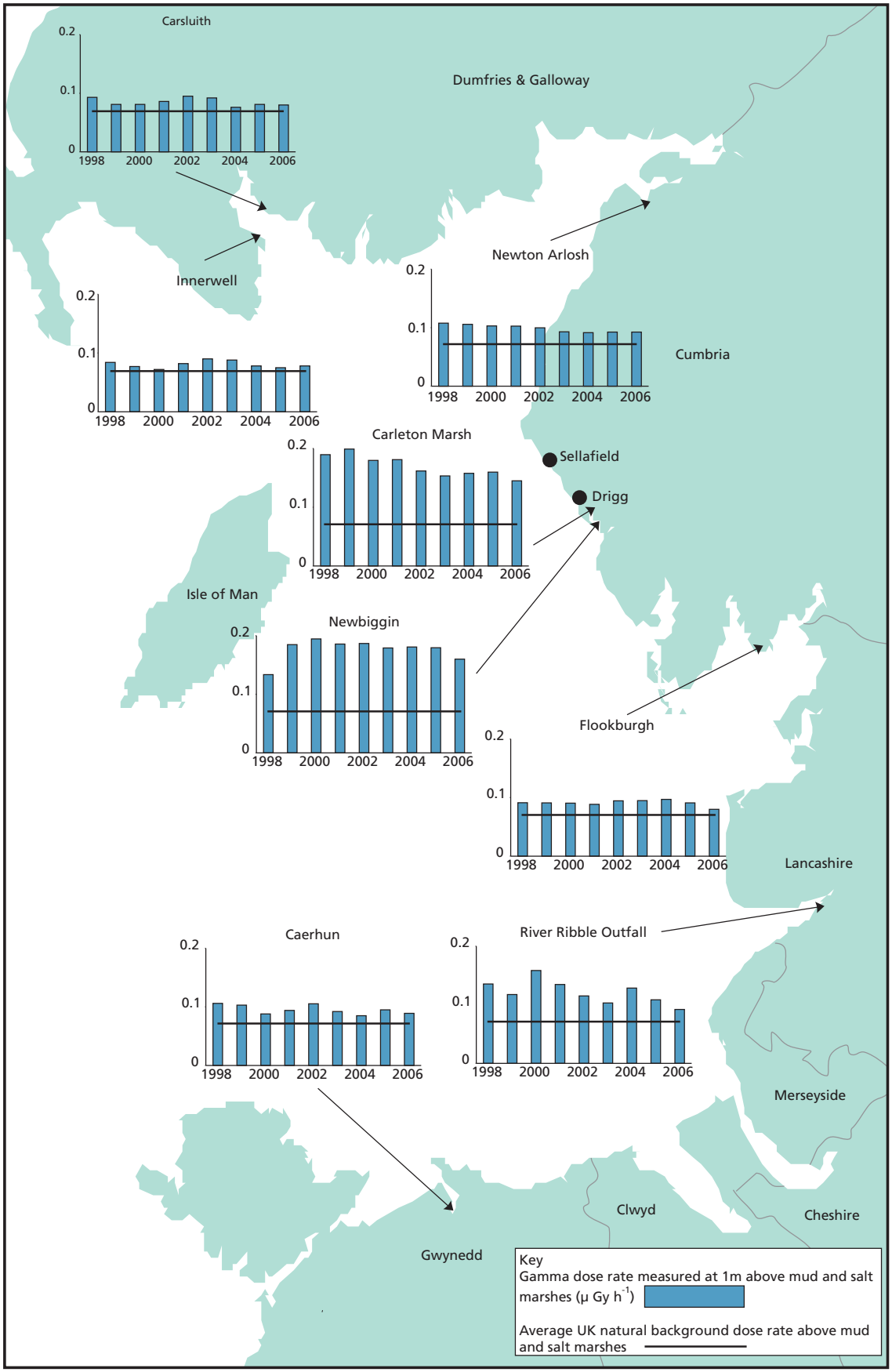


Figure 2.19. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 1998–2006

As part of the decommissioning operations at Sellafield, Sellafield Ltd. has removed three redundant sea discharge pipelines. Two of the pipes were of steel construction and one of plastic. This work commenced in 2005 and was completed in 2006.

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials; they concentrate particular radionuclides, so they greatly facilitate assessments and assist in the tracing of these radionuclides in the environment. Table 2.12 presents the results of measurements in 2006 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. Monitoring clearly showed the effects of discharges of technetium-99 from Sellafield. In the north-east Irish Sea there was a continued general decrease in concentrations of technetium-99 in *Fucus vesiculosus* in 2006; the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s (Figure 2.20). There is still a large reduction in concentrations of technetium-99 in *Fucus vesiculosus* with distance from Sellafield as the effect of the discharges becomes diluted in moving further afield. However, at Fishguard there appears to have been an increase in concentrations of technetium-99 in *Fucus vesiculosus* and seaweed over the period 2004 to 2006; there is similar evidence at Cemaes Bay on the Isle of Anglesey and possibly at Porthmadog. At Carlingford Lough in Ireland there was an increase in technetium-99 concentrations in *Fucus* in 2004 and 2006, but lower levels in 2005. These effects were most likely the result of complex hydrographic transport patterns in the Irish Sea, with individual technetium-99 pulses 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, 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), referred to later in this section in relation to doses from sea to land transfer,

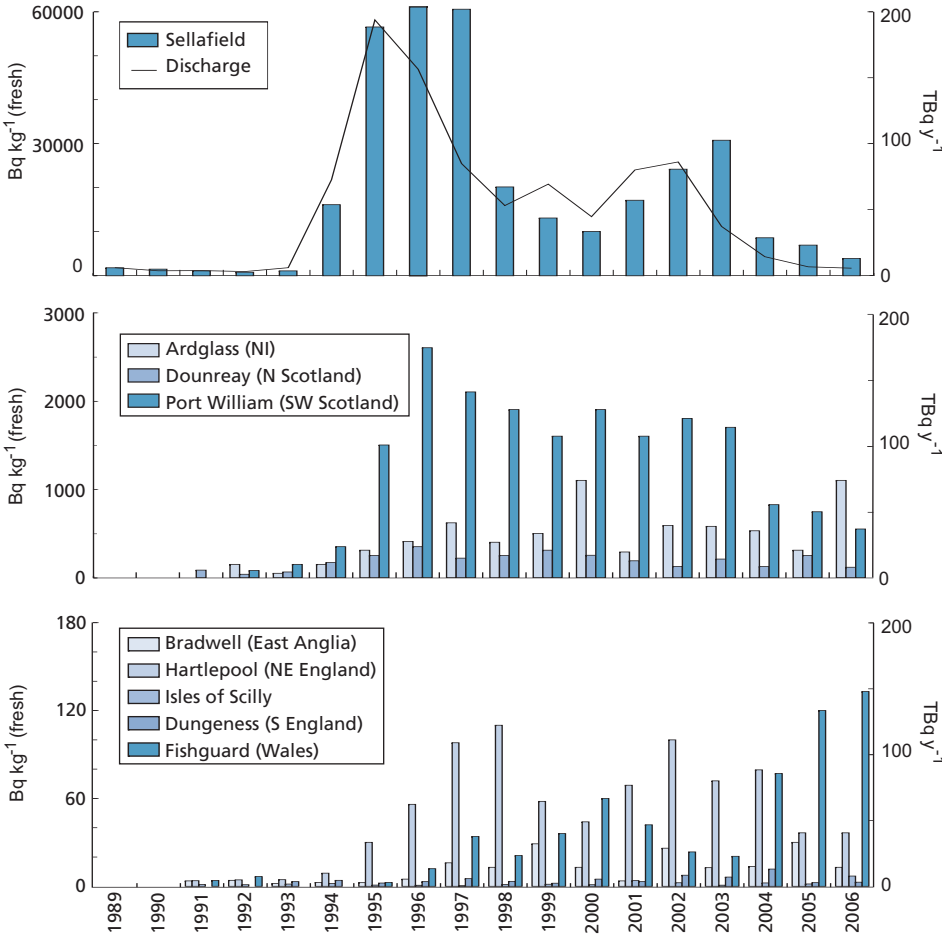


Figure 2.20. Technetium-99 liquid discharge from Sellafield and concentration in seaweed, *Fucus vesiculosus*

elevated concentrations of technetium-99 in sediments were reported for 2004 and 2005 in the Menai Strait. Concentrations in seaweed from the same vicinity were consistent with those reported for Cemaes Bay (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005). Further measurements were carried out on behalf of the Environment Agency (Environment Agency, 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 pathway was the subject of a continuing research study in 2006. The results are shown in Table 2.13. The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al.*, 2000). In 2006, seaweed harvesting in the Sellafield area continued to be rare. However, several plots of land previously fertilised by seaweed were identified and investigated further. Samples of soil were analysed for a range of radionuclides by gamma-ray spectrometry and for technetium-99. The soil and compost data show enhanced concentrations of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Various vegetable samples that had been grown in the soils from these plots were obtained. Where comparisons can be made, technetium-99 concentrations in edible parts of the vegetables were similar to those found in 2005. Low concentrations of gamma-emitting radionuclides were also found in some vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2006; this pathway has therefore remained essentially dormant. However, monitoring of *Porphyra* has continued in view of its potential importance, historical significance and the value of *Porphyra* as an environmental indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2006 are presented in Table 2.12. *Porphyra* from the Cumbrian coast in 2006 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 2006 are also presented in Table 2.12; concentrations of radionuclides were either undetectable or at very low levels.

In the Scottish islands, seaweed may be eaten directly by sheep grazing on the foreshore. A three-year study has commenced to investigate the potential transfer of radionuclides from seaweed to the food chain when seaweed is used as a soil conditioner, compost or animal feed. The first phase of the project was 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. Further stages of the project will include the sampling and analysis of control soils, treated soils, vegetable and fruit produce and sheep meat and liver for a range of radionuclides including strontium-90, technetium-99, caesium-137 and plutonium-239.

Investigations have shown that this does not take place to a significant extent in the Sellafield area.

Monitoring of seawashed pasture

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow-up sampling of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2006 (Table 2.13) suggests that this dose estimate remains valid.

Monitoring of sea to land transfer

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

The results of measurements in 2006 are presented in Table 2.14. In general, the data are similar to those for 2005 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. The evidence for sea to land transfer is limited. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. Where detectable, concentrations of transuranic radionuclides indicated an observed isotopic ratio for $^{239+240}$Pu:^{238}Pu somewhat lower than about 40:1 which would be expected if the source was only (or entirely) due to fallout. This may suggest a Sellafield influence.

Monitoring of fishmeal

Low concentrations of man-made radioactivity were found in fishmeal, which is fed to farmed fish, poultry, pigs, cows and sheep. A theoretical study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is unlikely to be of radiological significance (Smith and Jeffs, 1999). A detailed survey was undertaken in 2003 to confirm these findings. Samples were obtained from 14 fish farms in Scotland and three in Northern Ireland. They demonstrated that concentrations of radionuclides are indeed very low, most being less than the limits of detection, and the few that were positively

determined were all less than 1 Bq kg^{-1} (Food Standards Agency, 2003). Results in farmed salmon from the west of Scotland in 2006 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 carried out as part of the regular environmental monitoring programme around Sellafield; however, other environmental materials would be likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2006 are included in Table 2.15. The concentrations of total alpha and total beta activity were below the World Health Organisation (WHO) recommended values of 0.1 Bq l^{-1} and 1.0 Bq l^{-1} respectively.

Small amounts of activity are discharged from Sellafield under authorisation via the factory sewer outfall at the mouth of the River Calder. There was some evidence of tritium at the outfall (Table 2.15). However, the waters are not potable and the low concentrations are of no radiological significance. In addition, Table 2.15 includes the results of monitoring from the Ehen Spit (see 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 2006 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 level would have given a resultant dose of 1 mSv. Advice issued by MAFF on 14 February 1998 was that people should not handle, slaughter or consume pigeons within a 10 mile radius of the site. A full review of the incident was published in 1999 (Copeland Borough Council *et al.*, 1999). It was found that pigeons had access to the roof spaces in buildings on the Sellafield site and had become contaminated with radionuclides including caesium-137. The pigeons were also congregating in large numbers at a bird sanctuary in Seascale village and the environment around had become contaminated. Since then, BNFL have undertaken remedial measures, including a substantial cull of feral pigeons in the area and preventing access to the loft spaces in buildings on the Sellafield site. Results of the analysis of wood pigeon samples collected in 2006 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon was larger in 2006 (35 Bq kg^{-1}) than in 2005 (6 Bq kg^{-1}). Nevertheless, the concentrations of artificial radionuclides, including radiocaesium, 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 2006, samples were taken from the same drains as in previous years. The results of analyses in 2006 are shown in Table 2.16. 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 2.17. Calculations were performed for four ages (adult, 10y, 1y and prenatal); doses received by 1 year olds were found to be the highest, at 0.029 mSv (adult: 0.026; 10y: 0.021; prenatal: 0.016). The most significant contributions to the 1-year-old's dose were from strontium-90 and ruthenium-106, but it should be noted that the dose assessment used ruthenium-106 levels in foods at the limits of detection and are therefore likely to be a maximum value. The most important foodstuff was milk, which accounted for 58% of the dose.

The assessed dose due to high-rate food consumption by infants in 2006 (0.028 mSv) was slightly less than the corresponding dose in 2005 (0.033 mSv). Doses as a result of environmental non-food pathways (mostly inhalation of radionuclides and external dose from noble gases) were low in 2006 at less than 0.001 mSv.

The pathway (food and external/inhalation) and radionuclide contributions to dose from gaseous discharges from Sellafield for the period 2002 – 2006 are shown in Figure 2.21. The trend has been a generally declining one with reductions in doses of about 10% 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.

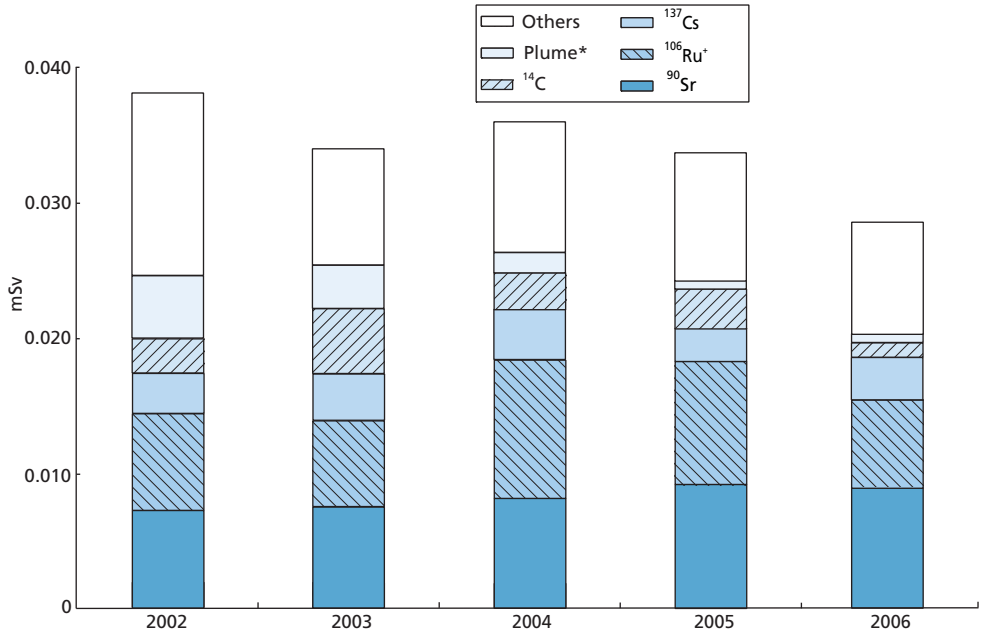


Figure 2.21. Contributions to dose due to gaseous discharges from Sellafield, 2002-2006 (* External and inhalation pathways, $^{+}$ Based on limits of detection for concentrations in foods)

Doses from liquid discharges

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

Doses from seafood consumption

The consumption and occupancy rates of the local critical group were reviewed in September 2006; small changes were found in the amounts and mixes of species consumed, with an increase in mollusc consumption. There was a decrease in occupancy 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 (2006 habits survey). The second was based on a five-year rolling average using habit data gathered from 2002 to 2006. Aquatic pathway habits are normally the most important in terms of dose at Sellafield and are surveyed every year. This allows generation of a unique yearly set of aquatic habit data and also rolling 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 2.17 summarises doses to seafood consumers in 2006. The dose to the local critical group of high-rate consumers from artificial radionuclides, using the moving average habits data, was 0.23 mSv. This dose includes a contribution due to external radiation exposure over sediments. This is a similar dose as reported for 2005 (0.22 mSv). Most of this dose was due to historic discharges from Sellafield. The breakdown by nuclide of the contributions to dose is shown in Figure 2.22. Recent and current discharges of technetium-99 contributed about 3% of the dose to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose (71%) 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, 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 2006 was estimated to be 0.24 mSv. Most of this was due to polonium-210 and lead-210 in shellfish. Although there was a small decrease in the polonium-210 concentration in some shellfish, the increase in dose from 2005 (0.23 mSv) was due to an increase in the consumption rate for molluscs.

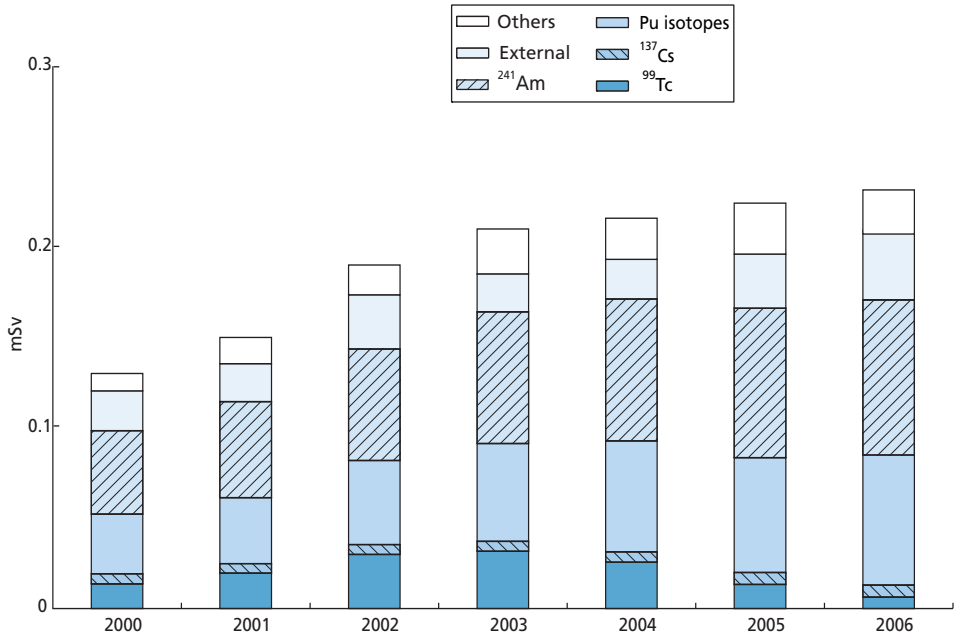


Figure 2.22. Contributions to dose to seafood consumers at Sellafield, 2000-2006

Taken with the 0.23 mSv dose from artificial radionuclides from Sellafield this gives, when rounded again to two significant figures, a total dose to the critical group of 0.47 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 2006 is provided in Table 2.17 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 2.17). Where appropriate, the dose from consumption of seafood has been summed with a contribution from external exposure over intertidal areas. The doses received by all these groups are significantly less than for the local Sellafield group because of the lower concentrations and dose rates further afield. There were small changes in the doses in each area when compared with those in 2005 (see table in following text and Figure 2.23). It is expected that there will be fluctuations in concentrations due to normal sampling variability. Whilst there have been changes in the concentrations of some radionuclides in seafood, their effect is relatively minor. All doses were well within the dose limit for members of the public of 1 mSv.

The dose from artificial radionuclides, equivalent to a consumption rate of 15 kg year^{-1} of fish from landings at Whitehaven and Fleetwood, is also given in Table 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 2006.

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 2006 are presented in Table 2.9. The results of the assessment of external exposure pathways are included in Table 2.17. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, are received by people who live in houseboats in the Ribble estuary in Lancashire. In 2006, their dose was 0.075 mSv or less than 8% of the dose limit for members of the public (see Section 2.2 Doses to the public). Other groups received lower external doses in 2006. The most important of these were found in the Ravenglass estuary;

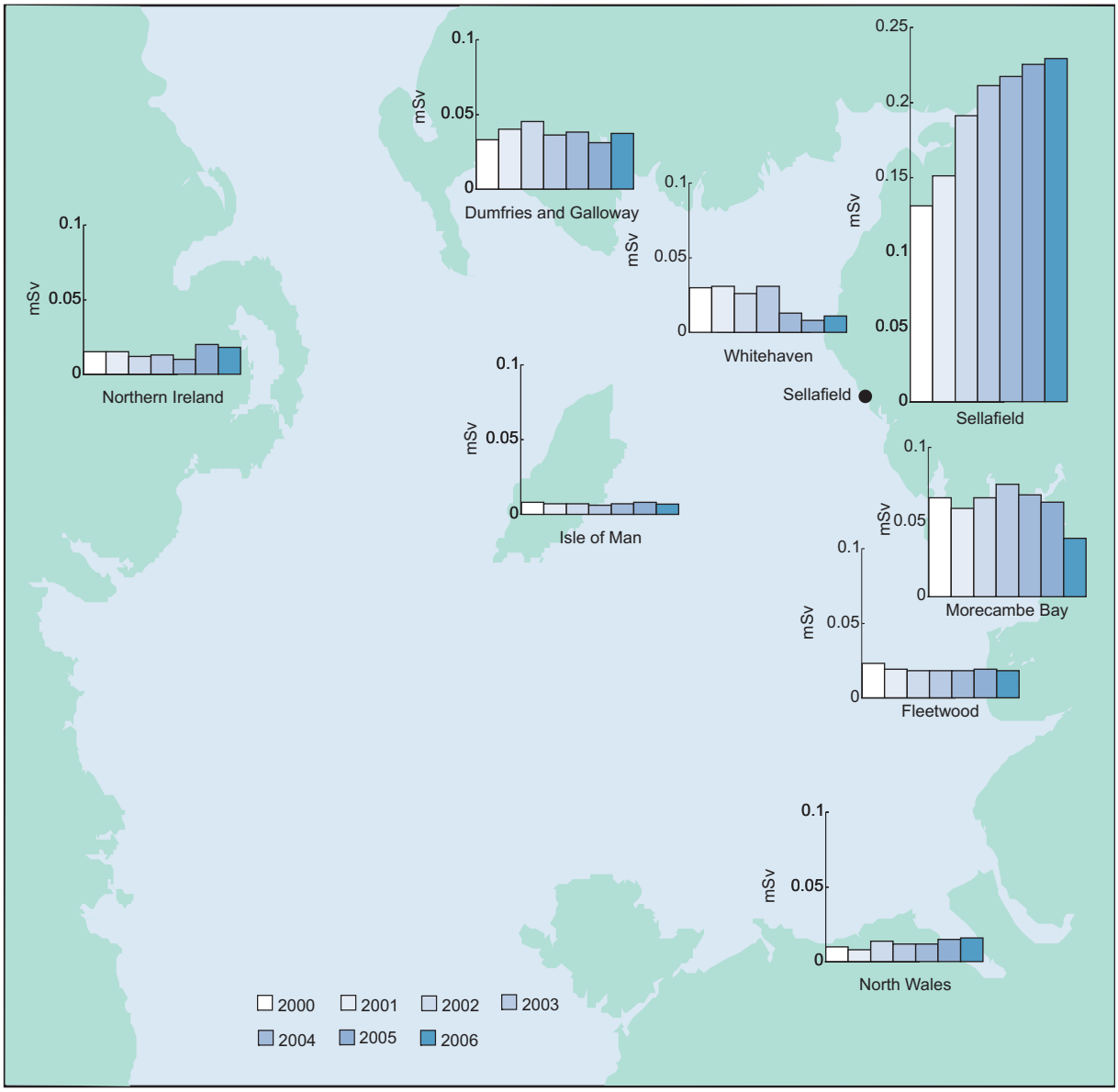


Figure 2.23. Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2006

Doses from artificial radionuclides in the Irish Sea				
Group	Dose, mSv			
	2003	2004	2005	2006
Isle of Man	0.006	0.007	0.008	0.007
Northern Ireland	0.013	0.010	0.020	0.018
Dumfries and Galloway	0.036	0.038	0.031	0.037
Whitehaven	0.031	0.013	0.008	0.011
Sellafield (average consumption 2002-6)	0.21	0.22	0.22	0.23
Morecambe Bay	0.075	0.068	0.063	0.038
Fleetwood	0.018	0.018	0.019	0.018
North Wales	0.012	0.012	0.015	0.016

exposures over salt marsh and mud ranged up to 0.042 mSv for high concentrations of recreational use and 0.030 mSv for a nature warden. The assessed dose for recreational use was higher than in 2005 (0.036 mSv) due to slightly higher gamma dose rates from the Ravenglass estuary (River Mite). The dose for a typical occupancy of a sandy beach close to Sellafield was estimated to be much less than 0.005 mSv. Dose rates in areas relevant to the Ravenglass nature warden have remained broadly similar over the period.

Doses from handling fishing gear and sediment

Exposures can also arise from contact with beta-emitters during handling of sediments or fishing gear on which fine particulates have become entrained. Habits surveys keep under review the amounts of time spent by fishermen handling their gear; for those most exposed, a time handling nets and pots of 730 h year^{-1} was appropriate. The skin dose from handling of fishing gear in 2006, including a component due to naturally-occurring radiation, was 0.068 mSv, which was less than 1% of the appropriate annual dose limit of 50 mSv specifically for skin. Handling of fishing gear is therefore a minor pathway of radiation exposure. The skin dose to bait diggers and shellfish collectors, based on a time handling sediment of 1000 h year^{-1}, was 0.19 mSv in 2006 which was also less than 1% of the skin dose limit. The decrease in dose from 2005 (0.26 mSv) was mostly due to reduced beta dose rate at Ravenglass (Salmon Garth) from 0.46 μSv h^{-1} (2005) to 0.20 μSv h^{-1} (2006).

Doses from atmospheric sea to land transfer

The exposure due to consumption of terrestrial foods potentially affected by sea to land transport by seaspray of radionuclides at Ravenglass in 2006 is given in Table 2.17. The adult age group received the highest exposures. Their dose, including contributions from Chernobyl and weapon test fallout, was calculated to be 0.013 mSv, which was approximately 1% of the dose limit for members of the public of 1 mSv. Sea-to-land transfer therefore is not of radiological importance in the Ravenglass area.

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

Doses from seaweed and seawashed pasture

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

Seaweeds are sometimes used as fertilisers and soil conditioners. Assuming that high-rate vegetable consumers obtain all of their supplies from monitored plots near Sellafield, the dose in 2006 was estimated to be 0.013 mSv. This was lower than in 2005 (0.069 mSv) because the dose assessment did not include concentrations of radionuclides in spinach, which concentrates technetium-99 to a greater extent than other vegetables. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales would be much lower than near Sellafield. The seaweed/vegetable pathway will be kept under review but it is likely that the doses due to direct consumption of seafood and external radiation from intertidal areas will remain more important.

Animals may graze on seaweeds at the upper tidal limit of coastal areas; however, there is no evidence of this taking place significantly near Sellafield. The Food Standards Agency undertook an assessment of the potential dose to a high-rate consumer of meat and liver from sheep grazing the seaweed using data relevant to the Shetlands and Orkneys. This showed that doses would have been well within the dose limit of 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 2006 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999).

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 2006 was 0.44 mSv to the shellfish consumer group. This is an increase from 0.41 mSv in 2005 and is due to more molluscs being eaten by some people in the local population in 2006 than in 2005. The *total dose* was made up of 0.21 mSv from radionuclides from Sellafield and 0.22 mSv from the residue of past discharges of natural nuclides (in particular polonium-210) from the now closed industrial phosphate plant near Whitehaven.

Table 2.1. Individual radiation exposures – Capenhurst and Springfields, 2006

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
Capenhurst	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	Children playing at Rivacre Brook[d]	0.008	-	-	0.008	<0.005
Springfields	Seafood consumers	0.022	0.007	-	0.014	-
	Houseboat occupants	0.075	-	-	0.075	-
	Fishermen handling nets or pots[c]	0.075	-	-	0.075	-
	Children playing at Lower Penwortham[d]	<0.005	-	-	<0.005	<0.005
	Farmers and wildfowlers	0.033	-	-	0.033	-
	Consumers of locally grown food[e]	<0.005	-	<0.005	-	-
	All sources[f]	0.13	-	-	-	-

[a] *Adults are the most exposed group unless otherwise stated*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *Children aged 10y*
[e] *Includes a component due to natural sources of radionuclides*
[f] *The total dose due to discharges and direct radiation. See Appendix 4*

Table 2.2(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2006

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	^{233}Pa	^{234}Th	^{234}U	^{235}U
Aquatic samples												
Flounder	Liverpool Bay	1	<25									
Flounder	Mersey Estuary	1	<25									
Dab	Liverpool Bay	1	<25									
Dab	Mersey Estuary	1	<25									
Shrimps	Wirral	2	<25	<0.05	0.57	<0.49	<0.13	1.7	*	*		
Mussels	Liverpool Bay	2	<25									
Mussels	Mersey Estuary	2	<25									
Cockles	River Dee	4		0.21	8.0	<0.42	<0.27	1.5	0.02	5.5		
Elodea canadensis	Rivacre Brook	2		<0.07	2.1	<0.66	<0.14	<0.09	<0.27	11	0.0034	0.00015
Sediment	Rivacre Brook (1.6 km downstream)	2[E]			64			2.1		<210	43	2.2
Sediment	Rivacre Brook (3.1 km downstream)	2[E]			25			1.4		<57	20	<0.98
Sediment	Rossmore (4.3 km downstream)	2[E]			53			2.6		430	44	1.7
Freshwater	Rivacre Brook	2[E]	<11		<0.44						0.068	<0.0060
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	<4.0		<0.43						0.039	<0.0055
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	<4.0		<0.39						0.054	<0.0060
Freshwater	Rossmore (4.3 km downstream)	2[E]	<4.0		<0.52						0.030	<0.0035
Freshwater	Dunkirk Lane Pond	2[E]	<9.8		<0.65						<0.0060	<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	Total alpha	Total beta
Aquatic samples											
Shrimps	Wirral	2					<0.19				
Cockles	River Dee	4			0.16	0.94	2.7	*	0.0018		
Elodea canadensis	Rivacre Brook	2	0.0018	0.14			<0.04				
Sediment	Rivacre Brook (1.6 km downstream)	2[E]	26	<1.2						330	540
Sediment	Rivacre Brook (3.1 km downstream)	2[E]	13	<1.1						260	480
Sediment	Rossmore (4.3 km downstream)	2[E]	26	<1.1						330	560
Freshwater	Rivacre Brook	2[E]	0.032	<0.10						0.095	0.35
Freshwater	Rivacre Brook (1.6 km downstream)	2[E]	0.018	<0.10						0.048	0.33
Freshwater	Rivacre Brook (3.1 km downstream)	2[E]	0.033	<0.10						<0.065	0.30
Freshwater	Rossmore (4.3 km downstream)	2[E]	0.017	<0.10						<0.035	0.38
Freshwater	Dunkirk Lane Pond	2[E]	<0.0070	<0.10						<0.12	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	<2.8	<0.0035				<0.0066
Gooseberries		1		<0.019	<0.0015	0.00050	<0.0013	<0.035
Lettuce		1		<0.041				<0.031
Potatoes		1		<0.026				<0.034
Grass		4		0.024				<0.054
Grass	max			0.028				0.078
Grass/herbage	North of Ledsham	1[E]		8.4	1.0	<0.20	1.0	
Grass/herbage	South of Capenhurst	1[E]		<1.0	<0.23	<0.13	<0.19	
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<1.0	<0.20	<0.20	<0.20	
Grass/herbage	East of station	1[E]		<0.90	<0.16	<0.14	<0.12	
Silage		2		0.024				1.2
Silage	max			0.028	0.026	<0.0010	0.026	2.3
Soil		1[#]			9.4	0.35	8.8	
Soil	North of Ledsham	1[E]		<3.0	18	0.66	17	
Soil	South of Capenhurst	1[E]		7.4	20	<0.85	21	
Soil	Off lane from Capenhurst to Dunkirk	1[E]		10	20	<1.3	20	
Soil	East of station	1[E]		<6.0	22	0.96	22	

** 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

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2006

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Concrete and mud	1	0.094
Rivacre Brook Plant outlet	Concrete	1	0.098
Rivacre Brook 1.5 km downstream	Grass and mud	2	0.078
Rivacre Brook 3.1 km downstream	Leaves and mud	1	0.077
Rivacre Brook 3.1 km downstream	Grass and mud	1	0.078
Rossmore Road West 4.3 km downstream	Grass and mud	1	0.068
Rossmore Road West 4.3 km downstream	Grass	1	0.078

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{14}C	^{60}Co	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples												
Flounder	Ribble Estuary	1		<0.07		<0.86	<0.21	5.4				*
Salmon	Ribble Estuary	1		<0.10		<1.2	<0.24	0.27				*
Sea trout	Ribble Estuary	1		<0.13		<1.3	<0.31	0.95				*
Bass	Ribble Estuary	1		<0.09		<0.97	<0.26	12				*
Grey mullet	Ribble Estuary	1		<0.12		<1.1	<0.27	3.9				*
Shrimps[d]	Ribble Estuary	2	78	<0.05	0.64	<0.49	<0.14	2.2	0.012	0.012	0.0027	*
Mussels	Ribble Estuary	2		<0.13		<0.53	0.25	1.2	0.27	0.29	0.089	*
Samphire	Marshside Sands	1		<0.04		<0.38	<0.09	0.96				*
Grass (washed)	Hutton Marsh	1			0.39							
Grass (unwashed)	Hutton Marsh	1			0.43							
Soil	Hutton Marsh	1			42							
Sediment	River Ribble outfall	4[E]		<1.5		<7.8		170	19	97	18	880
Sediment	Lea Gate	1[E]		2.0		<6.2		220	13	50	13	3100
Sediment	Lower Penwortham Park	4[E]		<2.3		<9.1		260	25	100	21	3200
Sediment	Penwortham rail bridge	4[E]		<1.9		<6.3		230	18	83	19	6400
Sediment	Penwortham rail bridge - West bank	2[E]		<1.9		<7.2		330	35	220	34	1400
Sediment	Penwortham position 1	4[E]		<1.4		<7.9		190	20	110	18	1400
Sediment	Penwortham position 2	1[E]		<0.78		<5.5		91	34	180	33	250
Sediment	Lytham Yacht Club	1[E]		4.0		<12		320	9.2	28	11	990
Sediment	Becconsall	4[E]		<2.3		<7.4		250	21	58	18	1900
Sediment	Freckleton	1[E]		2.9		<6.0		350	12	40	13	1000
Sediment	Hutton Marsh	1[E]		0.99		<4.8		500	57	400	53	200
Sediment	Longton Marsh	1[E]		<0.81		<6.1		130	23	92	20	330

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples												
Flounder	Ribble Estuary	1						<0.19				
Salmon	Ribble Estuary	1						<0.10				
Sea trout	Ribble Estuary	1						<0.13				
Bass	Ribble Estuary	1						<0.12				
Grey mullet	Ribble Estuary	1						<0.10				
Shrimps[d]	Ribble Estuary	2				0.0017	0.011	0.022	*	*		
Mussels	Ribble Estuary	2						1.4				
Samphire	Marshside Sands	1						0.23				
Sediment	River Ribble outfall	4[E]	21	1.1	20			100			830	1100
Sediment	Lea Gate	1[E]	39	1.5	31			160			750	2800
Sediment	Lower Penwortham Park	4[E]	30	1.3	28			150			930	2400
Sediment	Penwortham rail bridge	4[E]	31	<1.1	29			120			860	3900
Sediment	Penwortham rail bridge - West bank	2[E]	45	1.6	39			130			1700	1700
Sediment	Penwortham position 1	4[E]	26	<0.91	25			110			850	1400
Sediment	Penwortham position 2	1[E]	24	1.1	23			46			1200	740
Sediment	Lytham Yacht Club	1[E]	25	0.79	26			170			500	1200
Sediment	Becconsall	4[E]	24	0.99	22			110			770	1900
Sediment	Freckleton	1[E]	25	1.2	27			210			650	1400
Sediment	Hutton Marsh	1[E]	28	1.3	28			160			1300	1300
Sediment	Longton Marsh	1[E]	28	<0.80	29			71			960	1000

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{106}Ru	^{129}I	^{137}Cs	Total Cs
Terrestrial samples										
Apples		1	<5.0	7.0	<0.20	<0.0070	<1.5	<0.025		0.067
Beetroot		1	<5.0	3.0	<0.30	0.12	<1.8	0.044		0.069
Blackberries		1	<4.0	14	<0.10	0.087	<1.7	<0.032		0.044
Eggs		1	<6.0	25	<0.20	<0.0070	<1.4	<0.029		0.071
Onions		1	<5.0	9.0	<0.30	0.027	<1.7	<0.029		0.037
Potatoes		1	<5.0	16	<0.30	0.054	<1.3	<0.025		0.058
Runner beans		1	<5.0	<3.0	<0.20	0.050	<1.8	<0.035		<0.028
Sediment	Deepdale Brook	2[E]			<0.95		<5.7		<0.69	
Grass		1			<0.50		<2.2		2.2	

Material	Location or selection[a]	No. of sampling observations[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		1							<0.0066
Apples		1	0.0042	<0.00070					<0.027
Beetroot		1	0.0012	<0.0012					<0.034
Blackberries		1	0.0019	<0.00090					<0.031
Eggs		1	0.0016	<0.00080		<0.0013	<0.00040	<0.0012	<0.034
Onions		1	0.0023	<0.0010					<0.035
Potatoes		1	0.0069	0.0038		0.012	<0.00060	0.011	0.040
Runner beans		1	0.0015	<0.00090					<0.033
Sediment	Deepdale Brook	2[E]			370	41	1.1	41	
Grass		1				0.28	0.014	0.25	0.69
Grass	Site fence	1[E]				<0.30	<0.30	<0.40	
Grass	Opposite site entrance	1[E]				0.73	<0.20	0.53	
Grass	Opposite windmill	1[E]				1.2	<0.11	1.3	
Grass	Deepdale Brook	1[E]				1.2	<0.15	1.2	
Grass	Lea Town	1[E]				<0.50	<0.16	<0.25	
Grass	N of Lea Town	1[E]				0.58	<0.16	0.34	
Silage		1							0.40
Soil		1[#]				24	1.2	24	
Soil	Site fence	1[E]				140	6.5	120	
Soil	Opposite site entrance	1[E]				110	4.0	97	
Soil	Opposite windmill	1[E]				66	2.4	61	
Soil	Deepdale Brook	1[E]				110	4.0	100	
Soil	Lea Town	1[E]				30	1.1	29	
Soil	N of Lea Town	1[E]				43	1.9	43	
Freshwater	Deepdale Brook	4[E]				0.63	0.026	0.60	

Table 2.3(a). continued

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	Total alpha	Total beta
Terrestrial samples								
Apples		1	<0.00020	<0.00010	<0.037	0.00040		
Beetroot		1	<0.00030	<0.00030	<0.045	0.00040		
Blackberries		1	<0.00030	0.00030	<0.035	0.0011		
Eggs		1	<0.00010	<0.00020	<0.031	0.00030		
Onions		1	0.00020	<0.00060	<0.090	0.00020		
Potatoes		1	0.00020	0.00030	<0.028	0.00030		
Runner beans		1	<0.00030	0.00060	<0.041	0.0012		
Sediment	Deepdale Brook	2[E]					410	980
Grass		1				0.70		
Freshwater	Deepdale Brook	4[E]					0.72	0.56

** Not detected by the method used*

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

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

[d] *The concentration of ^{237}Np was 0.00026 Bq kg^{-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 2.3(b). Monitoring of radiation dose rates near Springfields, 2006

Location	Material or ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
Lytham Yacht Club	Mud	1	0.093
Warton Marsh	Mud[a]	4[F]	0.11
Warton Mud Marsh	Mud	1	0.10
Warton Mud Marsh	Grass and mud	1	0.13
Warton Salt Marsh	Salt marsh	2	0.11
Naze Point	Salt marsh	2	0.11
Banks Marsh	Mud[a]	4[F]	0.11
Banks Marsh	Salt marsh	4[F]	0.13
Banks Marsh	Salt marsh and mud	1	0.11
Banks Marsh	Salt marsh	1	0.13
Hesketh Bank	Salt marsh	2	0.12
Freckleton	Mud	1	0.11
Becconsall Boatyard	Mud[b]	1	0.11
Becconsall Boatyard	Mud	2	0.085
Becconsall Boatyard	Grass and mud	2	0.085
Becconsall (vicinity of houseboats)	Grass and mud	1	0.079
Becconsall (vicinity of houseboats)	Grass	1	0.079
Becconsall (port side of houseboats)	Wood[b]	1	0.089
Becconsall (starboard side of houseboats)	Wood[b]	1	0.087
Becconsall (rear of houseboats)	Wood[b]	1	0.083
Longton Marsh	Salt marsh and mud	1	0.13
Hutton Marsh	Salt marsh	1	0.12
River Ribble outfall	Mud	2	0.095
River Ribble outfall	Grass and mud	2	0.092
Savick Brook, confluence with Ribble	Mud	1	0.091
Savick Brook, confluence with Ribble	Grass and mud	1	0.085
Savick Brook, Lea Gate	Grass and mud	1	0.096
South bank opposite outfall	Salt marsh	1	0.10
Penworthham Bridge cadet hut	Grass and mud	1	0.076
Penworthham Bridge cadet hut	Grass	1	0.076
Lower Penwortham Park	Mud	1	0.089
Lower Penwortham Park	Grass and mud	1	0.079
Lower Penwortham Park	Grass	2	0.077
Lower Penwortham Railway Bridge	Mud	3	0.084
Lower Penwortham Railway Bridge	Mud and sand	1	0.090
River Darwen	Grass and mud	1	0.073
River Darwen	Grass	3	0.079
Riverbank Angler location 1	Mud	1	0.076
Riverbank Angler location 1	Grass and mud	1	0.074
Riverbank Angler location 1	Grass	2	0.069
Riverbank Angler location 2	Grass	1	0.073
Ulnes Walton, BNFL area survey	Grass	3	0.081
Mean beta dose rates			
Lytham - Granny's Bay	Mud and sand	1[F]	0.20
Ribble Estuary	Gill net	1[F]	0.096
Ribble Estuary	Shrimp net	2[F]	0.12
Banks Marsh	Mud	4[F]	2.0
Banks Marsh	Salt marsh	4[F]	0.43
Warton Marsh	Mud	4[F]	1.6
Warton Marsh	Salt marsh	4[F]	0.43

[a] *15cm above substrate*
[b] *data collected during survey of occupancies, 2006*
[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the Environment Agency*

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2006

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]		18	<4.9	<5.4	14	<0.22	0.075	<0.0035	<1.4	<0.44	<0.010
Milk[d]	max		<6.3	8.0	19	<0.40	0.23		<2.1	<0.63	<0.021
Apples		2	<9.0	8.5	9.0	<0.20	0.16	0.025	<1.8	<0.45	<0.030
Apples	max		<11	10	12		0.26		<1.9	<0.50	0.030
Barley		1		<7.0	90	<0.40	2.0		<2.4	<0.70	<0.032
Beef kidney		1	4.0	9.0	35	<0.20	0.16	<0.027	<1.5	<0.40	<0.062
Beef liver		1	<9.0	<9.0	31	<0.30	0.034	0.040	<1.2	<0.30	<0.027
Beef muscle		1	7.0	14	19	<0.30	0.0060	<0.026	<1.6	<0.40	<0.046
Blackberries		2	<4.5	5.5	21	<0.20	1.1		<1.2	<0.45	<0.028
Blackberries	max		<8.0	6.0						<0.50	<0.033
Cabbage		2	<4.0	<4.0	<2.5	<0.35	0.54		<1.7	<0.50	<0.028
Cabbage	max				<3.0	<0.40	0.84		<2.1	<0.60	<0.030
Carrots		1	<5.0	<5.0	3.0	<0.20	0.42	<0.013	<1.5	<0.50	<0.024
Cauliflower		1	<4.0	<4.0	<4.0	<0.20	0.12		<2.1	<0.60	0.044
Celeriac[e]		1	<6.0	<4.0	15	<0.20	1.2		<1.6	<0.30	<0.030
Duck		1	<6.0	<6.0	16	<0.10	<0.0080	<0.011	<1.7	<0.50	<0.036
Eggs		1	<6.0	<6.0	30	<0.20	0.039		<1.0	<0.40	<0.029
Elderberries		1	<6.0	5.0	15	<0.20	0.64		<1.8	<0.50	<0.035
Field beans		1		7.0	92	<0.30	0.53		<2.0	<0.70	<0.058
Honey		1		<7.0	46	<0.20	0.028		<1.4	<0.40	<0.014
Mushrooms		1	<3.0	<3.0	6.0	<0.30	0.073		<1.6	<0.40	0.031
Onions		1	<9.0	8.0	6.0	<0.20	0.13		<1.3	<0.40	<0.032
Pheasants		1	<8.0	8.0	20	<0.20	<0.0070	<0.011	<1.0	<0.40	<0.032
Potatoes		1	<5.0	5.0	14	<0.30	0.047		<1.6	<0.50	<0.024
Rabbit		1	<5.0	<5.0	30	<0.20	0.082	<0.043	<1.4	<0.30	<0.036
Sheep muscle		2	<4.5	<6.0	28	<0.25	0.019	<0.025	<1.5	<0.50	<0.038
Sheep muscle	max		<5.0	7.0	33	<0.30	0.025	0.038	<1.6		<0.043
Sheep offal		2	<6.5	<6.5	24	<0.25	0.16	<0.0095	<1.7	<0.50	<0.036
Sheep offal	max		<7.0	<7.0	27	<0.30	0.23	<0.010			<0.037
Sprouts		1	<4.0	<4.0	<2.0	<0.20	0.12		<1.3	<0.50	<0.024
Strawberries		1	7.0	10	5.0	<0.20	0.058		<2.2	<0.60	<0.027
Swede		1	<4.0	<4.0	10	<0.40	0.33		<1.7	<0.40	<0.032
Wheat		1		<6.0	89	<0.20	1.2		<0.70	<0.60	<0.045
Wood pigeon muscle		2	<6.0	<6.0	19	<0.30	0.021		<2.3	<0.80	<0.043
Wood pigeon muscle	max		<7.0	7.0			0.023		<2.4		<0.050
Grass		5				<0.40		<0.029	<1.7	<1.9	
Grass	max							<0.030	<2.3	3.9	
Soil		3				<0.33			<2.0	<0.60	
Soil[f]	max					0.50			<2.6		

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]		18	<0.20	<0.27	0.21		<0.00016	<0.00016	<0.027	<0.00014
Milk[d]	max		<0.30	<0.48	0.44		<0.00020	<0.00018	<0.029	<0.00015
Apples		2			0.40		<0.00025	0.00095	<0.044	0.0010
Apples	max				0.66		0.00030	0.0016	<0.048	0.0012
Barley		1			0.57		<0.0013	0.022	<0.15	0.017
Beef kidney		1			1.7		<0.00020	0.00030	<0.047	0.00050
Beef liver		1			0.92		0.00040	<0.0011	<0.15	<0.00070
Beef muscle		1			1.8		<0.00020	0.00030	<0.046	<0.00030
Blackberries		2			0.29		<0.00040	0.0055	<0.048	0.0015
Blackberries	max				0.33		0.00050	0.0057	<0.062	0.0020
Cabbage		2			0.061		<0.00035	<0.00045	<0.076	0.00050
Cabbage	max				0.067		0.00040	0.00050	<0.081	0.00060
Carrots		1			0.22		0.00040	0.0015	<0.067	0.0031
Cauliflower		1			0.15	<0.035	<0.00010	<0.00020	<0.050	0.00050
Celeriac[e]		1			0.55	0.062	0.00040	0.0021	<0.034	0.0030
Duck		1			3.3		<0.00020	0.00040	<0.074	0.00030
Eggs		1			0.14		<0.00010	0.00020	<0.028	0.0036
Elderberries		1			0.33		0.0017	0.0090	<0.035	0.018
Field beans		1			0.53		0.00090	0.00020	<0.037	0.00070
Honey		1			0.063		<0.00010	<0.00030	<0.038	0.00050
Mushrooms		1			0.25		0.00060	0.018	<0.068	0.0071
Onions		1			0.066		<0.00040	<0.00010	<0.087	0.00030
Pheasants		1			0.39		<0.00060	<0.00040	<0.17	0.00040
Potatoes		1			0.11		0.00010	0.00020	<0.033	0.00020
Rabbit		1			2.1		0.00040	0.00030	<0.092	0.0015
Sheep muscle		2			1.1		<0.00030	0.00050	<0.086	<0.00075
Sheep muscle	max				1.2			0.00070	<0.088	0.0013
Sheep offal		2			0.35		<0.00050	0.0018	<0.058	0.0015
Sheep offal	max				0.38		0.00070	0.0028	<0.062	0.0024
Sprouts		1			0.035		<0.00020	<0.00030	<0.036	0.00050
Strawberries		1			0.058		0.00020	<0.00030	<0.035	0.00070
Swede		1			0.081		<0.00010	0.00030	<0.034	0.00060
Wheat		1			0.37		0.00050	0.0042	<0.11	0.0010
Wood pigeon muscle		2			21		<0.00020	<0.00020	<0.089	0.00040
Wood pigeon muscle	max				35		<0.00030	0.00020	<0.091	0.00050
Grass		5	<0.30	2.0						
Grass	max			4.3						
Soil		3	<0.23	55						4.7
Soil[f]	max		<0.30	71						6.3

[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 <0.0080 Bq l^{-1} and the maximum was <0.0091 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 0.024, 0.0013 and 0.021 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 16, 0.72 and 15 Bq kg^{-1} respectively*

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2006

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
Cumbria									
Maryport	Plaice	4				<0.13		<0.63	<1.1
Parton	Cod	4				<0.09		<0.40	<0.72
Whitehaven	Cod	4			89	<0.09	0.13	<0.34	<0.51
Whitehaven	Plaice	4				<0.11	0.17	<0.64	<1.2
Whitehaven	Skates/rays	4				<0.17		<1.2	<0.63
Whitehaven	Sole	3				<0.13		<0.75	<0.88
Whitehaven	Dab	1				<0.24		<1.3	<2.3
River Ehen	Salmon	1				<0.08		<0.52	<1.0
Sellafield coastal area	Cod	10				<0.15		<0.45	<0.77
Sellafield coastal area	Plaice	4	77	91		<0.18		<0.74	<1.2
Sellafield coastal area	Bass	1				<0.15		<0.81	<1.9
Sellafield coastal area	Grey mullet	1				<0.13		<0.56	<0.77
Sellafield offshore area	Cod	2				<0.11		<0.35	<0.47
Sellafield offshore area	Plaice[a]	1			200	0.12	0.11	<0.08	<0.07
Sellafield offshore area	Dab	2				<0.24		<0.40	<0.57
Sellafield offshore area	Flounder	2			76	<0.16	0.075	<0.58	<0.77
Sellafield offshore area	Lesser spotted dogfish	1				<0.06		<0.22	<0.22
Sellafield offshore area	Pollack	1				<0.19		<0.99	<1.6
Sellafield offshore area	Skates/rays	1				<0.20		<0.56	<0.63
River Esk	Salmon	1				<0.09		<0.41	<0.76
River Esk	Sea trout	1				<0.14		<0.74	<1.3
River Calder	Salmon	1				<0.12		<0.51	<0.67
Ravenglass	Cod	6				<0.13		<0.52	<1.0
Ravenglass	Plaice	3	130	150		<0.13		<0.45	<0.59
Ravenglass	Grey mullet	1				<0.14		<0.54	<0.84
Morecambe Bay (Flookburgh)	Flounder	3			110	<0.18		<0.96	<2.0
Morecambe Bay (Flookburgh)	Plaice	1				<0.12		<0.68	<1.6
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Plaice	4	<30	48		<0.13	0.10	<0.88	<1.1
Morecambe Bay (Morecambe)	Bass	2				<0.10		<0.79	<0.74
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.09	0.11	<0.38	<0.67
River Duddon	Sea trout	1				<0.08		<0.40	<0.73
River Kent	Sea trout	1				<0.11		<0.56	<0.93
Fleetwood	Cod	4			77	<0.09	0.045	<0.51	<0.59
Fleetwood	Plaice	4				<0.11		<0.75	<1.4
Ribble Estuary	Flounder	1				<0.07		<0.58	<1.4
Ribble Estuary	Grey mullet	1				<0.12		<0.67	<1.1
Ribble Estuary	Salmon	1				<0.10		<0.64	<1.4
Ribble Estuary	Sea trout	1				<0.13		<0.77	<1.4
Ribble Estuary	Bass	1				<0.09		<0.44	<0.75
Liverpool Bay	Flounder	1		<25					
Liverpool Bay	Dab	1		<25					
Mersey Estuary	Flounder	1		<25					
Mersey Estuary	Dab	1		<25					
Scotland									
Shetland	Fish meal	4				<0.33	0.019	<2.7	<0.46
Shetland	Fish oil	4				<0.13		<0.81	<1.5
Minch	Herring	2				<0.10		<0.45	<0.75
Minch	Mackerel	2			43	<0.09	<0.046	<0.41	<0.65
West of Scotland	Mackerel	2				<0.12		<0.63	<1.2
West of Scotland	Farmed salmon	1				<0.12		<0.87	<2.1
Kirkcudbright	Plaice	1			140	<0.15		<0.48	<0.52
North Solway	Sole	1	<25	28		<0.16		<0.53	<0.65
North Solway	Whiting	1	25	26	86	<0.06	0.16	<0.24	<0.35
Inner Solway	Flounder	4			74	<0.12	<0.10	<1.2	<3.2
Inner Solway	Salmon	1		<5.0		<0.10		<0.53	<1.2
Inner Solway	Sea trout	1		6.0		<0.17		<1.7	<5.4

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	Total beta
Cumbria									
Maryport	Plaice	4		<1.2	<0.29	<0.13	3.1	<0.57	
Parton	Cod	4		<0.88	<0.25	<0.09	10	<0.53	
Whitehaven	Cod	4		<0.83	<0.22	<0.09	6.4	<0.47	
Whitehaven	Plaice	4		<1.2	<0.31	<0.12	3.2	<0.73	
Whitehaven	Skates/rays	4		<1.9	<0.42	<0.18	4.9	<0.87	
Whitehaven	Sole	3		<1.2	<0.28	<0.13	3.0	<0.54	
Whitehaven	Dab	1		<2.8	<0.60	<0.26	5.3	<1.4	
River Ehen	Salmon	1		<0.83	<0.18	<0.08	0.16	<0.39	
Sellafield coastal area	Cod	10		<0.97	<0.26	<0.11	8.7	<0.48	170
Sellafield coastal area	Plaice	4		<1.8	<0.48	<0.18	4.5	<1.0	160
Sellafield coastal area	Bass	1		<1.5	<0.42	<0.16	13	<1.1	
Sellafield coastal area	Grey mullet	1		<1.4	<0.38	<0.15	6.9	<0.98	
Sellafield offshore area	Cod	2		<0.89	<0.25	<0.09	7.0	<0.43	
Sellafield offshore area	Plaice[a]	1	30	<0.31	0.14	<0.04	5.8	<0.15	
Sellafield offshore area	Dab	2		<1.1	<0.30	<0.13	6.3	<0.57	
Sellafield offshore area	Flounder	2	2.6	<1.5	<0.39	<0.14	9.9	<0.76	
Sellafield offshore area	Lesser spotted dogfish	1		<0.65	<0.19	<0.07	10	<0.41	
Sellafield offshore area	Pollack	1		<2.0	<0.49	<0.21	8.6	<1.1	
Sellafield offshore area	Skates/rays	1		<1.8	<0.39	<0.18	5.8	<0.60	
River Esk	Salmon	1		<0.81	<0.19	<0.08	0.19	<0.38	
River Esk	Sea trout	1		<1.7	<0.37	<0.15	0.16	<0.85	
River Calder	Salmon	1		<1.4	<0.32	<0.13	4.5	<0.70	
Ravenglass	Cod	6		<1.0	<0.28	<0.11	8.0	<0.65	
Ravenglass	Plaice	3		<1.1	<0.30	<0.12	5.6	<0.55	
Ravenglass	Grey mullet	1		<1.2	<0.31	<0.14	6.4	<0.50	
Morecambe Bay (Flookburgh)	Flounder	3		<1.8	<0.48	<0.19	13	<0.82	
Morecambe Bay (Flookburgh)	Plaice	1		<1.0	<0.26	<0.12	5.6	<0.53	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Plaice	4	0.46	<1.5	<0.35	<0.14	4.8	<0.81	
Morecambe Bay (Morecambe)	Bass	2		<1.2	<0.30	<0.11	16	<0.65	
Morecambe Bay (Sunderland Point)	Whitebait	1		<0.89	<0.23	<0.09	5.3	<0.53	
River Duddon	Sea trout	1		<0.86	<0.23	<0.09	6.6	<0.59	
River Kent	Sea trout	1		<1.0	<0.26	<0.11	3.9	<0.55	
Fleetwood	Cod	4	0.22	<0.91	<0.21	<0.09	6.0	<0.44	
Fleetwood	Plaice	4		<1.2	<0.25	<0.11	4.1	<0.51	
Ribble Estuary	Flounder	1		<0.86	<0.21	<0.08	5.4	<0.54	
Ribble Estuary	Grey mullet	1		<1.1	<0.27	<0.12	3.9	<0.48	
Ribble Estuary	Salmon	1		<1.2	<0.24	<0.11	0.27	<0.52	
Ribble Estuary	Sea trout	1		<1.3	<0.31	<0.13	0.95	<0.66	
Ribble Estuary	Bass	1		<0.97	<0.26	<0.10	12	<0.51	
Scotland									
Shetland	Fish meal	4		<3.6	<0.82	<0.36	<0.51	<1.9	
Shetland	Fish oil	4		<1.4	<0.36	<0.15	<0.13	<0.81	
Minch	Herring	2		<0.99	<0.21	<0.11	<0.10	<0.40	
Minch	Mackerel	2		<0.93	<0.22	<0.10	0.12	<0.60	
West of Scotland	Mackerel	2		<1.1	<0.26	<0.12	<0.11	<0.50	
West of Scotland	Farmed salmon	1		<1.4	<0.32	<0.13	0.18	<0.64	
Kirkcudbright	Plaice	1	0.84	<1.3	<0.36	<0.14	4.3	<0.78	
North Solway	Sole	1		<1.7	<0.39	<0.17	3.1	<0.85	
North Solway	Whiting	1	0.78	<0.57	<0.15	<0.06	5.1	<0.28	
Inner Solway	Flounder	4	0.88	<1.3	<0.32	<0.11	16	<0.81	
Inner Solway	Salmon	1		<0.66	<0.16	<0.10	0.32	<0.44	
Inner Solway	Sea trout	1		<1.7	<0.41	<0.16	2.8	<1.1	

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
Isle of Man									
Isle of Man	Cod	4				<0.09		<0.64	<0.34
Isle of Man	Herring	4				<0.10		<0.64	<1.4
Wales									
North Anglesey	Skates/rays	4				<0.12		<1.1	<0.83
North Anglesey	Plaice	2	<25	<25	74	<0.13		<0.67	<1.3
North Anglesey	Bass	1				<0.03		<0.18	<0.31
Northern Ireland									
North coast	Cod	1				<0.04		<0.11	<0.12
North coast	Spurdog	4				<0.07		<0.51	<0.51
Portavogie	Haddock	1				<0.07		<0.33	<0.56
Portavogie	Spurdog	1				<0.09		<0.35	<0.47
Ardglass	Herring	2				<0.09		<0.67	<1.5
Kilkeel	Cod	3			55	<0.07		<0.46	<1.1
Kilkeel	Plaice	1				<0.08		<0.30	<0.45
Kilkeel	Whiting	1				<0.06		<0.23	<0.30
Kilkeel	Spurdog	2				<0.09		<0.74	<0.25
Kilkeel	Haddock	2				<0.13		<1.2	<0.46
Glenarm	Farmed salmon	1				<0.08		<0.86	*
Further afield									
Baltic Sea	Cod	2				<0.07		<0.63	<0.57
Baltic Sea	Herring	4				<0.09		<0.74	<1.0
Barents Sea	Cod	1				<0.07		<0.40	<0.65
Barents Sea	Haddock	1				<0.18		<0.74	<1.0
Norwegian Sea	Cod	3				<0.06		<0.48	<1.2
Norwegian Sea	Saithe	1				<0.05		<0.46	<1.2
Norwegian processed	Cod	2			23	<0.05		<0.26	<0.50
Iceland area	Cod	2				<0.05		<0.40	<0.15
Skagerrak	Cod	4				<0.06		<0.34	<0.61
Skagerrak	Herring	3				<0.08		<0.40	<0.70
Northern North Sea	Cod	1				<0.06		<0.63	*
Northern North Sea	Plaice	4				<0.05		<0.62	<0.11
Northern North Sea	Haddock	4			24	<0.05		<0.22	<0.35
Northern North Sea	Herring	2				<0.10		<0.60	<1.2
Northern North Sea	Whiting	2				<0.05	<0.035	<0.22	<0.37
Mid North Sea	Cod	3			25	<0.06	0.028	<0.39	<0.21
Mid North Sea	Plaice	3			38	<0.07	<0.030	<0.57	<0.33
Mid North Sea	Dab	1				<0.05		<0.55	*
Mid North Sea	Whiting	1				<0.05		<0.53	*
Gt Yarmouth (retail shop)	Cod	4				<0.04		<0.36	<0.41
Gt Yarmouth (retail shop)	Plaice	4				<0.05		<0.48	<0.29
Southern North Sea	Bass	3				<0.08	<0.030	<0.83	<0.23
Southern North Sea	Cod	1				<0.06		<0.37	<0.75
Southern North Sea	Sole	4				<0.05	0.023	<0.39	<0.87
Southern North Sea	Herring	2				<0.07		<0.50	<1.1
English Channel-East	Cod	1				<0.05		<0.22	<0.30
English Channel-East	Plaice	4				<0.06		<0.78	<0.04
English Channel-East	Whiting	3				<0.08		<0.64	<0.70
English Channel-West	Mackerel	4				<0.07		<0.50	<0.35
English Channel-West	Plaice	4			38	<0.08		<0.78	<0.39
English Channel-West	Whiting	4				<0.05		<0.37	<0.29
Celtic Sea	Cod	3			19	<0.05	0.016	<0.34	<0.24
Celtic Sea	Megrim	1				<0.17		<0.63	<0.83
Celtic Sea	Pollack	1				<0.06		<0.58	*
Celtic Sea	Whiting	2				<0.05		<0.37	<0.18
Celtic Sea	Lemon sole	1				<0.04		<0.15	<0.18
Northern Irish Sea	Dab	1				<0.08		<0.85	*
Northern Irish Sea	Lesser spotted dogfish	1				<0.19		<1.9	*
Northern Irish Sea	Skates/rays	1				<0.13		<1.3	*

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man								
Isle of Man	Cod	4		<0.96	<0.20	<0.10	2.4	<0.38
Isle of Man	Herring	4		<1.0	<0.22	<0.10	0.85	<0.46
Wales								
North Anglesey	Skates/rays	4		<1.4	<0.28	<0.13	2.0	<0.65
North Anglesey	Plaice	2		<1.4	<0.30	<0.13	2.0	<0.62
North Anglesey	Bass	1		<0.37	<0.10	<0.04	5.5	<0.25
Northern Ireland								
North coast	Cod	1		<0.34	<0.10	<0.04	2.4	<0.23
North coast	Spurdog	4		<0.84	<0.20	<0.09	2.0	<0.46
Portavogie	Haddock	1		<0.71	<0.18	<0.07	1.8	<0.48
Portavogie	Spurdog	1		<0.99	<0.24	<1.0	2.6	<0.41
Ardglass	Herring	2		<0.99	<0.22	<0.09	1.3	<0.53
Kilkeel	Cod	3		<0.72	<0.17	<0.07	2.9	<0.41
Kilkeel	Plaice	1		<0.78	<0.17	<0.08	2.7	<0.30
Kilkeel	Whiting	1		<0.53	<0.12	<0.06	0.36	<0.26
Kilkeel	Spurdog	2		<0.96	<0.22	<0.09	1.2	<0.47
Kilkeel	Haddock	2		<1.5	<0.27	<0.14	0.84	<0.55
Glenarm	Farmed salmon	1	<0.75	<0.90	<0.19	<0.08	0.50	<0.46
Further afield								
Baltic Sea	Cod	2		<0.73	<0.17	<0.07	7.4	<0.37
Baltic Sea	Herring	4		<0.99	<0.23	<0.09	5.3	<0.47
Barents Sea	Cod	1		<0.78	<0.18	<0.07	0.25	<0.50
Barents Sea	Haddock	1		<1.8	<0.35	<0.18	<0.16	<0.59
Norwegian Sea	Cod	3		<0.62	<0.13	<0.06	0.28	<0.30
Norwegian Sea	Saithe	1		<0.61	<0.14	<0.06	0.20	<0.41
Norwegian processed	Cod	2		<0.51	<0.12	<0.05	0.35	<0.27
Iceland area	Cod	2		<0.55	<0.12	<0.06	0.14	<0.31
Skagerrak	Cod	4		<0.64	<0.14	<0.07	0.29	<0.32
Skagerrak	Herring	3		<0.76	<0.18	<0.08	0.37	<0.43
Northern North Sea	Cod	1		<0.68	<0.13	<0.07	0.13	<0.29
Northern North Sea	Plaice	4		<0.55	<0.12	<0.05	<0.15	<0.29
Northern North Sea	Haddock	4		<0.48	<0.11	<0.05	0.15	<0.25
Northern North Sea	Herring	2		<1.0	<0.22	<0.11	<0.11	<0.47
Northern North Sea	Whiting	2		<0.45	<0.10	<0.05	0.26	<0.20
Mid North Sea	Cod	3		<0.58	<0.13	<0.06	0.24	<0.26
Mid North Sea	Plaice	3		<0.78	<0.17	<0.08	0.19	<0.44
Mid North Sea	Dab	1		<0.58	<0.13	<0.06	0.21	<0.39
Mid North Sea	Whiting	1		<0.55	<0.12	<0.06	0.41	<0.29
Gt Yarmouth (retail shop)	Cod	4		<0.47	<0.11	<0.05	0.17	<0.31
Gt Yarmouth (retail shop)	Plaice	4		<0.57	<0.13	<0.06	0.19	<0.30
Southern North Sea	Bass	3		<0.91	<0.20	<0.09	0.72	<0.45
Southern North Sea	Cod	1		<0.62	<0.13	<0.06	0.35	<0.30
Southern North Sea	Sole	4		<0.57	<0.13	<0.06	0.24	<0.35
Southern North Sea	Herring	2		<0.76	<0.18	<0.08	0.27	<0.50
English Channel-East	Cod	1		<0.52	<0.13	<0.06	0.21	<0.32
English Channel-East	Plaice	4		<0.73	<0.15	<0.07	<0.08	<0.37
English Channel-East	Whiting	3		<0.91	<0.19	<0.09	0.24	<0.42
English Channel-West	Mackerel	4		<0.72	<0.17	<0.08	0.30	<0.47
English Channel-West	Plaice	4		<0.92	<0.19	<0.09	<0.13	<0.44
English Channel-West	Whiting	4		<0.46	<0.10	<0.05	0.20	<0.24
Celtic Sea	Cod	3		<0.53	<0.12	<0.06	0.80	<0.29
Celtic Sea	Megrim	1		<1.6	<0.36	<0.18	0.21	<0.59
Celtic Sea	Pollack	1		<0.65	<0.15	<0.06	0.46	<0.45
Celtic Sea	Whiting	2		<0.52	<0.13	<0.05	0.37	<0.35
Celtic Sea	Lemon sole	1		<0.39	<0.10	<0.04	0.13	<0.26
Northern Irish Sea	Dab	1		<0.88	<0.20	<0.09	1.0	<0.48
Northern Irish Sea	Lesser spotted dogfish	1		<2.3	<0.47	<0.22	2.3	<1.3
Northern Irish Sea	Skates/rays	1		<1.6	<0.34	<0.14	1.6	<0.88

** Not detected by the method used*

[a] The concentrations of ^{129}I and ^{147}Pm were <0.23 and <0.17 Bq kg^{-1} respectively

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2006

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria												
Silloth	Mussels	4		<26		0.76	<0.24		<0.48	<0.92		<2.3
Silloth	Shrimps	4				<0.09	<0.22		<0.33	<0.56		<0.79
Parton	Crabs	4				0.58	<0.29		<0.49	<0.82		<1.2
Parton	Lobsters	4				0.68	<0.36		<0.65	<1.3		<1.3
Parton	Winkles	4				3.3	<0.24		<0.33	<0.44		5.9
Whitehaven	*Nephrops*	4			120	<0.15	<0.45	0.10	<1.1	<1.7	200	<1.7
Whitehaven	Cockles	2				<0.05	<0.13		<0.32	<0.77		<0.50
Whitehaven	Mussels	2				<0.04	<0.12	<0.032	<0.31	<0.69		<0.52
Whitehaven	Whelks	1				0.50	<0.46		<0.85	<1.7		<1.3
Whitehaven outer harbour	Mussels	2				1.3	<0.22		<0.46	<0.97		<1.4
Saltom Bay	Winkles	4				3.4	<0.44		<0.74	<1.2		<7.3
St Bees	Winkles[a]	4			200	6.0	<0.20	7.3	<0.37	<0.75	91	15
St Bees	Mussels	4				2.5	<0.23		<0.37	<0.57		7.1
St Bees	Limpets	4				2.1	<0.25		<0.41	<0.67		8.3
Nethertown	Winkles	12	<25	<28	230	7.4	<0.34	4.6	<0.57	<1.0	110	19
Nethertown	Mussels	4	78	91	310	3.4	<0.21		<0.28	<0.36	120	12
Sellafield coastal area	Crabs[b]	8			240	2.0	<0.18	0.90	<0.32	<0.37	25	<1.1
Sellafield coastal area	Lobsters	8			350	1.6	<0.27	0.40	<0.47	<0.85	1000	<1.4
Sellafield coastal area[c]	Winkles	8			180	4.7	<0.38	3.1	<0.63	<1.1	47	<15
Sellafield coastal area[c]	Mussels	4				1.8	<0.16	0.65	<0.23	<0.28		4.6
Sellafield coastal area[c]	Limpets	4			99	0.81	<0.30	2.4	<0.40	<0.55	88	2.9
Whitriggs	Shrimps	1				0.17	<0.31		<0.52	<0.86		<1.2
Drigg	Winkles	4			220	6.0	<0.32		<0.47	<0.70	93	16
Ravenglass	Crabs	4				1.3	<0.19	0.45	<0.27	<0.38	18	<1.0
Ravenglass	Lobsters	6				0.90	<0.34	0.82	<0.72	<1.5	480	<1.3
Ravenglass	Winkles	2				4.5	<0.26		<0.46	<0.79		18
Ravenglass	Cockles	4			210	12	<0.30	1.5	<0.53	<0.86	14	8.1
Ravenglass	Mussels	4		48		3.3	<0.19		<0.30	<0.44	860	8.3
Tarn Bay	Winkles	4				3.3	<0.27		<0.45	<0.81		7.5
Haverigg	Cockles	4				4.0	<0.30		<0.37	<0.47		<3.2
Millom	Mussels	2				0.73	<0.18		<0.48	<0.13		1.7
Barrow	Crabs	4				0.37	<0.21		<0.47	<0.99		<0.77
Barrow	Lobsters	4				0.33	<0.20		<0.31	<0.54	400	<0.72
Roosebeck	Pacific oysters	2				<0.11	<0.27		<0.59	<0.17		<1.1
Morecambe Bay (Flookburgh)	Shrimps	4			89	<0.09	<0.23		<0.39	<0.62	1.8	<0.85
Morecambe Bay (Flookburgh)	Cockles	1			97	1.6	<0.12	0.37	<0.15	<0.16	5.8	<0.50
Lancashire and Merseyside												
Morecambe Bay (Morecambe)	Mussels	4	<110	140	99	0.41	<0.14		<0.20	<0.27	160	<1.4
Red Nab Point	Winkles	4				0.45	<0.19		<0.26	<0.35		<1.0
Morecambe Bay (Middleton Sands)	Cockles	2				1.3	<0.17		<0.24	<0.34		<0.65
Knott End	Cockles	2				1.8	<0.27		<0.55	<0.97		<1.8
Fleetwood	Squid	1				<0.14	<0.43		<1.1	<3.0		<1.6
Ribble Estuary	Shrimps	2			78	<0.05	<0.12		<0.15	<0.18	0.64	<0.49
Ribble Estuary	Mussels	2				<0.13	<0.11		<0.16	<0.19		<0.53
Liverpool Bay	Mussels	2		<25								
Mersey Estuary	Mussels	2		<25								
Dee Estuary	Cockles	4				0.21	<0.09		<0.12	<0.13	8.0	<0.42
Wirral	Shrimps	2		<25		<0.05	<0.12		<0.16	<0.19	0.57	<0.49

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	Total beta
Cumbria											
Silloth	Mussels	4	<0.18	1.1	<0.10	4.2	<0.58		<0.25	<0.26	
Silloth	Shrimps	4	<0.16	<0.20	<0.08	3.7	<0.37		<0.23	<0.14	
Parton	Crabs	4	<0.31	<0.37	<0.11	1.4	<0.64		<0.32	<0.28	
Parton	Lobsters	4	<0.49	<0.35	<0.12	2.6	<0.55		<0.34	<0.20	
Parton	Winkles	4	0.64	1.9	<0.10	8.1	<0.55		<0.26	<0.25	
Whitehaven	*Nephrops*	4	<0.32	<0.41	<0.16	3.9	<0.93		<0.44	<0.36	230
Whitehaven	Cockles	2	<0.10	<0.11	<0.05	0.10	<0.22		<0.13	<0.09	
Whitehaven	Mussels	2	<0.10	<0.12	<0.05	<0.04	<0.32		<0.11	<0.12	
Whitehaven	Whelks	1	<0.31	<0.28	<0.14	0.52	<0.54		<0.39	<0.21	
Whitehaven outer harbour	Mussels	2	<0.18	1.4	<0.09	1.5	<0.59		<0.21	<0.24	
Saltom Bay	Winkles	4	<1.2	2.7	<0.17	7.3	<0.90		<0.47	<0.37	
St Bees	Winkles[a]	4	1.6	2.2	<0.08	10	<0.43	1.7	<0.26	<0.17	
St Bees	Mussels	4	<0.19	2.3	<0.09	2.7	<0.42		<0.23	<0.17	
St Bees	Limpets	4	1.0	3.9	<0.11	6.8	<0.61		<0.28	<0.27	
Nethertown	Winkles	12	2.5	2.7	<0.14	10	<0.78	3.1	<0.35	<0.34	300
Nethertown	Mussels	4	<0.16	3.3	<0.08	2.9	<0.46		<0.22	<0.21	230
Sellafield coastal area	Crabs[b]	8	0.74	0.70	<0.07	1.9	<0.33	1.4	<0.18	<0.13	150
Sellafield coastal area	Lobsters	8	1.5	<0.47	<0.10	2.9	<0.53	0.59	<0.28	<0.22	810
Sellafield coastal area[c]	Winkles	8	<1.8	2.3	<0.15	7.3	<0.80	0.98	<0.39	<0.34	
Sellafield coastal area[c]	Mussels	4	<0.13	2.1	<0.07	3.2	<0.42		<0.19	<0.19	
Sellafield coastal area[c]	Limpets	4	<0.31	2.6	<0.13	4.5	<0.59		<0.35	<0.27	
Whitriggs	Shrimps	1	<0.24	<0.32	<0.12	2.9	<0.75		<0.30	<0.34	
Drigg	Winkles	4	2.0	2.5	<0.13	7.5	<0.69	1.5	<0.34	<0.31	290
Ravenglass	Crabs	4	0.49	0.53	<0.07	1.4	<0.31		<0.19	<0.12	130
Ravenglass	Lobsters	6	1.0	<0.30	<0.12	2.3	<0.56		<0.34	<0.20	450
Ravenglass	Winkles	2	1.7	1.9	<0.10	8.2	<0.72		<0.26	<0.30	
Ravenglass	Cockles	4	<0.25	1.2	<0.11	4.0	<0.54		<0.27	<0.20	130
Ravenglass	Mussels	4	<0.15	2.4	<0.07	1.6	<0.44		<0.20	<0.19	
Tarn Bay	Winkles	4	1.2	1.3	<0.11	4.1	<0.51		<0.29	<0.20	
Haverigg	Cockles	4	<0.22	0.80	<0.13	4.1	<0.49		<0.33	<0.22	
Millom	Mussels	2	<0.15	0.6	<0.07	1.3	<0.48		<0.17	<0.19	
Barrow	Crabs	4	<0.18	<0.26	<0.07	1.2	<0.46		<0.20	<0.19	
Barrow	Lobsters	4	<0.27	<0.20	<0.07	1.8	<0.35		<0.21	<0.14	270
Roosebeck	Pacific oysters	2	<0.39	<0.23	<0.10	1.0	<0.44		<0.27	<0.18	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.17	<0.22	<0.09	5.2	<0.44		<0.25	<0.19	
Morecambe Bay (Flookburgh)	Cockles	1	<0.09	0.42	<0.05	4.4	<0.32		<0.14	<0.15	
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Mussels	4	<0.10	0.50	<0.06	2.5	<0.32		<0.16	<0.15	
Red Nab Point	Winkles	4	<0.14	0.56	<0.07	3.8	<0.35		<0.21	<0.16	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.12	0.43	<0.07	3.3	<0.30		<0.18	<0.12	
Knott End	Cockles	2	<0.19	<0.59	<0.10	5.3	<0.48		<0.27	<0.19	
Fleetwood	Squid	1	<0.30	<0.34	<0.15	0.67	<0.88		<0.39	<0.36	
Ribble Estuary	Shrimps	2	<0.09	<0.14	<0.05	2.2	<0.31		<0.14	<0.14	
Ribble Estuary	Mussels	2	<0.09	0.25	<0.05	1.2	<0.27		<0.13	<0.13	
Dee Estuary	Cockles	4	<0.07	<0.27	<0.05	1.5	<0.24		<0.11	<0.11	
Wirral	Shrimps	2	<0.09	<0.13	<0.05	1.7	<0.31		<0.14	<0.14	

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland											
Lewis	Mussels	1			<0.27	<0.71		<1.1	<1.3		<2.7
Skye	Lobsters	1			<0.37	<1.1		<1.4	<1.8	44	<3.6
Skye	Mussels	1			<0.27	<0.71		<0.96	<1.2		<2.5
Islay	Crabs	1			<0.28	<0.70		<0.85	<0.93		<2.5
Islay	Scallops	1			<0.13	<0.48		<1.5	<2.5		<1.3
Kirkcudbright	Scallops	8[F,S]			<0.10	<0.18		<0.33	<0.67	0.93	<0.57
Kirkcudbright	Queens	7[F,S]			<0.10	<0.23		<0.46	<0.79	1.5	<0.70
Southerness	Winkles	4	<19		0.84	<0.67	0.22	<0.91	<1.2	110	<1.9
North Solway coast	Crabs	8[F,S]		120	<0.34	<0.43	0.33	<0.63	<0.87	6.3	<1.4
North Solway coast	Lobsters	8[F,S]		81	<0.23	<0.45	0.12	<1.2	<4.5	380	<1.5
North Solway coast	Winkles	8[F,S]			0.79	<0.33	0.38	<0.50	<0.72	140	<1.3
North Solway coast	Cockles	5[F,S]		92	1.9	<0.21	0.77	<0.35	<0.56	9.9	<0.97
North Solway coast	Mussels	8[F,S]	<5.3	100	<0.54	<0.17	1.1	<0.32	<0.47	150	<1.2
Inner Solway	Shrimps	2	<5.2		<0.18	<0.41	<0.10	<0.39	<0.31	1.9	<1.5
Isle of Man											
Isle of Man	Lobsters	4			<0.06	<0.19		<0.41	<0.89	100	<0.63
Isle of Man	Scallops	4			<0.05	<0.18		<0.48	<0.26		<0.54
Wales											
Conwy	Mussels	2		69	<0.06	<0.14		<0.19	<0.23		<0.55
North Anglesey	Crabs	2			<0.10	<0.25		<0.41	<0.59	4.0	<0.98
North Anglesey	Lobsters	2			<0.05	<0.17		<0.27	<0.44	110	<0.57
Northern Ireland											
Ballycastle	Lobsters	2			<0.15	<0.45		<1.1	<0.71	110	<1.8
County Down	Scallops	2			<0.05	<0.14		<0.21	<0.35		<0.47
Ards Peninsula	Winkles	4			<0.13	<0.34		<0.67	<0.39		<1.3
Kilkeel	Crabs	3			<0.14	<0.41		<1.1	<2.7		<1.7
Kilkeel	Lobsters	2			<0.06	<0.17		<0.35	<0.73	100	<0.63
Kilkeel	*Nephrops*	4			<0.09	<0.28		<0.57	<1.1	34	<1.1
Carlingford Lough	Mussels	2			<0.09	<0.29		<1.0	<0.57	20	<1.2
Further afield											
Northern North Sea	*Nephrops*	4			<0.11	<0.33		<0.74	<0.79	3.7	<1.2
Cromer	Crabs	1			<0.06	<0.16		<0.20	<0.22		<0.59
Southern North Sea	Cockles	2			<0.06	<0.21		<0.35	<0.09		<0.47
Southern North Sea	Mussels	4			<0.09	<0.26		<0.63	<0.57	0.99	<0.98
Southern North Sea	Cockles[d]	2			<0.08	<0.13		<0.38	<0.63	0.20	<0.91
Southern North Sea	Mussels[d]	2			<0.05	<0.13		<0.28	<0.59		<0.56
English Channel-East	Scallops	4		25	<0.07	<0.20		<0.45	<0.15		<0.61
English Channel-West	Crabs	4		42	<0.12	<0.39		<1.2	<0.84		<1.5
English Channel-West	Lobsters	4			<0.07	<0.25		<0.78	<0.43	0.28	<0.91
English Channel-West	Scallops	4		20	<0.05	<0.17		<0.40	<0.23		<0.51

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	Total beta
Scotland										
Lewis	Mussels	1	<0.30	<0.68	<0.27	<0.20	<1.6	<0.35	<0.65	
Skye	Lobsters	1	<0.40	<0.93	<0.38	<0.35	<2.4	<0.50	<0.94	
Skye	Mussels	1	<0.29	<0.67	<0.25	<0.26	<1.6	<0.33	<0.63	
Islay	Crabs	1	<0.27	<0.65	<0.25	<0.25	<1.5	<0.32	<0.57	
Islay	Scallops	1	<0.17	<0.30	<0.12	0.22	<0.79	<0.14	<0.26	
Kirkcudbright	Scallops	8[F,S]	<0.10	<0.15	<0.08	<0.37	<0.39	<0.13	<0.16	
Kirkcudbright	Queens	7[F,S]	<0.12	<0.19	<0.09	<0.31	<0.44	<0.14	<0.19	
Southerness	Winkles	4	<0.30	<0.81	<0.22	1.0	<1.3	<0.27	<0.52	
North Solway coast	Crabs	8[F,S]	<0.25	<0.38	<0.16	1.2	<0.81	<0.29	<0.33	
North Solway coast	Lobsters	8[F,S]	<0.24	<0.36	<0.16	<1.5	<0.90	<0.27	<0.34	
North Solway coast	Winkles	8[F,S]	<0.26	<0.69	<0.13	1.3	<0.68	<0.22	<0.29	
North Solway coast	Cockles	5[F,S]	<0.14	0.59	<0.08	5.0	<0.44	<0.17	<0.19	
North Solway coast	Mussels	8[F,S]	<0.20	<0.67	<0.10	<2.8	<0.46	<0.16	<0.21	
Inner Solway	Shrimps	2	<0.23	<0.42	<0.16	4.5	<0.85	<0.21	<0.39	
Isle of Man										
Isle of Man	Lobsters	4	<0.13	<0.15	<0.06	0.44	<0.34	<0.19	<0.14	170
Isle of Man	Scallops	4	<0.12	<0.12	<0.05	0.36	<0.32	<0.15	<0.13	
Wales										
Conwy	Mussels	2	<0.11	<0.14	<0.06	0.26	<0.25	<0.17	<0.11	
North Anglesey	Crabs	2	<0.18	<0.22	<0.09	0.55	<0.41	<0.26	<0.15	
North Anglesey	Lobsters	2	<0.12	<0.14	<0.06	0.59	<0.39	<0.18	<0.24	140
Northern Ireland										
Ballycastle	Lobsters	2	<0.32	<0.35	<0.16	0.36	<0.76	<0.43	<0.27	
County Down	Scallops	2	<0.10	<0.11	<0.05	0.36	<0.25	<0.16	<0.11	
Ards Peninsula	Winkles	4	<0.24	<0.31	<0.13	<0.34	<0.66	<0.34	<0.25	
Kilkeel	Crabs	3	<0.31	<0.33	<0.15	0.33	<0.77	<0.39	<0.28	
Kilkeel	Lobsters	2	<0.13	<0.14	<0.06	0.38	<0.34	<0.16	<0.13	
Kilkeel	*Nephrops*	4	<0.21	<0.25	<0.10	0.67	<0.62	<0.29	<0.26	
Carlingford Lough	Mussels	2	<0.21	<0.24	<0.11	0.62	<0.56	<0.26	<0.20	
Further afield										
Northern North Sea	*Nephrops*	4	<0.23	<0.25	<0.11	<0.15	<0.59	<0.31	<0.23	
Cromer	Crabs	1	<0.12	<0.14	<0.06	0.07	<0.27	<0.17	<0.11	
Southern North Sea	Cockles	2	<0.10	<0.12	<0.05	0.10	<0.33	<0.12	<0.13	
Southern North Sea	Mussels	4	<0.18	<0.19	<0.09	<0.09	<0.38	<0.24	<0.13	
Southern North Sea	Cockles[d]	2	<0.16	<0.21	<0.09	0.16	<0.49	<0.22	<0.21	
Southern North Sea	Mussels[d]	2	<0.11	<0.14	<0.06	<0.05	<0.38	<0.13	<0.17	17
English Channel-East	Scallops	4	<0.14	<0.13	<0.06	<0.06	<0.34	<0.19	<0.13	
English Channel-West	Crabs	4	<0.28	<0.30	<0.13	<0.11	<0.65	<0.35	<0.23	
English Channel-West	Lobsters	4	<0.18	<0.20	<0.08	<0.07	<0.56	<0.21	<0.20	
English Channel-West	Scallops	4	<0.11	<0.12	<0.05	<0.05	<0.30	<0.17	<0.12	

[a] *The concentration of ^{129}I was <0.65 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <0.34 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, 2006

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		0.92	5.0		8.8	*	0.013
Silloth	Shrimps	1		0.0015	0.010	1.6	0.021	*	*
Maryport	Plaice	4					<0.19		
Parton	Cod	4					<0.33		
Parton	Crabs	4					1.5		
Parton	Lobsters	4					1.7		
Parton	Winkles	1		1.5	8.1	69	16	0.019	0.018
Whitehaven	Cod	1		0.00033	0.0017		0.0030	0.000054	*
Whitehaven	Plaice			0.00060	0.0036		0.0083	0.000038	*
Whitehaven	Skates/rays	1		0.00084	0.0050		0.0095	*	*
Whitehaven	Sole	1		0.0024	0.013		0.021	*	0.000038
Whitehaven	Dab	1					<0.47		
Whitehaven	*Nephrops*	1		0.032	0.19		0.84	*	0.0014
Whitehaven	Cockles	1		0.0017	0.0082		0.010	0.000038	0.00053
Whitehaven	Mussels	1		0.00074	0.0043	<0.45	0.0056	0.000031	0.00015
Whitehaven	Whelks	1					0.40		
Whitehaven outer harbour	Mussels	2					5.6		
Saltom Bay	Winkles	4					16		
St Bees	Winkles	1	0.075	2.7	13	120	25	0.070	0.057
St Bees	Mussels	2		1.4	6.6	64	14	*	0.024
St Bees	Limpets	1		1.7	9.4		19	0.022	0.023
Nethertown	Winkles	4	0.050	3.1	16	140	31	<0.015	<0.037
Nethertown	Mussels	4		1.5	6.9		14	<0.015	0.030
River Ehen	Salmon	1					<0.08		
Sellafield coastal area	Cod	2		0.0013	0.0061		0.011	*	0.000020
Sellafield coastal area	Plaice	1		0.0042	0.022		0.039	*	0.000077
Sellafield coastal area	Bass	1					<0.63		
Sellafield coastal area	Grey mullet	1					<0.38		
Sellafield coastal area	Crabs	2	0.0049	0.11	0.49	5.4	1.9	<0.0013	0.0046
Sellafield coastal area	Lobsters	2	0.016	0.079	0.34	4.4	4.4	<0.0061	0.0054
Sellafield coastal area[a]	Winkles	2	0.013	1.9	9.9	89	20	*	0.024
Sellafield coastal area[a]	Mussels	1		0.86	4.6	42	9.2	*	0.030
Sellafield coastal area[a]	Limpets	1		0.91	4.5	40	7.3	*	*
Sellafield offshore area	Cod	2					<0.10		
Sellafield offshore area	Plaice	1	0.00019	0.0057	0.030		0.054	0.000070	0.000070
Sellafield offshore area	Dab	2					<0.26		
Sellafield offshore area	Flounder	1		0.0074	0.038		0.063	*	0.00010
Sellafield offshore area	Lesser spotted dogfish	1					<0.19		
Sellafield offshore area	Pollack	1					<0.69		
Sellafield offshore area	Skates/rays	1					<0.13		
River Calder	Salmon	1					<0.27		
Whitriggs	Shrimps	1					<0.51		
River Esk	Sea trout	1					<0.30		
River Esk	Salmon	1					<0.09		
Drigg	Winkles	1	0.10	2.8	14	130	0.13	*	0.059
Ravenglass	Cod	1		0.0013	0.0048		0.0079	*	*
Ravenglass	Plaice	1		0.0040	0.021		0.041	0.000054	0.000040
Ravenglass	Grey mullet	1					<0.12		
Ravenglass	Crabs	1		0.071	0.36	3.1	1.5	*	0.0030
Ravenglass	Lobsters	1		0.064	0.32	3.3	7.6	*	0.013
Ravenglass	Winkles	2					24		
Ravenglass	Cockles	1		1.6	8.2	78	24	*	0.046
Ravenglass	Mussels	1		1.2	5.7	55	12	0.023	0.024
Tarn Bay	Winkles	1		1.2	5.7	49	12	*	0.017
Haverigg	Cockles	1		1.4	7.5		22	*	0.034
Millom	Mussels	2					3.5		
Barrow	Crabs	1		0.018	0.097		0.53	*	0.00082
Barrow	Lobsters	4					0.91		
Roosebeck	Pacific oysters	1		0.19	0.93		0.48	0.0053	0.0012
Morecambe Bay (Flookburgh)	Flounder	1		0.00032	0.0016		0.0027	*	*
Morecambe Bay (Flookburgh)	Plaice	1					<0.11		
Morecambe Bay (Flookburgh)	Shrimps	1		0.0041	0.025	0.11	0.042	*	0.000025
Morecambe Bay (Flookburgh)	Cockles	1		0.43	2.4	18	6.3	*	0.0077

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)	Plaice	4					<0.36		
Morecambe Bay (Morecambe)	Bass	2					<0.28		
Morecambe Bay (Morecambe)	Mussels	1		0.26	1.4		2.5	*	0.0026
Red Nab Point	Winkles	1		0.19	1.1		2.3	*	0.0034
Morecambe Bay (Middleton Sands)	Cockles	1		0.39	2.3		5.8	*	0.0072
Morecambe Bay (Sunderland Point)	Whitebait	1		0.039	0.25	1.9	0.45	*	0.00046
River Duddon	Sea trout	1					<0.23		
River Kent	Sea trout	1					<0.12		
Fleetwood	Cod	1		0.00032	0.0015		0.0028	0.000025	0.000018
Fleetwood	Plaice	1		0.00030	0.0015		0.0021	*	0.000017
Knott End	Cockles	1		0.79	4.6		11	*	0.014
Fleetwood	Squid	1					<0.49		
Ribble Estuary	Flounder	1					<0.19		
Ribble Estuary	Grey mullet	1					<0.10		
Ribble Estuary	Salmon	1					<0.10		
Ribble Estuary	Sea trout	1					<0.13		
Ribble Estuary	Bass	1					<0.12		
Ribble Estuary	Shrimps	1	0.00026	0.0017	0.011		0.022	*	*
Ribble Estuary	Mussels	2					1.4		
Dee Estuary	Cockles	1		0.16	0.94		2.7	*	0.0018
Wirral	Shrimps	2					<0.19		
Scotland									
Shetland	Fish meal	1		0.000031	0.00046		0.00052	*	*
Shetland	Fish oil	4					<0.16		
Minch	Herring	2					<0.09		
Minch	Mackerel	1		0.000014	0.000049		0.00053	*	*
West of Scotland	Mackerel	2					<0.11		
West of Scotland	Farmed salmon	1					<0.12		
Lewis	Mussels	1					<0.37		
Skye	Lobsters	1					<0.47		
Skye	Mussels	1					<0.37		
Islay	Crabs	1					<0.33		
Islay	Scallops	1					<0.15		
Kirkcudbright	Plaice	1		0.047	0.0081		0.0036		
Kirkcudbright	Scallops	2		0.011	0.059		0.027	*	*
Kirkcudbright	Queens	2		0.0076	0.035		0.036	*	*
Southerness	Winkles	1		0.20	1.2		2.5		
North Solway	Sole	1					<0.58		
North Solway	Whiting	1		0.033	0.18		0.31	0.00045	0.00033
North Solway coast	Crabs	2^{F,S}		0.10	0.57	0.90	1.3	*	0.0021
North Solway coast	Lobsters	2^{F,S}		0.020	0.10	0.84	0.58	0.0020	0.0016
North Solway coast	Winkles	2^{F,S}		0.25	1.3	11	2.5	*	0.0034
North Solway coast	Cockles	5^{F,S}		1.0	5.5	42	15	*	0.021
North Solway coast	Mussels	2^{F,S}		0.82	2.6	33	9.9	*	0.019
Inner Solway	Flounder	1		0.0028	0.017		0.040		
Inner Solway	Salmon	1					<0.14		
Inner Solway	Sea trout	1					0.19		
Inner Solway	Shrimps	1		0.0021	0.011		0.026		
Isle of Man									
Isle of Man	Cod	1		0.000068	0.00036		0.00070	0.0000086	*
Isle of Man	Herring	1		0.0013	0.0086		0.013	*	*
Isle of Man	Lobsters	4					<0.13		
Isle of Man	Scallops	1		0.020	0.11		0.033	*	*
Wales									
Conwy	Mussels	1		0.023	0.13		0.24	*	0.00022
North Anglesey	Skates/rays	1		0.000096	0.00056		0.00094	*	*
North Anglesey	Plaice	1					<0.18		
North Anglesey	Bass	1					<0.10		
North Anglesey	Crabs	1		0.0061	0.033		0.11	0.00010	0.00011
North Anglesey	Lobsters	2					<0.34		

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
Northern Ireland							
North coast	Cod	1			<0.10		
North coast	Spurdog	4			<0.14		
Ballycastle	Lobsters	1			0.27		
County Down	Scallops	2			<0.13		
Ards Peninsula	Winkles	1	0.027	0.15	0.14	0.00032	*
Portavogie	Haddock	1			<0.33		
Portavogie	Spurdog	1			<0.10		
Ardglass	Herring	2			<0.15		
Kilkeel	Cod	3			<0.16		
Kilkeel	Plaice	1			<0.07		
Kilkeel	Whiting	1			<0.06		
Kilkeel	Spurdog	2			<0.09		
Kilkeel	Haddock	2			<0.10		
Kilkeel	Crabs	3			<0.28		
Kilkeel	Lobsters	2			<0.12		
Kilkeel	*Nephrops*	1	0.0017	0.0087	0.018	*	*
Carlingford Lough	Mussels	2			<0.22		
Glenarm	Farmed salmon	1			<0.08		
Further afield							
Baltic Sea	Cod	2			<0.07		
Baltic Sea	Herring	4			<0.09		
Barents Sea	Cod	1			<0.19		
Barents Sea	Haddock	2			<0.12		
Norwegian Sea	Cod	3			<0.06		
Norwegian Sea	Saithe	1			<0.15		
Norwegian processed	Cod	1	0.0000065	0.000038	0.000073	*	*
Iceland area	Cod	2			<0.14		
Skagerrak	Cod	4			<0.12		
Skagerrak	Herring	3			<0.20		
Northern North Sea	Cod	1			<0.06		
Northern North Sea	Plaice	4			<0.06		
Northern North Sea	Haddock	1	0.000040	0.00021	0.00020	*	*
Northern North Sea	Herring	2			<0.10		
Northern North Sea	Whiting	1	0.000025	0.00020	0.00020	*	*
Northern North Sea	*Nephrops*	1	0.000081	0.00092	0.0017	*	*
Mid North Sea	Cod	3			<0.06		
Mid North Sea	Plaice	3			<0.14		
Mid North Sea	Dab	1			<0.21		
Mid North Sea	Whiting	1			<0.06		
Cromer	Crabs	1			<0.06		
Gt Yarmouth (retail shop)	Cod	4			<0.18		
Gt Yarmouth (retail shop)	Plaice	4			<0.10		
Southern North Sea	Bass	3			<0.11		
Southern North Sea	Cod	1			<0.06		
Southern North Sea	Sole	4			<0.12		
Southern North Sea	Herring	2			<0.27		
Southern North Sea	Cockles	1	0.0016	0.011	0.0062	*	*
Southern North Sea	Mussels	1	0.0018	0.012	0.0049	0.000021	*
Southern North Sea	Cockles[b]	1	0.0016	0.010	0.010	0.000026	0.00043
Southern North Sea	Mussels[c]	1	0.00011	0.0016	0.00073	*	0.000019
English Channel-East	Cod	1			<0.23		
English Channel-East	Plaice	4			<0.10		
English Channel-East	Whiting	3			<0.10		
English Channel-East	Scallops	1	0.00048	0.0019	0.00062	*	0.000043
English Channel-West	Mackerel	4			<0.27		
English Channel-West	Plaice	4			<0.10		
English Channel-West	Whiting	4			<0.06		
English Channel-West	Crabs	1	0.000039	0.00052	0.00062	*	0.000011
English Channel-West	Lobsters	4			<0.18		
English Channel-West	Scallops	1	0.00038	0.0059	0.0020	0.0000084	0.000011
Celtic Sea	Cod	3			<0.08		
Celtic Sea	Megrim	1			<0.13		
Celtic Sea	Pollack	1			<0.16		
Celtic Sea	Whiting	2			<0.16		
Celtic Sea	Lemon sole	1			<0.11		
Northern Irish Sea	Dab	1			<0.09		
Northern Irish Sea	Lesser spotted dogfish	1		<0.69			
Northern Irish Sea	Skates/rays	1			<0.26		

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

Table 2.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2006

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	3	<2.2		<2.0	<1.7	<5.9		<6.5	<0.65	240	<3.5
Maryport Outer Harbour	Sediment	2	<1.9	<4.5	<1.4	<1.5	<2.8		<3.8	<0.31	75	<1.8
Workington Harbour	Sediment	2	<6.1		<1.2	<2.0	<8.9		<8.0	<0.45	180	<2.7
Harrington Harbour	Sediment	2	4.8		<1.7	<1.9	<3.7		<6.3	<0.42	140	<2.5
Whitehaven Outer Harbour	Sediment	4	<1.4	<1.8	<1.8	<1.5	<4.5		<8.8	<0.59	91	<2.7
St Bees	Sand	4[F]	3.5		<4.6	<1.8	<6.4	<1.1	<1.9	<0.63	71	<5.0
St Bees beach	Sediment	4	<3.4		<1.1	<0.81	<3.3		<3.0	<0.38	88	<1.8
Sellafield	Sand	4[F]	3.4		<3.0	<5.1	<6.1	<1.1	<1.9	<0.62	59	<4.2
Ehen Spit	Sediment	2	<2.1		<1.2	<1.3	<2.3		<1.8	<0.29	35	<1.6
River Calder - downstream	Sediment	2	<0.63		<1.3	<1.5	<2.9		<1.8	<0.33	110	<1.9
River Calder - upstream	Sediment	2	<0.53		<1.4	<1.1	<3.1		<3.1	<0.43	44	<1.9
Seascale beach	Sediment	4	<2.1		<1.2	<0.96	<2.7		<2.1	<0.36	45	<1.7
Ravenglass - Carleton Marsh	Mud	4[F]	24		<6.8	<6.5	<66	<2.2	18	<1.3	460	<8.8
Ravenglass - Carleton Marsh	Sediment	4	25		<2.3	<1.7	<64		18	<0.88	430	<6.3
River Mite Estuary	Sediment	4	21	330	<3.5	<2.5	<35		<18	<1.1	1300	<5.2
Ravenglass - Raven Villa	Mud and sand	4[F]	16		<5.4	<6.0	34	<1.7	15	<1.1	310	<8.5
Ravenglass - Raven Villa	Sediment	4	16		<1.6	<1.3	<31		14	<0.54	320	<3.6
Newbiggin (Eskmeals)	Sediment	4	24	180	<2.5	<3.4	35		18	<0.77	940	<4.0
Haverigg	Sediment	2	<2.1		<0.95	<0.88	<2.0		<2.9	<0.22	27	<1.3
Millom	Sediment	2	7.5		<1.9	<2.1	<13		<9.5	<0.52	120	<2.6
Low Shaw	Sediment	2	<1.1		<1.5	<1.4	<3.2		<1.6	<0.37	94	<2.0
Walney Channel - N of discharge point	Sediment	2	<1.9		<1.3	<1.1	<5.7		<3.3	<0.34	56	<1.6
Walney Channel - S of discharge point	Sediment	2	<4.1		<2.0	<1.8	<9.5		<6.7	<0.53	120	<2.6
Sand Gate Marsh	Turf	4[F]	<1.0		<4.9	<2.4	<9.7	<1.6	<3.2	<1.1	150	<5.9
Sand Gate Marsh	Sediment	4	<0.97		<1.3	<1.1	<4.3		<3.8	<0.43	150	<2.4
Flookburgh	Sediment	1	<0.51		<1.9	<1.2	<3.7		<4.0	<0.44	110	<1.9
Lancashire												
Morecambe	Sediment	2	2.2								150	
Half Moon Bay	Sediment	2	<1.3								24	
Heysham pipelines	Sediment	2	<0.84								24	
Potts Corner	Sediment	2	<0.61								30	
Sunderland Point	Sediment	4	<1.1		<1.4	<1.5	<3.4		<3.6	<0.45	66	<2.4
Conder Green	Turf	4[F]	3.6		<5.7	<13	<11	<1.8	7.0	<1.1	270	<6.6
Conder Green	Sediment	4	1.5		<2.2	<1.2	<4.5		<3.8	<2.3	120	<2.3
Hambleton	Sediment	4	3.4		<4.1	<1.6	<9.7		<9.0	<4.7	380	<4.8
Skippool Creek	Sediment	4	3.3		<4.5	<1.9	<10		<8.8	<4.9	350	<5.0
Fleetwood	Sediment	4	<0.52		<2.2	<2.5	<3.4		<2.9	<0.44	23	<1.9
Blackpool	Sediment	4	<0.30		<1.1	<1.7	<2.5		<1.4	<0.25	4.1	<1.2
Crossens Marsh	Sediment	4	<1.6		<4.5	<1.9	<9.0		<7.5	<4.9	130	<4.4
Ainsdale	Sediment	4	<0.52		<2.2	<1.1	<4.5		<3.1	<3.5	6.4	<1.8
Rock Ferry	Sediment	4	<0.81		<1.8	<1.0	<4.1		<4.1	<0.52	92	<2.3
New Brighton	Sediment	4	<0.33		<1.1	<0.89	<2.1		<1.8	<0.28	4.4	<1.3
Scotland												
Campbeltown	Sediment	1	<0.10		<0.25	<0.15	<0.64	<0.10	<0.20	<0.10	9.9	<0.52
Garlieston	Sediment	1	0.40		<0.18	<0.15	<0.71	<0.11	1.2	<0.10	28	<0.68
Innerwell	Mud	2[F]	2.7		<4.4	<6.5	<10	<1.9	<3.2	<1.3	96	<6.8
Innerwell	Sediment	1	2.7		<0.39	<0.85	3.4	<0.17	4.1	<0.14	110	<1.2
Carsluith	Sediment	1	<0.10		<0.15	<0.16	<0.47	<0.10	<0.16	<0.10	11	<0.44
Skyreburn	Sediment	1	1.6		<0.23	<0.20	<0.93	<0.13	2.5	<0.10	77	<0.90
Cutter's Pool	Sediment	1	1.2		<0.29	<0.11	1.4	<0.13	1.3	<0.12	49	<0.87
Rascarrel Bay	Sediment	1	0.40		<0.61	<0.93	<1.3	<0.20	0.83	<0.15	35	<1.3
Palnackie Harbour	Sediment	1	2.2		<1.1	<0.45	1.5	<0.10	2.1	<0.10	100	<0.72
Gardenburn	Sediment	1	0.55		<0.20	<0.22	<0.67	<0.10	0.62	<0.10	29	<0.61
Kippford Slipway	Sediment	1	2.6		<1.2	<0.79	2.8	<0.17	2.7	<0.13	120	<1.2
Kippford Merse	Sediment	1	2.9		<1.2	<0.99	3.2	<0.20	2.9	<0.16	260	<1.6
Southerness	Sediment	1	0.24		<0.18	<0.15	<0.65	<0.10	0.81	<0.10	14	<0.64
Kirkconnel Merse	Sediment	1	0.51		<0.27	<0.64	<0.93	<0.11	0.75	<0.10	210	<0.82

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	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Cumbria												
Newton Arlosh	Sediment	3	<3.6	<1.7				190			530	810
Maryport Outer Harbour	Sediment	2	<1.3	<0.87	11	60	440	97			330	470
Workington Harbour	Sediment	2	<1.1	<1.6				220			730	970
Harrington Harbour	Sediment	2	<2.2	<1.2				290			870	680
Whitehaven Outer Harbour	Sediment	4	<3.2	<1.7	8.6	47	300	63			490	730
St Bees	Sand	4[F]	<1.5	<2.1				170				
St Bees beach	Sediment	4	<2.3	<1.1				170			490	360
Sellafield	Sand	4[F]	<1.6	<1.9				160				
Ehen Spit	Sediment	2	<0.77	<2.1				180			310	350
River Calder - downstream	Sediment	2	<0.94	<0.97				<15			500	1000
River Calder - upstream	Sediment	2	<2.3	<1.2							300	880
Seascale beach	Sediment	4	<1.9	<0.96				120			250	390
Ravenglass - Carleton Marsh	Mud	4[F]	10	<3.8				1100				
Ravenglass - Carleton Marsh	Sediment	4	7.8	<5.9				1200			1900	1200
River Mite Estuary	Sediment	4	14	<6.5	470	2500	22000	3500			5200	3300
Ravenglass - Raven Villa	Mud and sand	4[F]	<4.9	<3.8				740				
Ravenglass - Raven Villa	Sediment	4	<5.1	<4.6				810			1700	960
Newbiggin (Eskmeals)	Sediment	4	12	<3.9	180	950	7300	1600			2900	1600
Haverigg	Sediment	2	<0.89	<0.64				71			290	310
Millom	Sediment	2	<2.9	<1.5				260			830	630
Low Shaw	Sediment	2	<1.2	<1.1				120			390	500
Walney Channel - N of discharge point	Sediment	2	<1.1	<0.75				100			310	430
Walney Channel - S of discharge point	Sediment	2	<1.7	<1.3				200			460	890
Sand Gate Marsh	Turf	4[F]	<2.5	<2.7				92				
Sand Gate Marsh	Sediment	4	<2.0	<1.4				98			430	520
Flookburgh	Sediment	1	<2.3	<1.1				45			180	460
Lancashire												
Morecambe	Sediment	2						140				
Half Moon Bay	Sediment	2						21				
Half Moon Bay	Mud and sand	1[F]			12	67		120	*	0.14		
Heysham pipelines	Sediment	2						24				
Potts Corner	Sediment	2						17				
Sunderland Point	Sediment	4	<2.0	<1.3				55			330	580
Conder Green	Turf	4[F]	<2.8	<2.8				190				
Conder Green	Sediment	4	<2.8	<1.2				95			450	600
Hambleton	Sediment	4	<5.9	<2.6				310			790	1100
Skippool Creek	Sediment	4	<5.8	<2.7				280			740	990
Fleetwood	Sediment	4	<2.6	<1.1				20			160	400
Blackpool	Sediment	4	<1.3	<0.61				3.1			100	230
Crossens Marsh	Sediment	4	<6.5	<2.4				110			380	650
Ainsdale	Sediment	4	<3.1	<1.0				3.6			110	180
Rock Ferry	Sediment	4	<2.8	<1.3				53			260	700
New Brighton	Sediment	4	<1.8	<0.71				2.8			110	280
Scotland												
Campbeltown	Sediment	1	<0.13	<0.23				0.76				
Garlieston	Sediment	1	<0.17	<0.33	4.5	23		38				
Innerwell	Mud	2[F]	<2.7	<3.1				150				
Innerwell	Sediment	1	1.0	1.2				170				
Carsluith	Sediment	1	<0.11	<0.21	2.7	13		15			250	790
Skyreburn	Sediment	1	0.56	1.1				80				
Cutter's Pool	Sediment	1	0.21	<0.30				66				
Rascarrel Bay	Sediment	1	<0.27	0.69				21				
Palnackie Harbour	Sediment	1	<0.19	<0.34	14	87		130				
Gardenburn	Sediment	1	<0.15	<0.29	17	93		180				
Kippford Slipway	Sediment	1	0.56	1.1	14	69		130				
Kippford Merse	Sediment	1	1.3	<0.94	29	150		270				
Southerness	Sediment	1	<0.16	<0.27	2.0	11		19				
Kirkconnel Merse	Sediment	1	0.50	<0.38	19	120		210			89	160

Table 2.8. continued

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
Isle of Man												
Ramsey	Sediment	1	<0.51		<1.2	<0.35	<2.9		<2.6	<0.43	9.4	<1.7
Wales												
Rhyl	Sediment	2	<0.51		<2.2	<1.7	<3.6		4.8	<0.45	78	<2.6
Llandudno	Sediment	2	<0.31		<1.4	<0.90	<2.0		<1.8	<0.36	3.1	<1.3
Caerhun	Sediment	2	<0.75		<3.5	<3.3	<5.8		<6.3	<0.81	160	<3.4
Llanfairfechan	Sediment	2	<0.44		<1.9	<1.3	<3.1		<3.2	<0.44	49	<1.9
Northern Ireland												
Carrichue	Sand	1^{N}	<0.40		<9.4	*	<5.4	<1.1	<1.1	<0.55	1.8	<3.5
Carrichue	Shell and sand	1^{N}	<0.33		<1.4	<1.7	<3.6	<0.68	<0.86	<0.43	3.0	<2.1
Portrush	Sand	2^{N}	<0.39		<5.7	<1.7	<5.3	<1.1	<1.1	<0.50	<0.60	<3.3
Oldmill Bay	Mud	2^{N}	<0.91		<5.5	<11	<9.1	<1.9	<2.5	<1.1	48	<4.7
Ballymacormick	Mud	2^{N}	<0.52		<3.2	<5.8	<5.6	<1.1	<1.6	<0.67	22	<3.5
Strangford Lough - Nicky's Point	Mud	2^{N}	<0.61		<8.0	<2.4	<8.1	<1.6	<2.0	<0.92	29	<5.5
Dundrum Bay	Mud	2^{N}	<0.67		<15	<2.5	<8.2	<1.9	<1.8	<0.92	6.8	<5.3
Carlingford Lough	Mud	2^{N}	<0.86		<9.8	<2.9	<10	<2.3	<3.5	<1.3	91	<5.6

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	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Isle of Man												
Ramsey	Sediment	1	<3.6	<1.1							180	540
Wales												
Rhyl	Sediment	2	<2.1	<1.3				43			450	880
Llandudno	Sediment	2	<1.4	<0.79							<100	230
Caerhun	Sediment	2	<3.3	<2.0				61			270	570
Llanfairfechan	Sediment	2	<1.9	<1.1				26			250	510
Northern Ireland												
Carrichue	Sand	1^{N}	<1.2	<1.1	0.024	0.20		0.22	*	*		
Carrichue	Shell and sand	1^{N}	<1.0	<0.96				<0.62				
Portrush	Sand	2^{N}	<1.2	<1.4				<2.0				
Oldmill Bay	Mud	2^{N}	<2.7	<2.0				26				
Ballymacormick	Mud	2^{N}	<1.7	<1.4				16				
Strangford Lough - Nicky's Point	Mud	2^{N}	<2.0	<2.2				9.6				
Dundrum Bay	Mud	2^{N}	<2.1	<2.0				<2.8				
Carlingford Lough	Mud	2^{N}	<2.9	<2.0	2.1	14		9.3	*	0.0063		

** 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 Environment and Heritage Service
All other measuremetns are made on behalf of the Environment Agency

Table 2.9. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2006

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Salt marsh	2	0.084
Burgh Marsh	Salt marsh	2	0.080
Port Carlisle 1	Mud	2	0.084
Port Carlisle 1	Grass and mud	1	0.084
Port Carlisle 1	Sand	1	0.085
Port Carlisle 2	Salt marsh	2	0.092
Port Carlisle 2	Grass and salt marsh	1	0.093
Port Carlisle 2	Grass	1	0.11
Greenend 1	Mud	3	0.089
Greenend 1	Sand	1	0.093
Greenend 2	Mud	1	0.088
Greenend 2	Salt marsh	2	0.084
Greenend 2	Sand	1	0.090
Greenend 3	Salt marsh and mud	1	0.093
Greenend 3	Salt marsh	2	0.083
Greenend 3	Sand	1	0.095
Cardurnock Marsh	Salt marsh	4	0.081
Newton Arlosh	Salt marsh and mud	1	0.086
Newton Arlosh	Salt marsh	2	0.099
Silloth harbour	Mud and sand	1	0.098
Silloth harbour	Mud and pebbles	1	0.080
Silloth harbour	Mud and stones	1	0.093
Silloth harbour	Pebbles and sand	1	0.10
Silloth silt pond	Grass	1	0.080
Silloth silt pond	Grass and sand	2	0.075
Silloth silt pond	Sand	1	0.078
Allonby	Sand	3	0.084
Allonby	Pebbles and sand	1	0.094
Maryport harbour	Mud and sand	1	0.097
Maryport harbour	Sand	1	0.088
Parton	Winkle bed	4[F]	0.086
Workington harbour	Mud	1	0.11
Workington harbour	Mud and pebbles	1	0.10
Harrington harbour	Sand	1	0.11
Harrington harbour	Pebbles and sand	1	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	3	0.10
Whitehaven - outer harbour	Pebbles and sand	1	0.097
Saltom Bay	Winkle bed	4[F]	0.097
St Bees	Sand	3	0.075
St Bees	Pebbles and rock	1	0.12
Nethertown beach	Pebbles and sand	1	0.11
Nethertown beach	Rock	1	0.080
Braystones	Pebbles and sand	1	0.10
Braystones	Pebbles	1	0.11
Sellafield beach	Sand	2	0.090
Sellafield beach	Grass and sand	2	0.091
Pipeline on foreshore	Sand	1	0.087
Pipeline on foreshore	Pebbles and sand	1	0.11
Ehen Spit seashore	Sand	1	0.082
Ehen Spit seashore	Pebbles and sand	1	0.089
River Calder downstream of factory sewer	Pebbles and sand	1	0.10
River Calder downstream of factory sewer	Pebbles and rock	1	0.11
River Calder upstream of factory sewer	Grass and mud	1	0.092
River Calder upstream of factory sewer	Grass	1	0.095
Seascale	Sand	3	0.083
Seascale	Grass	4	0.081
Seascale	Pebbles and sand	1	0.099
Drigg Barn Scar	Mussel bed	4[F]	0.083

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Salt marsh and mud	2	0.15
Ravenglass - Carleton Marsh	Grass and mud	1	0.16
Ravenglass - Carleton Marsh	Salt marsh	1	0.14
Ravenglass - River Mite estuary	Salt marsh and mud	2	0.18
Ravenglass - River Mite estuary	Grass and mud	2	0.18
Ravenglass - Raven Villa	Salt marsh and mud	3	0.15
Ravenglass - Raven Villa	Salt marsh	1	0.16
Ravenglass - boat area	Mud and pebbles	2	0.10
Ravenglass - boat area	Pebbles and sand	2	0.099
Ravenglass - ford	Mud	2	0.098
Ravenglass - ford	Mud and sand	2	0.12
Muncaster Bridge	Grass and mud	2	0.12
Muncaster Bridge	Grass	2	0.12
Ravenglass - salmon garth	Mud	1	0.11
Ravenglass - salmon garth	Mud and pebbles	1	0.11
Ravenglass - salmon garth	Pebbles and sand	1	0.11
Ravenglass - salmon garth	Pebbles	1	0.098
Ravenglass - Eskmeals Nature Reserve	Mud	1	0.10
Ravenglass - Eskmeals Nature Reserve	Salt marsh and mud	2	0.12
Ravenglass - Eskmeals Nature Reserve	Salt marsh	1	0.12
Newbiggin/Eskmeals viaduct	Salt marsh and mud	3	0.15
Newbiggin/Eskmeals viaduct	Salt marsh	1	0.16
Newbiggin/Eskmeals bridge	Salt marsh and mud	3	0.16
Newbiggin/Eskmeals bridge	Salt marsh	1	0.16
Tarn Bay	Winkle bed	2[F]	0.074
Tarn Bay	Sand	2	0.071
Silecroft	Sand	1	0.072
Silecroft	Pebbles	1	0.11
Haverigg	Mud and sand	1	0.067
Haverigg	Sand	1	0.078
Millom	Mud	1	0.10
Millom	Mud and sand	1	0.11
Low Shaw	Salt marsh	1	0.082
Low Shaw	Grass and mud	1	0.088
Askam	Sand	2	0.089
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud and pebbles	2	0.092
Walney Channel, S of discharge point	Mud	1	0.089
Walney Channel, S of discharge point	Mud and sand	1	0.094
Tummer Hill Marsh	Salt marsh	2	0.13
Roa Island	Pebbles	2	0.094
Greenodd	Salt marsh	2	0.073
Sand Gate Marsh	Salt marsh	3	0.089
Sand Gate Marsh	Grass and mud	1	0.091
Flookburgh	Salt marsh	1	0.080
High Foulshaw	Salt marsh	4	0.079
Arnside 1	Mud and sand	2	0.080
Arnside 1	Sand	2	0.080
Arnside 2	Salt marsh	4	0.094
Lancashire and Merseyside			
Morecambe Central Pier	Sand	2	0.076
Half Moon Bay	Rock and sand	2	0.073
Middleton Sands	Sand	1	0.077
Middleton Sands	Salt marsh and sand	1	0.075
Sunderland Point	Mud	2	0.090
Sunderland Point	Mud and sand	2	0.093
Sunderland	Mud	3	0.089
Sunderland	Mud and sand	1	0.094
Colloway Marsh	Salt marsh	2	0.10
Lancaster	Grass and mud	4	0.080
Aldcliffe Marsh	Salt marsh	4	0.10
Conder Green	Mud	2	0.086
Conder Green	Grass and mud	2	0.086

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Lancashire and Merseyside			
Pilling Marsh	Salt marsh	2	0.098
Knott End	Mud and sand	2[F]	0.076
Heads - River Wyre	Grass and mud	1	0.10
Heads - River Wyre	Salt marsh and mud	1	0.095
Heads - River Wyre	Salt marsh	2	0.10
Height o' th' hill - River Wyre	Salt marsh	3	0.12
Height o' th' hill - River Wyre	Grass and salt marsh	1	0.12
Hambleton	Mud	1	0.11
Hambleton	Grass and mud	3	0.11
Skippool Creek 1	Grass and mud	4	0.12
Skippool Creek 2	Mud	1	0.089
Skippool Creek 2	Grass and mud	3	0.098
Skippool Creek 3	Wood	3	0.10
Skippool Creek boat 2	Wood	4	0.094
Skippool Creek boat 2 - in vicinity of boats	Mud	2	0.093
Skippool Creek boat 2 - in vicinity of boats	Grass and mud	2	0.099
Fleetwood shore 1	Sand	4	0.075
Fleetwood shore 2	Salt marsh	4	0.14
Blackpool	Sand	4	0.063
Crossens Marsh	Salt marsh and mud	1	0.085
Crossens Marsh	Salt marsh	3	0.087
Ainsdale	Sand	4	0.062
Rock Ferry	Mud and sand	3	0.083
Rock Ferry	Sand	1	0.073
New Brighton	Sand	4	0.064
West Kirby	Sand	4	0.068
Little Neston Marsh 1	Salt marsh and mud	1	0.095
Little Neston Marsh 1	Mud and sand	1	0.098
Little Neston Marsh 2	Salt marsh	2	0.090
Flint 1	Mud	2	0.097
Flint 2	Salt marsh	2	0.088
Scotland			
Piltanton Burn	Salt marsh	4	0.060
Garlieston	Mud	4	0.063
Innerwell	Mud	4[F]	0.078
Innerwell	Mud	4	0.078
Bladnoch	Mud	4	0.086
Carsluith	Mud	4	0.080
Skyreburn Bay (Water of Fleet)	Salt marsh	4	0.076
Kirkcudbright	Salt marsh	4	0.079
Cutters Pool	Winkle bed	4[F]	0.085
Cutters Pool	Winkle bed	4	0.087
Rascarrel Bay	Winkle bed	4[F]	0.11
Rascarrel Bay	Winkle bed	4	0.11
Gardenburn	Salt marsh	1	0.097
Palnackie Harbour	Mud	1	0.077
Kippford - Slipway	Mud	4	0.11
Kippford - Merse	Salt marsh	1	0.098
Southerness	Winkle bed	4	0.060
Kirkconnell Marsh	Salt marsh	1	0.096
Isle of Man			
Ramsey	Mud	1	0.099
Wales			
Prestatyn	Sand	2	0.063
Rhyl	Mud	1	0.070
Rhyl	Mud and stones	1	0.068
Llandudno	Pebbles and sand	1	0.075
Llandudno	Sand and stones	1	0.085
Caerhun	Salt marsh and mud	2	0.089
Llanfairfechan	Mud and shale	1	0.063
Llanfairfechan	Salt marsh	1	0.080

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1 m, μGy h^{-1}
Northern Ireland			
Lisahally	Mud	1	0.072
Eglington	Shingle	1	0.064
Bellerena	Mud	1	0.064
Carrichue	Mud	1	0.060
Benone	Sand	1	0.064
Castlerock	Sand	1	0.062
Portstewart	Sand	1	0.058
Portrush, Blue Pool	Sand	1	0.065
Portrush, White Rocks	Sand	1	0.066
Portballintrea	Sand	1	0.061
Giant's Causeway	Sand	1	0.062
Ballycastle	Sand	1	0.060
Cushendun	Sand	1	0.062
Cushendall	Sand and stones	1	0.061
Red Bay	Sand	1	0.064
Carnlough	Sand	1	0.060
Glenarm	Sand	1	0.054
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.060
Drains Bay	Sand	1	0.054
Larne	Sand	1	0.063
Whitehead	Sand	1	0.062
Carrickfergus	Sand	1	0.062
Belfast Lough	Sand	1	0.061
Helen's Bay	Sand	1	0.064
Groomsport	Sand	1	0.065
Millisle	Sand	1	0.065
Ballywalter	Sand	1	0.066
Ballyhalbert	Sand	1	0.066
Cloughy	Sand	1	0.071
Portaferry	Shingle and stones	1	0.097
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.092
Ards Maltings	Mud	1	0.090
Island Hill	Mud	1	0.074
Nicky's Point	Mud	1	0.067
Strangford	Shingle and stones	1	0.087
Kilclief	Sand	1	0.069
Ardglass	Mud	1	0.087
Killough	Mud	1	0.085
Rocky Beach	Sand	1	0.076
Tyrella	Sand	1	0.080
Dundrum	Mud	1	0.094
Newcastle	Sand	1	0.090
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.090
Greencastle	Sand	1	0.090
Mill Bay	Mud	1	0.11
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.10

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

Table 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2006

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
M	Nets	4	0.15
S	Nets	4	0.053
	Pots	3	0.083
T	Gill nets	4	0.093
	Pots	4	0.14
W	Gill nets	2	0.052
	Pots	2	0.079
X	Gill nets	3	0.055
	Pots	4	0.10
Z	Nets	4	0.13

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2006

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, μSv h^{-1}
Whitehaven - outer harbour	Mud and sand	2	0.35
St Bees	Sand	2	0.12
Nethertown	Winkle bed	2	0.30
Sellafield pipeline	Sand	2	0.18
Drigg Barn Scar	Mussel bed	2	0.19
Ravenglass - Raven Villa	Salt marsh	2	0.66
Ravenglass - salmon garth	Mussel bed	2	0.20
Tarn Bay	Sand	1	0.12
Tarn Bay	Winkle bed	1	0.076

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2006

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		<1.7		<3.0	<1.6	1300	<10
Harrington Harbour	Seaweed	2		<1.8		<3.1	<1.6	1400	<11
St Bees	*Fucus vesiculosus*[a]	4[F]		2.4	1.9	<0.30	<0.62	2000	<0.63
St Bees	*Porphyra*	4[F]	49	0.39	0.24	<0.36	<0.51	2.1	4.7
St Bees	Seaweed	2		4.4		<2.2	<1.1	2000	<7.0
Braystones South	*Porphyra*	4[F]		0.68		<0.26	<0.37		11
Sellafield	*Fucus vesiculosus*	1[F]			1.4				
Sellafield	*Rhodymenia spp.*	2		0.50		<0.58	<0.66		6.6
Sellafield	Seaweed	2		8.7		<2.5	<1.3	3900	<8.4
Seascale	*Porphyra*[b]	52[F]		<0.49		<0.48	<0.28		<11
Ravenglass	Samphire	1[F]		0.12		<0.29	<0.70	1.5	<0.41
Ravenglass	Seaweed	2		6.5		<2.4	<1.3	2900	<8.8
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]		0.38		<0.41	<0.67	670	<0.92
Half Moon Bay	Seaweed	2		<0.97		<1.8	<0.89	280	<6.2
Marshside Sands	Samphire	1[F]		<0.04		<0.28	<0.69		<0.38
Cockerham Marsh	Samphire	1[F]		<0.04		<0.25	<0.46		<0.42
Scotland									
Aberdeen	*Fucus vesiculosus*	1		<0.10		<0.10	<0.10		<0.12
Wick	*Fucus vesiculosus*	1[F]		<0.07		<0.34	<0.58		<0.66
Lerwick	*Fucus serratus*	1		<0.10		<0.24	<0.21	4.5	<0.78
Cape Wrath	*Ascophyllum nodosum*	1[F]		<0.07		<0.35	<0.49	49	<0.70
Lewis	*Fucus vesiculosus*	1		<0.10		<0.11	<0.23	170	<0.10
Islay	*Fucus vesiculosus*	1		<0.10		<0.94	2.3	170	<0.99
Campbeltown	*Fucus vesiculosus*	1		<0.10		<0.50	<0.81	660	<0.78
Knock Bay	*Porphyra*	4[F]		<0.07		<0.26	<0.40		<0.62
Port William	*Fucus vesiculosus*	4[F]		<0.15		<0.38	<0.58	380	<0.82
Port William	*Fucus vesiculosus*	4		<0.17		<0.18	<0.21	720	<0.38
Garlieston	*Fucus vesiculosus*	4[F]		0.56		<0.32	<0.52	430	<0.71
Garlieston	*Fucus vesiculosus*	4		0.71		<0.43	<0.74	1100	<0.80
Auchencairn	*Fucus vesiculosus*	4[F]		0.67		<0.31	<0.47	790	<0.71
Auchencairn	*Fucus vesiculosus*	3		1.1		<0.42	<0.85	1900	<0.63
Auchencairn	*Ascophyllum nodosum*	1		0.19		<0.10	<0.10	690	<0.13
Isle of Man	*Fucus vesiculosus*	4[F]		<0.08		<0.42	<0.44	580	<0.60
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]		<0.06		<0.34	<0.64	140	<0.57
Cemaes Bay	Seaweed	2		<3.0		<5.5	<2.7	590	<19
Porthmadog	Seaweed	2		<0.88		<1.7	<0.80	46	<5.7
Lavernock Point	*Fucus serratus*	2[F]		<0.06		<0.30	<0.52	9.0	<0.55
Fishguard	*Fucus vesiculosus*	1[F]		<0.06		<0.13	<0.11	180	<0.46
Fishguard	Seaweed	2		<1.5		<2.7	<1.4	85	<9.3
South Wales									
Manufacturer A	Laverbread	4[F]		<0.07		<0.35	<0.66		<0.80
Manufacturer C	Laverbread	4[F]		<0.08		<0.41	<0.72		<0.84
Manufacturer D	Laverbread	4[F]		<0.07		<0.35	<0.30		<0.74
Manufacturer E	Laverbread	1[F]		<0.07		<0.58	<1.5		<0.80
Northern Ireland									
Portrush	*Fucus spp.*	4		<0.07		<0.33	<0.60		<0.67
Strangford Lough	*Rhodymenia spp.*	3		<0.14		<0.56	<0.87	16	<1.4
Ardglass	*Ascophyllum nodosum*	2		<0.10		<0.51	<0.95		<0.87
Ardglass	*Fucus vesiculosus*	2		<0.20		<1.3	<2.8	1100	<2.1
Carlingford Lough	*Ascophyllum nodosum*	1		<0.11		<1.0	*		<1.1
Carlingford Lough	*Fucus spp.*	3		<0.12		<0.51	<0.85	1100	<1.0
Isles of Scilly	*Fucus vesiculosus*	1[F]		<0.12		<0.39	<0.47	7.0	<1.2

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	<1.8	<8.7	<1.4	6.1	<4.8		
Harrington Harbour	Seaweed	2	<1.7	<8.3	<1.4	3.9	<4.9		
St Bees	*Fucus vesiculosus*[a]	4[F]	<0.35	1.1	<0.06	3.6	<0.25	<0.17	<0.11
St Bees	*Porphyra*	4[F]	<0.18	0.79	<0.09	1.4	<0.47	<0.29	<0.22
St Bees	Seaweed	2	<1.3	<5.7	<0.93	4.4	<3.5		
Braystones South	*Porphyra*	4[F]	<0.14	1.4	<0.07	1.5	<0.40	<0.22	<0.18
Sellafield	*Rhodymenia spp.*	2	<0.34	<0.79	<0.19	9.4	<0.76	<0.56	<0.33
Sellafield	Seaweed	2	<1.4	<7.0	<1.1	5.8	<3.9		
Seascale	*Porphyra*[b]	52[F]	<0.52	<1.7	<0.31	1.3	<1.4	<0.92	<0.67
Ravenglass	Samphire	1[F]	<0.08	0.18	<0.04	1.5	<0.20	<0.11	<0.07
Ravenglass	Seaweed	2	<1.4	<7.2	<1.1	12	<4.2		
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]	<0.19	0.68	<0.11	5.2	<0.48	<0.30	<0.22
Half Moon Bay	Seaweed	2	<1.0	<5.0	<0.83	5.5	<3.1		
Marshside Sands	Samphire	1[F]	<0.09	<0.09	<0.04	0.96	<0.21	<0.11	<0.07
Cockerham Marsh	Samphire	1[F]	<0.08	<0.11	<0.04	0.91	<0.21	<0.12	0.13
Scotland									
Aberdeen	*Fucus vesiculosus*	1	<0.10	<0.10	<0.10	0.16	<0.10	<0.10	<0.10
Wick	*Fucus vesiculosus*	1[F]	<0.14	<0.16	<0.07	0.07	<0.42	<0.22	<0.19
Lerwick	*Fucus serratus*	1	<0.10	<0.21	<0.10	0.11	<0.45	<0.11	<0.21
Cape Wrath	*Ascophyllum nodosum*	1[F]	<0.16	<0.17	<0.08	0.53	<0.45	<0.26	<0.22
Lewis	*Fucus vesiculosus*	1	<0.10	<0.10	<0.10	0.49	<0.11	<0.10	<0.10
Islay	*Fucus vesiculosus*	1	<0.14	<0.24	<0.10	0.31	<0.67	<0.12	<0.25
Campbeltown	*Fucus vesiculosus*	1	<0.12	<0.19	<0.10	0.97	<0.49	<0.10	<0.14
Knock Bay	*Porphyra*	4[F]	<0.12	<0.13	<0.06	<0.23	<0.27	<0.20	<0.11
Port William	*Fucus vesiculosus*	4[F]	<0.18	<0.33	<0.10	1.4	<0.37	<0.30	<0.17
Port William	*Fucus vesiculosus*	4	<0.12	0.35	<0.11	1.3	<0.26	<0.11	<0.14
Garlieston	*Fucus vesiculosus*	4[F]	<0.15	0.63	<0.08	3.6	<0.40	<0.24	<0.18
Garlieston	*Fucus vesiculosus*	4	<0.15	<0.65	<0.11	5.7	<0.51	<0.12	<0.22
Auchencairn	*Fucus vesiculosus*	4[F]	<0.15	0.81	<0.09	4.2	<0.43	<0.24	<0.20
Auchencairn	*Fucus vesiculosus*	3	<0.12	1.6	<0.10	7.2	<0.42	<0.11	<0.31
Auchencairn	*Ascophyllum nodosum*	1	<0.10	0.29	<0.10	0.73	<0.10	<0.10	<0.10
Isle of Man	*Fucus vesiculosus*	4[F]	<0.13	0.24	<0.07	0.91	<0.36	<0.20	<0.15
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]	<0.13	<0.13	<0.07	0.77	<0.27	<0.20	<0.11
Cemaes Bay	Seaweed	2	<3.3	<15	<2.6	<2.4	<7.9		
Porthmadog	Seaweed	2	<0.98	<4.8	<0.81	<0.79	<2.9		
Lavernock Point	*Fucus serratus*	2[F]	<0.12	<0.13	<0.06	0.33	<0.35	<0.19	<0.16
Fishguard	*Fucus vesiculosus*	1[F]	<0.10	<0.12	<0.06	0.23	<0.29	<0.19	<0.16
Fishguard	Seaweed	2	<1.6	<7.7	<1.3	<1.1	<4.5		
South Wales									
Manufacturer A	Laverbread	4[F]	<0.13	<0.17	<0.08	<0.13	<0.38	<0.21	<0.16
Manufacturer C	Laverbread	4[F]	<0.15	<0.17	<0.08	<0.12	<0.36	<0.23	<0.15
Manufacturer D	Laverbread	4[F]	<0.14	<0.16	<0.07	<0.10	<0.29	<0.23	<0.11
Manufacturer E	Laverbread	1[F]	<0.16	<0.15	<0.07	0.25	<0.31	<0.22	<0.10
Northern Ireland									
Portrush	*Fucus spp.*	4	<0.14	<0.16	<0.07	<0.10	<0.40	<0.22	<0.18
Strangford Lough	*Rhodymenia spp.*	3	<0.26	<0.29	<0.14	0.79	<0.59	<0.44	<0.25
Ardglass	*Ascophyllum nodosum*	2	<0.20	<0.41	<0.10	0.86	<0.55	<0.30	<0.23
Ardglass	*Fucus vesiculosus*	2	<0.41	<0.45	<0.22	0.84	<0.90	<0.60	<0.37
Carlingford Lough	*Ascophyllum nodosum*	1	<0.24	<0.27	<0.11	0.76	<0.59	<0.33	<0.20
Carlingford Lough	*Fucus spp.*	3	<0.22	<0.46	<0.12	0.95	<0.63	<0.36	<0.30
Isles of Scilly	*Fucus vesiculosus*	1[F]	<0.21	<0.29	<0.12	<0.11	<0.61	<0.36	<0.26

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	Total beta
Cumbria									
Silloth	Seaweed	2				<3.9			
Harrington Harbour	Seaweed	2				<3.9			
St Bees	*Fucus vesiculosus*[a]	4[F]	1.2	5.1		2.3	*	0.0069	
St Bees	*Porphyra*	4[F]	0.32	1.6	14	3.8	0.0054	0.0053	170
St Bees	Seaweed	2				7.2			
Braystones South	*Porphyra*	4[F]	0.38	1.8	18	4.7	*	0.0040	
Sellafield	*Fucus vesiculosus*	1[F]	2.2	9.4		4.1	*	0.0071	
Sellafield	*Rhodymenia spp.*	2	0.95	5.0		8.1	*	0.014	
Sellafield	Seaweed	2				10			
Seascale	*Porphyra*[b]	52[F]				4.0			
Ravenglass	Samphire	1[F]				2.9			
Ravenglass	Seaweed	2				44			
Lancashire									
Half Moon Bay	*Fucus vesiculosus*	4[F]				0.90			
Half Moon Bay	Seaweed	2				<4.1			
Marshside Sands	Samphire	1[F]				0.23			
Cockerham Marsh	Samphire	1[F]				0.46			87
Scotland									
Aberdeen	*Fucus vesiculosus*	1				0.13			
Wick	Fucus vesiculosus	1[F]				<0.28			
Lerwick	Fucus serratus	1				<0.14			
Cape Wrath	*Ascophyllum nodosum*	1[F]				<0.33			
Lewis	*Fucus vesiculosus*	1				<0.10			
Islay	*Fucus vesiculosus*	1				<0.27			
Campbeltown	*Fucus vesiculosus*	1				<0.12			
Knock Bay	*Porphyra*	4[F]				0.30			
Port William	*Fucus vesiculosus*	4[F]				0.63			
Port William	*Fucus vesiculosus*	4				<0.57			
Garlieston	*Fucus vesiculosus*	4[F]				3.8			
Garlieston	*Fucus vesiculosus*	4				6.5			
Auchencairn	*Fucus vesiculosus*	4[F]				2.9			
Auchencairn	*Fucus vesiculosus*	3				6.0			
Auchencairn	*Ascophyllum nodosum*	1				0.68			
Isle of Man	*Fucus vesiculosus*	4[F]				<0.20			
Wales									
Cemaes Bay	*Fucus vesiculosus*	2[F]				<0.08			
Cemaes Bay	Seaweed	2				<3.4			
Porthmadog	Seaweed	2				<1.3			
Lavernock Point	*Fucus serratus*	2[F]				<0.20			
Fishguard	*Fucus vesiculosus*	1[F]				<0.24			
Fishguard	Seaweed	2				<1.9			
South Wales									
Manufacturer A	Laverbread	4[F]				<0.26			
Manufacturer C	Laverbread	4[F]				<0.19			
Manufacturer D	Laverbread	4[F]				<0.10			80
Manufacturer E	Laverbread	1[F]				0.18			
Northern Ireland									
Portrush	*Fucus spp.*	4				<0.23			
Strangford Lough	*Rhodymenia spp.*	3	0.058	0.31		0.42	*	0.00080	
Ardglass	*Ascophyllum nodosum*	2				<0.22			
Ardglass	*Fucus vesiculosus*	2				<0.44			
Carlingford Lough	*Ascophyllum nodosum*	1				0.28			
Carlingford Lough	*Fucus spp.*	3				<0.40			
Isles of Scilly	*Fucus vesiculosus*	1[F]				<0.25			

** Not detected by the method used*
[a] The concentration of ^{129}I was <7.4 Bq kg^{-1}
[b] 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, 2006

Location	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	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Newton Arlosh	Grass	1				0.23								
Newton Arlosh	Washed grass	1				0.38								
Newton Arlosh	Soil	1				4.4								
Sellafield 14[b]	Onions	1	<0.04	<0.12	<0.12	4.8	<0.40	<0.09	<0.04	<0.04	<0.19	<0.12	<0.10	<0.13
Sellafield 14[b]	Potatoes	1	<0.08	<0.73	*	17	<0.85	<0.19	<0.09	0.18	<0.55	<0.24	<0.22	<0.34
Sellafield 14[b]	Runner Beans	1	<0.04	<0.35	<0.91	35	<0.45	<0.08	<0.04	0.05	<0.17	<0.14	<0.06	<0.03
Sellafield 14[b]	Soil	1	24	<0.78	<0.86	6400	12	9.9	<0.28	58	<1.5	0.66	0.92	69
Sellafield 1710[b]	Onions	1	<0.05	<0.36	<0.82	12	<0.56	<0.12	<0.05	0.08	<0.27	<0.17	<0.10	<0.06
Sellafield 1710[b]	Soil	1	1.9	<2.7	<4.0	390	<5.7	<1.8	<0.77	51	<4.7	<1.5	<2.1	5.2
Hutton Marsh	Grass	1				0.43								
Hutton Marsh	Washed grass	1				0.39								
Hutton Marsh	Soil	1				42								

** 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, 2006

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	<5.0	16	<0.24	0.049	<0.40	<0.32	<0.0048	<1.6	<0.47	<0.0098
Milk	max		<5.3	17	<0.25	0.055	<0.42		<0.0060	<1.7	<0.51	<0.013
Apples		1	<5.0	11	<0.20	0.073	<0.40	<0.30	<0.026	<1.5	<0.40	<0.025
Barley		1	<7.0	45	<0.30	0.51	<0.60	<0.40	<0.022	<2.1	<0.60	<0.061
Beef kidney		1	<9.0	44	<0.10	0.48	<0.40	<0.30	<0.026	<2.0	<0.70	0.080
Beef liver		1	<9.0	28	<0.20	0.15	<0.30	<0.20	<0.027	<1.2	<0.40	<0.044
Beef muscle		1	8.0	17	<0.20	0.0080	<0.40	<0.30	<0.023	<1.8	<0.30	<0.031
Beetroot		1							<0.013			
Blackberries		1	<4.0	15	<0.20	0.47	<0.30	<0.30	<0.021	<1.8	<0.50	<0.050
Broad beans[e]		1							<0.0090			
Cabbage		1	<4.0	<3.0	<0.30	0.53	<0.40	<0.30	<0.012	<2.0	<0.80	<0.034
Carrots		1	<4.0	10	<0.30	0.16	<0.40	<0.30	<0.014	<1.7	<0.60	<0.027
Dwarf beans		1	<5.0	<3.0	<0.30	0.090	<0.40	<0.30	<0.012	<1.7	<0.50	<0.026
Honey		1	<6.0	100	<0.20	0.056	<0.10	<0.20	0.019	<1.1	<0.40	<0.018
Pheasants		1	<5.0	27	<0.20	0.044	<0.30	<0.20	0.016	<1.6	<0.40	<0.050
Potatoes		1	<5.0	18	<0.30	<0.0090	<0.40	<0.30	<0.015	<1.1	<0.60	<0.027
Sheep muscle		2	<6.0	29	<0.15	<0.0095	<0.30	<0.25	<0.021	<1.7	<0.45	<0.025
Sheep muscle	max			33	<0.20	0.012	<0.40	<0.30	<0.029	<2.1	<0.50	<0.026
Sheep offal		2	<7.5	23	<0.30	0.14	<0.45	<0.30	<0.039	<2.0	<0.65	<0.038
Sheep offal	max		<8.0	29	<0.40	0.15	<0.60	<0.40	0.042	<2.3	<0.80	
Grass		2							<0.026			
Grass	max								<0.029			

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	0.18	<0.93		<0.00018	<0.00016	<0.026	<0.00017
Milk	max		0.21	<0.99		<0.00020	<0.00018	<0.027	<0.00020
Apples		1	0.083	<0.90		<0.00020	0.00030	<0.061	0.00070
Barley		1	0.16	<1.4		<0.00090	<0.00060	<0.15	0.0025
Beef kidney		1	0.82	<2.4		0.0013	0.0071	<0.091	0.029
Beef liver		1	0.66	<0.90		0.015	0.074	0.53	0.17
Beef muscle		1	1.1	<1.0		0.00030	0.00090	<0.048	0.0023
Beetroot		1			<0.033				
Blackberries		1	0.12	<0.80		0.00030	0.0014	<0.036	0.0031
Broad beans[e]		1			<0.034				
Cabbage		1	0.21	<1.2		<0.00030	0.00090	<0.079	0.0012
Carrots		1	0.16	<0.80		<0.00020	0.00020	<0.035	0.00030
Dwarf beans		1	0.18	<1.1		<0.00030	<0.00030	<0.031	0.00050
Honey		1	0.35	<1.5		0.00060	<0.00020	<0.077	0.00050
Pheasants		1	0.44	<0.90		<0.00010	<0.00040	<0.093	<0.00020
Potatoes		1	0.25	<0.80		0.00040	<0.00020	<0.035	0.00030
Sheep muscle		2	1.9	<0.80		<0.00025	<0.00035	<0.059	0.00095
Sheep muscle	max		2.2	<0.90		<0.00030	0.00050	<0.070	0.0015
Sheep offal		2	1.3	<2.1		0.0057	0.029	<0.29	0.037
Sheep offal	max		1.9			0.011	0.056	0.53	0.072
Soil[f]		1							

[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 concentrations of ^{134}Cs and ^{137}Cs were <0.21 (max <0.22) and <0.24 Bq l^{-1}*

[e] *The concentrations of ^{234}U, ^{235}U and ^{238}U were <0.0015, <0.0005 and 0.0025 Bq kg^{-1} respectively*

[f] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 11, 0.36 and 9.8 Bq kg^{-1} respectively*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2006

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	Total alpha	Total beta
Ehen Spit issue	4	340	<0.23	<0.030	<0.22	<0.27	<0.012	<0.0058	<2.2	10
Seaburn sewer outfall	3	<10	<0.34	<0.030	<0.32	<0.28	<0.010	<0.0053	<0.028	0.46
River Calder (downstream)	4	<4.3	<0.20	<0.053	<0.19	<0.17	<0.011	<0.0053	<0.027	<0.10
River Calder (upstream)	4	<4.1	<0.18	<0.038	<0.18	<0.16	<0.011	<0.0050	<0.032	<0.10
Wast Water	1	<4.0	<0.25			<0.19			<0.020	<0.10
Ennerdale Water	1	<4.0	<0.32			<0.27			<0.020	<0.10
Devoke Water	1	<4.0	<0.16			<0.13			<0.020	<0.10
Thirlmere	1	<4.0	<0.52			<0.37			<0.020	<0.10

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2006

Location	No. of sampling observations	Radioactivity concentration (dry), Bq kg^{-1}						
		^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Seascale SS 204	1	<1.0	<2.0	<0.92	270	3.1	19	22
Seascale SS 233	1	<0.76	3.0	<0.65	330	7.4	55	28
Seascale SS 209	1	<0.26	<3.0	<0.24	18	1.5	4.9	8.2
Seascale SS 232	1	<0.97	<2.0	<0.80	16	0.63	1.3	4.7
Seascale SS 231	1	<0.50	<2.0	<0.59	29	3.4	19	25
Whitehaven SS 201	1	<0.58	<1.0	<0.53	35	1.0	2.1	5.5

Table 2.17. Individual radiation exposures, Sellafield, 2006

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 2002-6)	0.47[d]	0.19	0.24	-	0.036	-	-
Local seafood consumers (habits for 2006)	0.50[e]	0.21	0.26	-	0.023	-	-
Whitehaven seafood consumers	0.011	0.011	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.037	0.019	-	-	0.018	-	-
Morecambe Bay seafood consumers	0.039	0.015	-	-	0.023	-	-
Fleetwood seafood consumers	0.018	0.018	-	-	-	-	-
Isle of Man seafood consumers	0.007	0.007	-	-	-	-	-
Northern Ireland seafood consumers	0.018	0.012	-	-	0.006	-	-
North wales seafood consumers	0.016	0.013	-	-	<0.005	-	-
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Other groups							
Ravenglass estuary, recreational use	0.042	-	-	-	0.031	0.011	-
Ravenglass estuary, nature warden	0.030	-	-	-	0.024	0.007	-
Fishermen handling nets or pots[c]	0.068	-	-	-	0.068	-	-
Bait diggers and shellfish[c] collectors	0.19	-	-	-	0.19	-	-
Ribble estuary houseboats	0.075	-	-	-	0.075	-	-
Average beach occupancy in Cumbria	<0.005	-	-	-	<0.005	-	-
Local consumers at Ravenglass[b]	0.013	-	-	0.013	-	-	-
Local consumers of vegetables grown on land with seaweed added	0.013	-	-	0.013	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.029	-	-	0.029	-	-	<0.005
Average consumer of locally grown food	0.014	-	-	0.014	-	-	-
All sources[f]	0.44	-	-	-	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *The dose due to nuclear industry discharges was 0.23 mSv*
[e] *The dose due to nuclear industry discharges was 0.24 mSv*
[f] *The total dose due to discharges and direct radiation. See Appendix 4*

3. Research establishments

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

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

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

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

Key points

- Generally, concentrations and dose rates similar to 2005 for all establishments (including Harwell and other minor sites). At Culham there was an increase in the measured tritium concentration in grass collected near the site perimeter. The effect is thought to be transient
- A new more stringent authorisation for Winfrith came into force in March 2006 for both the UKAEA site and the newly formed Waste Management Technology Ltd (WMTL)
- A new authorisation for Windscale came into force on 1st January 2006 which is more stringent but allows flexibility for decommissioning activities

Dounreay, Highland

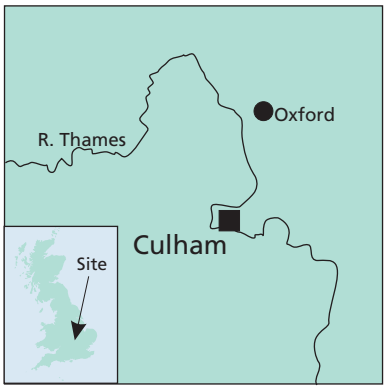
- UKAEA prepared a long term decommissioning plan (Lifetime Plan)
- UKAEA applied for planning permission for a Low Level Radioactive Waste Disposal facility adjacent to the site
- Inspections of UKAEA's compliance with SEPA's requirements for gaseous, liquid and solid disposal systems were completed
- The Dounreay Cementation Plant remained shut down during 2006
- Construction of the Breeder Fuel Removal Plant progressed
- Active commissioning of the new Effluent Treatment Plant at the Prototype Fast Reactor progressed during 2006
- Operations in Prototype Fast reactor resulted in an unintended discharge of krypton-85 to atmosphere in July 2006
- Dounreay Particles Advisory Group's (DPAG) Third Interim Report, published in November 2006
- Discharges, concentrations and dose rates similar to 2005. Local milk sampling introduced in 2006
- Dose to terrestrial consumers (Table 3.1) was less than 4% of the dose limit
- The *total dose* from all sources was less than 3% of the dose limit

Winfrith, Dorset, Harwell, Oxfordshire and Windscale, Cumbria

- Discharges similar to 2005 at all sites
- Concentrations and dose rates similar to 2005
- Radiation doses (Table 3.1) were less than 0.5% of the dose limit

3.1 Culham, Oxfordshire

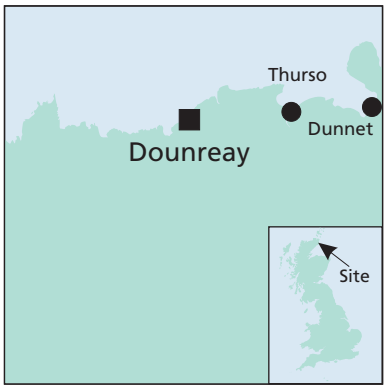
Culham is home to an experimental fusion reactor, the Joint European Torus. Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2006. Locations and data are shown in Figure 3.1 and Table 3.2 respectively. The main effect of the site's operation was increased tritium found in grass collected near the site perimeter. Although the value found in 2006 was relatively high (570 Bq kg^{-1}), the concentration would be likely to have been transient due to the nature of the discharges. The Environment Agency will continue to monitor the situation in 2007. In the extreme, if all terrestrial foods were contaminated at the same concentration and it is assumed that tritium is present as the organic form, the exposure of high-rate consumers would have been 0.027 mSv, which was less than 3% of the annual dose limit for members of the public of 1 mSv (Table 3.1).



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 2006 was estimated to be much less than 0.005 mSv (Table 3.1).

3.2 Dounreay, Highland

Radioactive waste discharges from Dounreay are made by UKAEA under authorisations granted by SEPA. The quantities discharged in 2006 were generally similar to those in 2005 (Appendix 2). Radioactive waste discharges from the site also include a minor contribution from the adjoining reactor site (Vulcan NRTE), which the Defence Procurement Agency operates.



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

In common with other NDA sites, UKAEA has prepared a long term decommissioning plan known as the Lifetime Plan. The NDA's ministerially agreed strategy includes a timetable for putting the management of the decommissioning sites out to competitive tender. As an enabling measure, UKAEA has initiated the process of forming a Site Licence Company (SLC) for Dounreay and setting up a branch of UKAEA that will put in bids for the management contracts as a Parent Body Organisation (PBO).

UKAEA and the SLC will jointly apply to transfer its authorisations held under the Radioactive Substances Act to the Site Licence Company before the SLC takes over the site management contract.

UKAEA introduced a new structure in April 2006 which included the introduction of staff seconded in from UKAEA's partner organisations – AMEC and CH2M Hill. The re-structure was aimed at facilitating operation as an SLC.

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 the successor SLC will have to apply to SEPA for authorisation to dispose of the waste.

An inspection of UKAEA's compliance with SEPA's requirements for solid radioactive waste disposal was carried out in May 2006. In general, UKAEA were found to be complying with those parts of the conditions of the Solid Radioactive Waste Disposal Authorisation which were inspected against. Across the site, improvement was observed in the handling of solid waste in comparison with the findings of SEPA's previous inspection of the management of Low Level Waste (performed in August 2000). Several areas for improvement were identified by SEPA, and recommendations have been made for further improvement.

An inspection of UKAEA's compliance with SEPA's requirements for making and retaining a true and accurate record of all gaseous waste discharged on or from the premises was carried out in August 2006. Several areas for improvement were identified by SEPA, and requirements and recommendations have been made for further improvement.

An inspection of UKAEA's compliance with SEPA's requirements for maintaining and inspecting the liquid radioactive waste handling, treatment and discharge systems was carried out in November 2006. Several areas for improvement were identified by SEPA, and recommendations have been made for further improvement.

Significant engineering work was carried out around the Shaft to construct a raised working platform from which the grouting work around the Shaft will be carried out. SEPA employed a contractor to assess UKAEA's proposals for grouting around the Shaft to isolate it hydraulically prior to being emptied. Fourteen areas of concern were identified

and subsequently addressed before SEPA agreed to the project proceeding.

The Dounreay Cementation Plant remained shut down during 2006 whilst the clean-up of the spillage of raffinate which occurred in 2005 continued. This has involved the use of remote handling techniques due to the high radiation levels.

The construction of the Breeder Fuel Removal Plant immediately adjacent to the sphere of the Dounreay Fast Reactor progressed. The exterior of the building was completed and work on the building internals was in progress.

SEPA had a significant involvement in scrutinizing the Best Practicable Means case for the abatement of radioactivity in the liquor to be produced by the destruction of the bulk sodium/potassium (NaK) coolant from the Dounreay Fast Reactor.

Active commissioning of the new Effluent Treatment Plant at the Prototype Fast Reactor progressed during 2006.

The sodium disposal plant, which opened in 2002, closed for maintenance midway through 2006 having destroyed in the order of 1000 tonnes of sodium. The re-start was delayed to give time for some complex work to be carried out in the reactor cooling circuits to facilitate removal of the sodium coolant.

During July 2006, operations in the Prototype Fast reactor resulted in an abnormal discharge of krypton-85 to atmosphere. Although the dose implications of this were low, the quantity discharged over about one day was close to the annual discharge limit for this radionuclide from this facility.

In October 2006, SEPA issued a report containing an independent review of proposals for the construction of a grouted Isolation Barrier around shaft D1225 at the Dounreay site (Scottish Environment Protection Agency, 2006e). In November 2006, SEPA issued a report containing an independent review of proposals, put forward by UKAEA, in relation to the control of groundwater entering shaft D1225 (Scottish Environment Protection Agency, 2006f).

Monitoring conducted in 2006 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 2006. 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. The results of SEPA's monitoring are presented in Tables 3.3(a) and (b).

During 2006, 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 2006, access was periodically withdrawn and as a result monitoring was interrupted throughout the year.

In 2006, 19 fragments were recovered from Sandside Bay and four from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 8.2 kBq and 400 kBq. In December 2006, during the monitoring of Sandside Beach, UKAEA detected and recovered a contaminated plastic item with an activity of approximately 4.6 kBq of caesium-137.

In 2005, UKAEA deployed a remotely operated survey vehicle to assist with demarcation of the extent of contamination of the marine environment. In 2006, further monitoring has taken place to provide more information on the extent of the contamination of the environment. Surveys undertaken by a remotely operated vehicle during 2006 identified 16 fragments on the offshore seabed, none 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).

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).

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. Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. Concentrations of radionuclides in 2006 (see Table 3.3 (a)) were generally similar to those for 2005. Technetium-99 in seaweed remained at the expected levels

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

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

for this distance from Sellafield. The estimated dose from consumption of fish and shellfish by high-rate consumers was less than 0.005 mSv or less than 0.5% of the annual dose limit for members of the public of 1 mSv (Table 3.1).

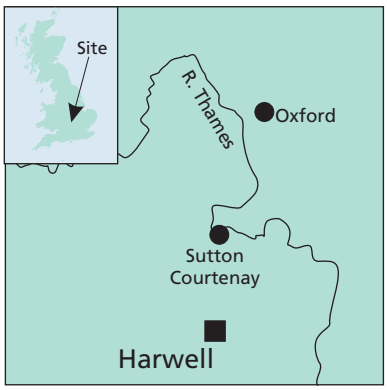
The second potential pathway relates to external exposure over local beaches. Gamma dose rates measured over intertidal areas (see Table 3.3(b)) were close to or less than those measured in previous years. The radiation dose due to occupancy in such areas was less than 0.005 mSv, which was less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The third potential pathway relates to external exposure from the uptake of radioactivity by particulate material that has accumulated in rocky areas of the foreshore. Monitoring of spume at Oigin's Geo and measurements of gamma dose rates (see Table 3.3(b)) above areas of the foreshore remained similar to those for 2005. The radiation dose to the public from these rocky areas was less than 0.005 mSv, which was less than 0.5% of the annual dose limit for members of the public of 1 mSv.

The fourth potential pathway relates to external exposure from radioactivity adsorbed on fine particulate matter that becomes entrained on fishing gear that is regularly handled. This results in a radiation dose to the skin of the hands and forearms of fishermen, mainly from beta radiation. The critical group is represented by a small number of people who operate a fishery close to Dounreay. The measurements in 2006 gave results less than the Limit of Detection (LoD) (Table 3.3(b)). The estimated dose based on these LoDs was of no radiological significance.

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 strontium-90, niobium-95, caesium-137, europium-155, uranium, plutonium and americium-241 were reported in samples. The dose to the critical group of local terrestrial consumers, including a contribution due to weapon test fallout, was estimated to be 0.039 mSv, which was less than 4% of the annual dose limit for members of the public of 1 mSv. The critical age group was 1-year-old infants, as opposed to 10-year-old children in 2005. The estimated dose in 2005 was similar at 0.040 mSv. The increase in dose in recent years was largely attributable to the inclusion of monitoring for radionuclides in goats' milk (all below LoD) in 2006, and an increase in the LoD for iodine-129 analysis in 2005. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.029 mSv or approximately 3% of the dose limit.

3.3 Harwell, Oxfordshire



Discharges of radioactive wastes from Harwell continued in 2005 under authorisation to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site, while gaseous discharges were made to the atmosphere. The Environment Agency launched a public consultation in February 2004 to consider an application by one of the tenants on the site, Amersham plc, to vary its authorisations for disposal of radioactive waste. Further details are provided in Section 6.

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. Monitoring of the aquatic environment at Newbridge (upstream of the site) is undertaken as a control site to indicate background levels remote from nuclear establishments.

The results of measurements of radioactivity concentrations and dose rates are shown in Tables 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 local pike were below the LoD; only caesium-137 was positively detected. The concentration of caesium-137 in pike (1.7 Bq kg^{-1}) at Sutton Courtenay although higher than that in 2005 (0.37 Bq kg^{-1}) was within concentrations expected through biological variation. Concentrations of transuranic elements were similar to those in 2005.

Habits surveys have identified anglers as the critical group affected by direct discharges into the river. Their occupancy of the riverbank has been assessed to estimate their external exposures. Consumption of indigenous freshwater fish was not found to occur, but it is considered prudent to include a component in the assessment of the angler's exposure. A consumption rate of 1 kg $year^{-1}$ was selected. On this basis, and excluding a background dose rate of 0.06 µGy h^{-1}, the radiation dose to anglers in 2006 was 0.008 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 3.1). 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.

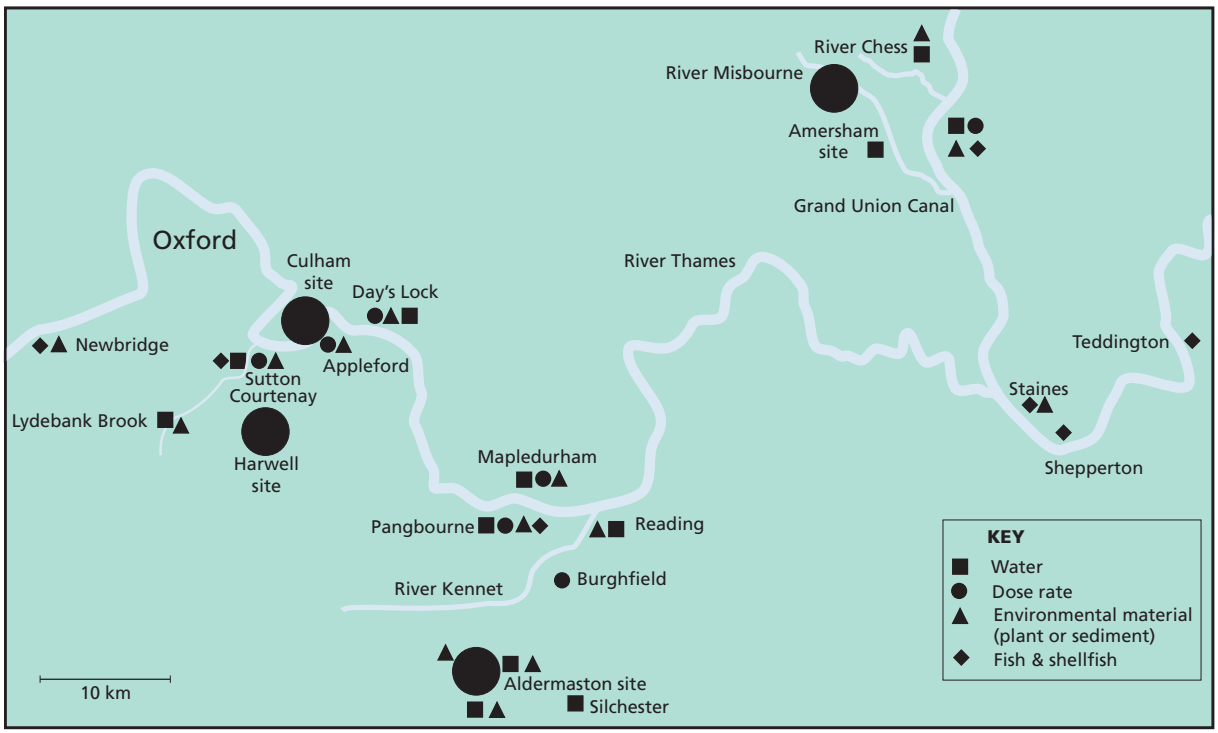


Figure 3.1. Monitoring locations at Thames sites (excluding farms)

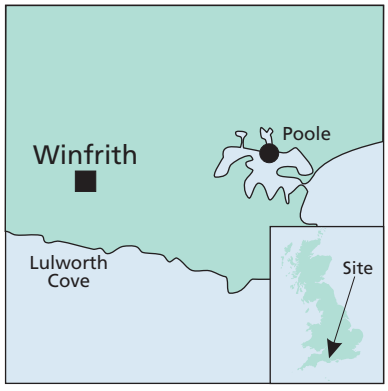
The results of tritium and gamma-ray spectrometry analyses of terrestrial food samples were all below detection limits. The dose to the critical group of terrestrial food consumers was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv.

Regular monitoring of the environment by the Environment Agency and the Food Standards Agency is carried out as part of the overall programme for the Sellafield site. The results of this monitoring and the implications in terms of dose to critical groups are described in Section 2.3.

3.4 Windscale, Cumbria

This site, which is operated by the UKAEA, adjoins the north part of the Sellafield Ltd. Sellafield site. 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 by authorised transfer to the Sellafield Ltd. Sellafield site, whence they are discharged after appropriate treatment to the Irish Sea via the Sellafield pipelines. The liquid discharges are included as part of the authorised Sellafield discharges (Table A2.2). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from Sellafield Ltd. Sellafield.

3.5 Winfrith, Dorset



Discharges of radioactive wastes from this site continued in 2006, 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 WMTL and these came into effect on 23 March 2006 (Environment Agency, 2006f, g). UKAEA have applied to vary their existing authorisation to dispose of radioactive waste, to increase their tritium discharges, from the Winfrith site.

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

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 total alpha and total beta activities were below the WHO's screening values for drinking water. The critical group for gaseous discharges was terrestrial food consumers who were estimated to receive a dose of less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 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 2006 at less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.0005 mSv or 0.5% of the dose limit.

3.6 Minor sites

Three minor licenced sites with very low concentrations of discharge are monitored using a small sampling programme of environmental materials. The results, given in the following sections, show that there was no detected impact on the environment in 2006 due to operation of these sites.

3.6.1 Imperial College Reactor Centre, Ascot, Berkshire

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

The discharges are very low and the environmental monitoring of their effects comprises sampling of grass. Two grass samples were analysed by gamma-ray spectrometry. Both sets of results in 2006 were either close to or less than the limits of detection.

3.6.2 Imperial Chemical Industries plc, Billingham, Cleveland

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

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

3.6.3 Scottish Universities' Environmental Research Centre, South Lanarkshire

The small research reactor at this site has been decommissioned and the waste disposed of under the authorisations granted by SEPA in 2001 for decommissioning. The site continues to hold a nuclear site licence and is currently progressing delicencing of this site. Routine laboratory work continues at the site, resulting in the authorised disposal of small quantities of radioactive substances. SEPA has received applications for the registration of 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, 2006

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
Culham	Drinkers of river water	<0.005	-	-	-	<0.005
Dounreay	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	<0.005	-	-	<0.005	-
	Geo occupants	<0.005	-	-	<0.005	-
	Consumers of locally grown food[b]	0.039	-	0.039	-	-
	All sources[c]	0.029	-	-	-	-
Harwell	Anglers	0.008	<0.005	-	0.008	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Winfrith	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	All sources[c]	<0.005	-	-	-	-

[a] *Adults are the most exposed age 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, 2006

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	Total alpha	Total beta
Freshwater	River Thames (upstream)	2	<4.1				<0.11	<0.052	0.25
Freshwater	River Thames (downstream)	2	<4.0				<0.23	<0.045	0.24
Grass	1 km west of site perimeter	1	570	<25	<4.2	<0.50	<2.9		170
Sediment	River Thames (upstream)	2					12		
Sediment	River Thames (downstream)	2					31		
Soil	1 km west of site perimeter	1	140	<25	26	3.0	6.1		450

[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, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs
Marine samples										
Crabs	Pipeline inner zone	4		<0.21	<0.10	<20	1.0	<2.2	<0.49	<0.18
Crabs	Pipeline	1		<0.12		<1.4		<1.2	<0.29	<0.11
Crabs	Strathy	4		<0.16		<1.9		<1.5	<0.39	<0.16
Crabs	Kinlochbervie	4		<0.25		<1.2	1.4	<2.4	<0.61	<0.24
Crabs	Melvich Bay	4		<0.15		<1.7	0.77	<1.4	<0.35	<0.17
Winkles	Brims Ness	4		<0.21	<0.10	<1.2		<1.9	<0.49	<0.20
Winkles	Sandside Bay	4		<0.22	<0.10	<1.5	5.4	<2.2	<0.56	<0.23
Mussels	Echnaloch Bay	4		<0.21		<1.5	19	<1.8	<0.48	<0.26
Mussels	Thurso East Mains	2		<0.20		<7.4		<1.8	<0.45	<0.19
Fucus vesiculosus	Kinlochbervie	4		<0.10		<0.51	120	<0.66	<0.20	0.43
Fucus vesiculosus	Brims Ness	4		<0.10		<1.3		<0.83	<0.21	0.20
Fucus vesiculosus	Sandside Bay	4		<0.10		<0.51	71	<0.67	<0.17	0.22
Fucus vesiculosus	Burwick Pier	4		<0.10		<0.61	160	<0.61	<0.16	<0.13
Sediment	Oigins Geo	1		<0.17		<4.1		<1.7	<0.43	5.5
Sediment	Brims Ness	1		<0.10		<0.19		0.29	<0.16	1.3
Sediment	Sandside Bay	1		<0.10		<0.13		<0.61	<0.18	3.0
Sediment	Rennibister	1		<0.10		<2.7		<0.81	<0.21	16
Seawater	Brims Ness	4	<2.5	<0.10		<0.10		<0.15	<0.10	<0.10
Seawater	Sandside Bay	4	<2.2	<0.10		<0.11		<0.13	<0.10	<0.10
Spume	Oigins Geo	3		<2.4		<28		<20	<5.6	18

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	Total alpha	Total beta
Marine samples									
Crabs	Pipeline inner zone	4	<0.23	<0.43	0.0024	0.015	0.023	2.4	75
Crabs	Pipeline	1	<0.15	<0.28			<0.17		
Crabs	Strathy	4	<0.20	<0.37	0.0017	0.0071	0.0092		
Crabs	Kinlochbervie	4	<0.31	<0.58	0.0014	0.0065	0.0071		
Crabs	Melvich Bay	4	<0.18	<0.32	0.0015	0.0074	0.011		
Winkles	Brims Ness	4	<0.24	<0.45	0.0089	0.041	0.041		
Winkles	Sandside Bay	4	<0.28	<0.52	0.023	0.095	0.012		
Mussels	Echnaloch Bay	4	<0.24	<0.47	0.0071	0.041	0.021		
Mussels	Thurso East Mains	2	<0.22	<0.41	0.0095	0.060	0.042		
Fucus vesiculosus	Kinlochbervie	4	<0.10	<0.15			<0.26		
Fucus vesiculosus	Brims Ness	4	<0.11	<0.21			<0.13	<4.6	310
Fucus vesiculosus	Sandside Bay	4	<0.11	<0.18			<0.21	<5.3	430
Fucus vesiculosus	Burwick Pier	4	<0.10	<0.16			<0.12		
Sediment	Oigins Geo	1	<0.25	0.64	3.8	13	18		
Sediment	Brims Ness	1	<0.10	<0.24	12	6.8	8.1		
Sediment	Sandside Bay	1	0.37	<0.21	11	12	12		
Sediment	Rennibister	1	<0.13	0.95	<0.21	0.42	5.2		
Seawater	Brims Ness	4	<0.10	<0.10			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.10			<0.10		
Spume	Oigins Geo	3	<2.6	<5.1	2.4	7.5	47		

Table 3.3(a). continued

Material	Location or Selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce
Terrestrial samples											
Barley		1	<5.0	<0.05	0.41	<0.08	<0.39	<0.10	<0.05	<0.05	<0.25
Beef muscle		1	<5.0	<0.05	<0.10	<0.07	<0.39	<0.10	<0.05	<0.05	<0.29
Beef offal		1	<5.0	<0.05	<0.30	<0.05	<0.13	<0.10	<0.05	0.08	<0.09
Cabbage		1	<5.0	<0.05	<0.10	<0.08	<0.30		<0.05	0.18	<0.17
Corn		1	<5.0	<0.05	0.48	<0.72	<0.38		<0.05	0.08	<0.27
Elderberries		1	<5.0	<0.07	<0.10	<0.16	<0.60	<0.10	<0.07	0.19	<0.40
Goat's milk		1	<5.0	<0.05	<0.10	<1.3	<0.46	<0.10	<0.05	<0.05	<0.29
Lamb muscle		1	<5.0	<0.05	<0.10	<0.05	<0.33	<0.10	<0.05	0.14	<0.20
Mushrooms		1	<5.0	<0.05	<0.10	<0.13	<0.35	<0.10	<0.05	1.4	<0.21
Potatoes		1	<5.0	<0.06	0.65	<0.18	<0.48	<0.10	<0.05	0.22	<0.28
Rosehips		1	<5.0	<0.08	0.72	<0.28	<0.73	<0.10	<0.07	0.61	<0.43
Rowan berries		1	<5.0	<0.05	0.47	<0.18	<0.46	<0.10	<0.05	20	<0.30
Swede		1	<5.0	<0.08	1.6	<0.28	<0.67	<0.10	<0.07	0.49	<0.38
Grass		6	<4.7	<0.05	1.7	<0.25	<0.36	<0.22	<0.05	0.16	<0.24
Grass	max		<5.0		4.4	<0.70	<0.46	<0.49		0.28	<0.32
Soil		6	<5.0	<0.09	2.3	<0.97	<0.78	<0.11	<0.09	25	<0.78
Soil	max			<0.11	9.0	1.8	<0.91	<0.12	<0.12	38	<0.89

Material	Location or Selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples									
Barley		1					<0.050	<0.050	<0.050
Beef muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Beef offal		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Cabbage		1					<0.050	<0.050	<0.050
Corn		1					<0.050	<0.050	<0.050
Elderberries		1					<0.050	<0.050	<0.050
Goats' milk		1							<0.06
Lamb muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Mushrooms		1					<0.050	<0.050	<0.050
Potatoes		1					<0.050	<0.050	<0.050
Rosehips		1					<0.050	<0.050	<0.050
Rowan berries		1					<0.050	<0.050	<0.050
Swede		1					<0.050	<0.050	<0.050
Grass		6		<0.14	<0.050	<0.13	<0.050	<0.050	<0.097
Grass	max			0.35		0.33			0.33
Soil		6	1.7	31	1.6	28	<0.057	0.41	<0.22
Soil	max			51	3.0	44	0.081	0.60	0.33

[a] *Except for seawater where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima If no 'max' value is given the mean value is the most appropriate for dose assessments*

Table 3.3(b). Monitoring of radiation dose rates near Dounreay, 2006

Location	Material or ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.061
Sandside Bay	Winkle bed	2	0.096
Oigins Geo	Spume/sludge	4	0.21
Brims Ness	Shingle/stones	2	0.084
Melvich	Salt Marsh	2	0.077
Melvich	Sand	2	0.053
Strathy	Sand	2	<0.047
Thurso	Riverbank	2	0.086
Achreregan Hill	Soil	2	<0.047
Thurso Park	Soil	2	0.094
Borrowston Mains	Soil	2	0.084
East of Dounreay	Soil	2	0.078
Castletown Harbour	Sand	2	0.061
Dunnet	Sand	2	<0.045
Mean beta dose rates			µSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigins 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, 2006

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Shebster	12	<0.010	<0.0091	0.14
Reay	11	<0.018	<0.013	0.17
Balmore	12	<0.010	<0.011	0.14

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{57}Co	^{60}Co	^{137}Cs	^{238}Pu
Freshwater samples								
Pike	Outfall (Sutton Courtenay)	1	<25	<25	<0.05	<0.06	1.7	
Pike	Newbridge	1	<25	<25	<0.03	<0.04	<0.04	0.000022
Pike	Staines	1	<25	<25	<0.04	<0.06	0.15	
Pike	Shepperton	1	<25	<25	<0.04	<0.06	0.18	
Pike	Teddington	1	<25	<25	<0.04	<0.06	0.10	
Flounder	Beckton	1		<25	<0.08	<0.20	0.20	
Nuphar lutea	Newbridge	1		<25	<0.05	<0.06	0.07	
Nuphar lutea	Staines	1		<25	<0.04	<0.07	0.06	
Sediment	Appleford	4[E]				<0.42	13	<0.60
Sediment	Outfall (Sutton Courtenay)	4[E]				<0.27	8.5	<0.60
Sediment	Day's Lock	4[E]				<0.94	14	<0.60
Sediment	Lydebank Brook	4[E]				<1.4	7.8	<0.60
Freshwater	Day's Lock	4[E]		<4.0		<0.19	<0.16	
Freshwater	Lydebank Brook	4[E]		<4.0		<0.23	<0.19	
Freshwater	R Thames (above discharge point)	4[E]		<4.0		<0.32	<0.26	
Freshwater	R Thames (below discharge point)	4[E]		<4.0		<0.20	<0.18	

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	Total alpha	Total beta
Freshwater samples								
Pike	Outfall (Sutton Courtenay)	1		<0.06				
Pike	Newbridge	1	0.00015	0.00029	0.000020	*		
Pike	Staines	1		<0.06				
Pike	Shepperton	1		<0.07				
Pike	Teddington	1		<0.07				
Flounder	Beckton	1		<0.15				
Nuphar lutea	Newbridge	1		<0.13				
Nuphar lutea	Staines	1		<0.05				
Sediment	Appleford	4[E]	<0.30	1.8			<130	220
Sediment	Outfall (Sutton Courtenay)	4[E]	0.52	3.1			<190	300
Sediment	Day's Lock	4[E]	0.52	3.1			200	330
Sediment	Lydebank Brook	4[E]	0.56	2.5			<180	340
Freshwater	Day's Lock	4[E]					<0.045	0.27
Freshwater	Lydebank Brook	4[E]					<0.074	0.23
Freshwater	R Thames (above discharge point)	4[E]					<0.037	0.22
Freshwater	R Thames (below discharge point)	4[E]					<0.040	0.26

Material	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	<4.8	<0.20
Apples	1	<5.0	<5.0	<0.30
Beetroot	1	<5.0	<5.0	<0.20
Blackberries	1	<4.0	<4.0	<0.20
Cabbage/Brussels sprouts	1	<4.0	<4.0	<0.30
Honey	1		<7.0	<0.20
Potatoes	1	<5.0	<5.0	<0.30

** Not detected by the method used*

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

[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, 2006

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Mud	1	0.065
Appleford	Mud and sand	1	0.054
Sutton Courtenay	Grass and mud	2	0.074
Day's Lock	Grass and mud	2	0.064

Table 3.5(a). Concentrations of radionuclides in food and the environment near Winfrith, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples									
Plaice	Weymouth Bay	2		<0.03	<0.10	<0.15		0.09	
Bass	Weymouth Bay	2		<0.06	<0.20	<0.10		0.27	
Crabs	Chapman's Pool	1		0.13	<0.19	<0.19		<0.07	0.00012
Crabs	Lulworth Banks	1	20	0.13	<0.15	<0.13		<0.05	0.00019
Pacific Oysters	Poole	1		<0.13	<0.47	*		<0.10	
Cockles	Poole	1		0.18	<0.17	*		<0.05	
Whelks	Poole Bay	1		<0.16	<0.33	<0.29		<0.13	0.00023
Whelks	Lyme Regis	1		<0.05	<0.13	<0.14		<0.05	0.00031
Scallops	Lulworth Ledges	1		<0.24	<0.48	<0.58		<0.18	0.00049
Clams	Portland Harbour	1		0.15	<0.27	<0.82		<0.08	
Fucus serratus	Kimmeridge	2		<0.22	<0.24	<0.07	0.68	<0.06	
Fucus serratus	Bognor Rock	2		0.22	<0.20	<0.60	1.5	0.06	
Seaweed	Lulworth Cove	2[E]		<1.2		<1.0	2.8	<0.82	
Seawater	Lulworth Cove	2[E]		<0.17				<0.15	

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	Total alpha	Total beta
Marine samples								
Plaice	Weymouth Bay	2		<0.07				
Bass	Weymouth Bay	2		<0.06				
Crabs	Chapman's Pool	1	0.00048	0.0012	0.000026	0.000037		
Crabs	Lulworth Banks	1	0.00061	0.0013	0.000016	0.000031		
Pacific Oysters	Poole	1		<0.09				
Cockles	Poole	1		<0.22				
Whelks	Poole Bay	1	0.0014	0.00095	*	0.000035		
Whelks	Lyme Regis	1	0.0028	0.0018	*	0.000061		
Scallops	Lulworth Ledges	1	0.0024	0.00072	*	0.000019		
Clams	Portland Harbour	1		<0.19				
Fucus serratus	Kimmeridge	2		<0.07				
Fucus serratus	Bognor Rock	2		<0.16				
Seaweed	Lulworth Cove	2[E]		<1.4				
Seawater	Lulworth Cove	2[E]		<0.32			<1.3	5.4

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{95}Nb	^{137}Cs	Total alpha	Total beta
Terrestrial samples										
Milk		4	<4.9	<4.9	16	<0.21	<0.65	<0.20		
Milk	max		<5.3	<5.3	17	<0.25	<0.73			
Apples		1	<5.0	<5.0	7.0	<0.10	<0.20	<0.20		
Blackberries		1	<5.0	<4.0	14	<0.20	<0.20	0.20		
Cabbage		1	<5.0	<5.0	<3.0	<0.30	<0.20	<0.20		
Carrots		1	<5.0	<5.0	5.0	<0.40	<0.50	<0.30		
Honey		1		<7.0	67	<0.10	<0.10	0.10		
Potatoes		1	<5.0	<5.0	15	<0.30	<0.30	<0.20		
Grass		2	<13	<8.5	<13	<0.35	<0.40	<0.40		
Grass	max		<19	11	20	<0.40	<0.50			
Sediment	North of site (Stream A)	2[E]				<0.46		6.0	<100	<100
Sediment	R Frome (upstream)	2[E]				<2.4		6.8	270	270
Sediment	R Frome (downstream)	2[E]				<1.8		11	310	250
Sediment	R Win, East of site	2[E]				<0.35		<0.74	<260	270
Freshwater	North of site (Stream A)	2[E]		19		<0.23		<0.19	<0.035	<0.11
Freshwater	R Frome (upstream)	2[E]		<4.0		<0.13		<0.13	<0.040	<0.10
Freshwater	R Frome (downstream)	2[E]		<4.0		<0.16		<0.14	<0.030	<0.10
Freshwater	R Win, East of site	2[E]		<4.0		<0.22		<0.18	<0.085	<0.14

** 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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Pebbles and shingle	1	0.053
Red Cliffe Point to Black Head	Shingle	1	0.052
Osmington Mills	Pepples and stones	1	0.059
Ringstead Bay	Pebbles and shingle	1	0.052
Durdle Door	Shingle	1	0.052
Lulworth Cove	Shingle	1	0.055
Kimmeridge Bay	Pebbles	1	0.083
Swanage Bay 1	Sand	1	0.059
Swanage Bay 2	Sand	1	0.060
Swanage Bay 3	Sand	1	0.053
Poole Harbour	Shingle	1	0.054

4. Nuclear power stations

Key points

- In 2006, Defra completed and published its review of the Environment Agency Magnox Authorisation Review carried out in 2002 on the accumulation and disposal of radioactive wastes at eight Magnox sites in England and Wales. Defra and Welsh Assembly Government decided in 2006 not to change any of the Environment Agency's decisions
- Electricity production continued in 2006 at four Magnox stations - Oldbury, Dungeness 'A', Sizewell 'A' 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 sampling carried out at Oldbury, Sizewell 'A' and Wylfa - weekly discharge advisory levels were approached or exceeded, but no significant increase in environmental levels were found
- 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 consulted on its review of all the British Energy power station authorisations. Following this, the Environment Agency completed its review and determined the permits. New authorisations for all the BE sites in England were issued in April 2007
- Discharges were similar to 2005, except at Dungeness 'A' where argon-41 gaseous discharges increased and at Sizewell 'B' where liquid tritium discharges increased
- Consultation and/or decision documents issued by Environment Agency for changes in authorisations (at Berkeley, Dungeness, Hartlepool, Heysham, Hinkley Point, Oldbury and Sizewell)
- New surveys of local diet and occupancy habits at Hinkley Point and Heysham were carried out
- Atmospheric sampling trials undertaken at Dungeness
- Concentrations and dose rates were generally similar to those in 2005
- Concentrations due to natural radionuclides and carbon-14 were enhanced at Hartlepool due to factors other than power station operation (probably including non-nuclear industry discharges)
- At Dungeness, terrestrial foods dose increased to 13% of the dose limit due to increased argon-41 discharges
- At Heysham, seafood consumer dose reduced due to decreased consumption rates
- At Hinkley Point, local fishermen dose increased due to increased occupancy and dose rate measurements
- Doses from discharges (Table 4.1) were generally less than 1% of dose limit and similar to 2005
- At most sites, *total dose*s from all sources were generally less than 5% of the dose limit

continued:

Scotland

- Consultation documents issued by SEPA for changes in authorisations (Hunterston and Torness)
- At Chapelcross, relatively few contaminated particles (3) were found at the end of the liquid discharge pipe in 2006
- Discharges, concentrations and dose rates were generally similar in 2005
- At Hunterston, dose increased to approximately 2% of dose limit
- Doses from discharges (Table 4.1) were less than 3% of dose limit and similar to 2005
- The *total dose*s from all sources were generally less than 3% of the dose limit (Hunterston 10%)

Wales

- Discharges, concentrations and dose rates were generally similar in 2005
- Doses from discharges (Table 4.1) were less than 1% of dose limit and similar to 2005
- The *total dose*s from all sources were generally less than 3% of the dose limit

This section considers the effects of discharges from nuclear power stations during 2006. 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 Ltd.* (a wholly owned subsidiary of BNG) on behalf of the NDA. In 2006, seven of these Magnox stations were in the process of decommissioning, whilst four continued to generate electricity. Discharges from one of the Magnox stations at Calder Hall are considered in Section 2 because it is located at Sellafield. British Energy Generation Ltd and British Energy Generation (UK) Ltd 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 2006. 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. It is the owner of all the Magnox nuclear power stations. Following the formation of the NDA, BNG became a contractor to the NDA. In April 2007, the NDA published their Annual Plan, which summarises 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 October 2005, Defra issued a consultation, concerning its draft decision document for applications by BNFL, to dispose of or accumulate radioactive wastes on or from eight of the Magnox Power Stations (Berkeley, Bradwell, Dungeness A, Hinkley Point A, Oldbury, Sizewell A, Trawsfynydd and Wylfa) and the Environment Agency's decisions and recommendations with regard to the applications (Department for Environment, Food and Rural Affairs, 2005e). A public consultation on a draft of the Magnox decision document ran from 21 October 2005 to 16 January 2006. Defra published a decision document in August 2006 (Department for Environment, Food and Rural Affairs, 2006a) stating it was decided not to change any of the Environment Agency's decisions.

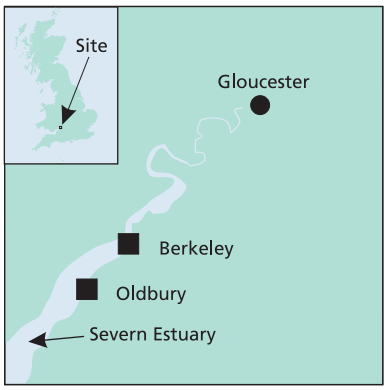
Gaseous and liquid discharges from each of the power stations are authorised by the Environment Agency for England and Wales, and by SEPA for Scotland. In 2006, gaseous and liquid discharges were below limits for each of the power stations (see Appendix 2). Independent monitoring of the environment around each of the power stations is carried out by the Food Standards Agency and the Environment Agency for England and Wales, and by SEPA for Scotland.

Estimates of dose discussed in this section (and summarised in Table 4.1) do not always include a component from direct radiation from the site (unless specifically stated that they do include direct radiation). Separate estimates of *total dose* around the power stations taking into account direct radiation are available for all of the power stations except Berkeley, Bradwell and Oldbury, and and where available are discussed at the end of each sub-section. *Total dose*s at these latter three will be added in 2007. The sites are grouped in the section according to whether they are in England, Scotland or Wales.

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

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station ceased electricity generation in March 1989, but radioactive wastes have been and are still generated by decommissioning operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples. The Oldbury Power Station has continued operation and because the effects of both sites are on the same area, Berkeley and Oldbury are considered together for the purposes of environmental monitoring. Oldbury power station is scheduled for closure in 2008.

In 2006, Magnox Electric Ltd. requested removal of authorised discharge outlets, with a reduction in the associated limits, to allow most of the Berkeley Centre part of the site to be delicenced. To accelerate the decommissioning programme, a short-term increase in tritium gaseous discharges on site, an increase in transfers of wastes to the Low-Level Waste Repository (near Drigg), and to an off site incinerator in Hythe (Hampshire) were requested. The Environment Agency issued an explanatory document to assist the consultation process, and a decision document was issued in July 2006 (Environment Agency, 2006h). Magnox Electric Ltd. have also applied to vary their existing authorisation at Oldbury power station. The Environment Agency issued an explanatory document to assist the consultation process (Environment Agency, 2006i).

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. Data for 2006 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 levels slightly above background values. Total alpha and total beta concentrations in surface waters were less than the WHO screening levels. An atmospheric dispersion computer model has been used to estimate the radionuclides in air due to gaseous releases from the Oldbury site (Appendix 1). In September 2006, the site operators at Oldbury reported that the weekly advisory levels for carbon-14 had been exceeded. The Food Standards Agency undertook extra analyses of carbon-14 in samples of local milk but found no elevated concentrations of this radionuclide.

Liquid waste discharges and aquatic monitoring

Liquid radioactive wastes are discharged to the Severn estuary. A habits survey has established that the two potentially critical pathways for public radiation exposure in the aquatic environment were internal radiation following consumption of locally-caught fish and shellfish, and external exposure from occupancy of muddy intertidal areas. Therefore, samples of seafood were analysed and gamma dose rates monitored. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from the GE Healthcare radiopharmaceutical plant in Cardiff (see Section 6). In addition, measurements of external exposure are supported by analyses of intertidal mud. Data for 2006 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 the same 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 critical group dose from gaseous releases including consumption of foodstuffs was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit. The total dose to the critical group of fish and shellfish consumers was estimated to be 0.012 mSv, which was approximately 1% 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 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.

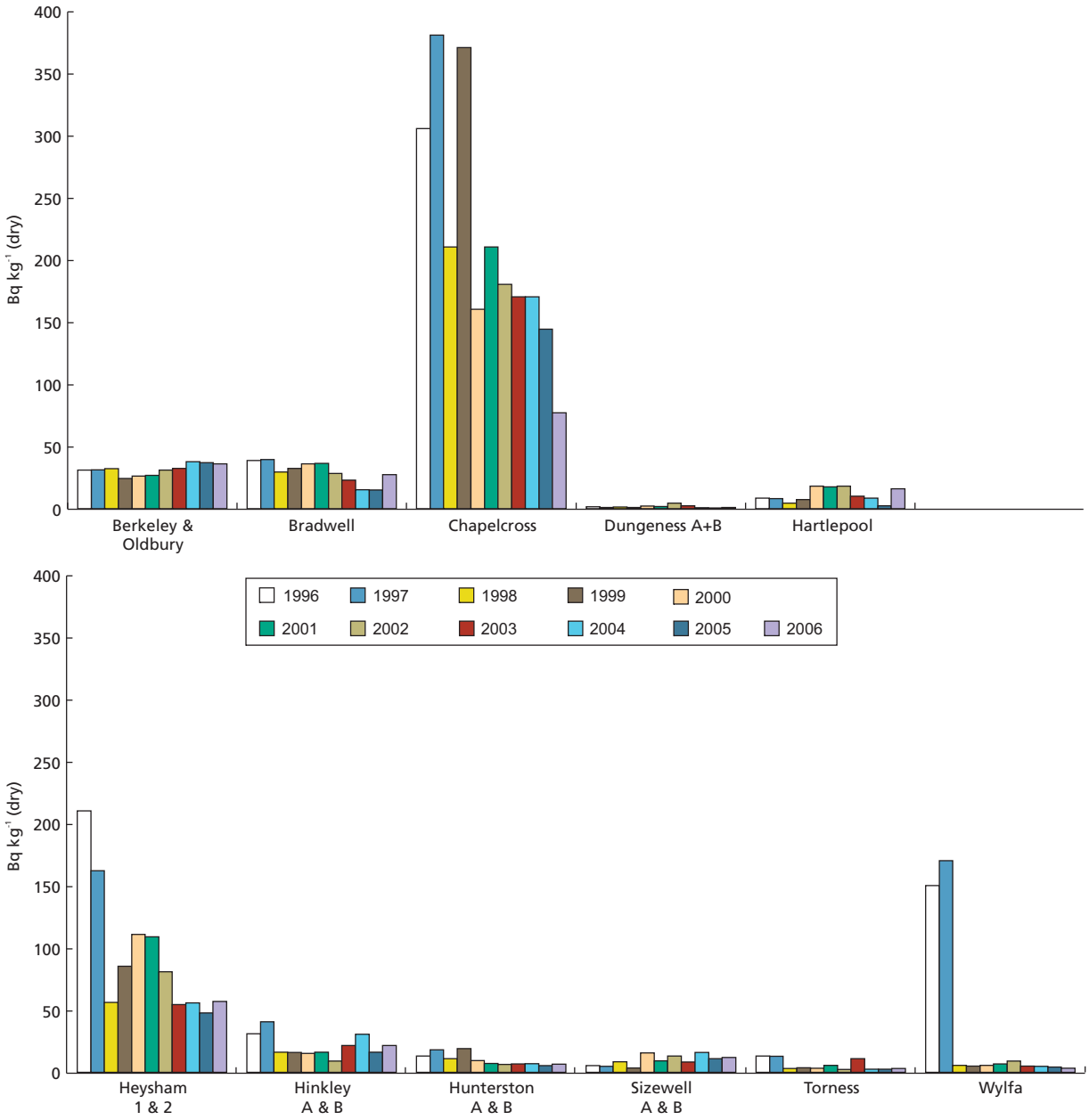
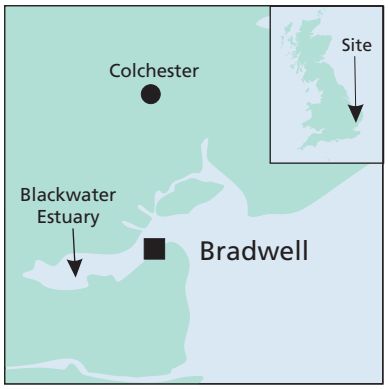


Figure 4.1. Caesium-137 concentration in sediments near nuclear power stations

4.2 Bradwell, Essex

This Magnox power station stopped electricity production in March 2002 after 40 years of operation and is now undergoing defuelling prior to decommissioning.



Gaseous discharges and terrestrial monitoring

This power station is authorised to discharge gaseous wastes to the local environment. 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 2006 are presented in Table 4.3(a). Concentrations of activity were low in terrestrial food samples, though some enhancements of carbon-14 levels in terrestrial samples were apparent. The alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. The total beta activity in water from the coastal ditch continued to be enhanced above background levels and was in excess of the WHO screening level of 1 Bq l^{-1} for drinking water. Tritium concentrations in the ditch were similar to values reported in 2005, but were substantially below the EU reference level for tritium of 100 Bq l^{-1}. The ditch is not known to be used as a drinking water source.

Liquid waste discharges and aquatic monitoring

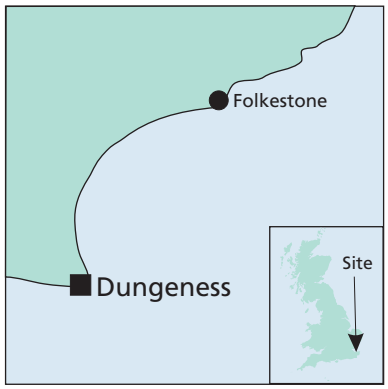
Liquid wastes are discharged to the estuary of the River Blackwater. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. 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. Measurements for 2006 are summarised in Tables 4.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; concentrations were generally similar to those for 2005, however, there is evidence for a decline in caesium-137 concentrations in sediments (Figure 4.1). The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity, though there may be a small contribution from discharges from the reprocessing plant at Cap de la Hague. Gamma dose rates on beaches were difficult to distinguish from natural background.

Doses to the public

The critical group dose from consumption of locally grown foodstuffs was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv. The critical group of seafood consumers received 0.010 mSv, mostly due to the effects of external exposure, which was 1% of the dose limit for members of the public of 1 mSv (Table 4.1). The trend in marine doses at Bradwell and in the South East generally is shown in Figure 4.2. 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.

4.3 Dungeness, Kent

There are two separate 'A' and 'B' nuclear power stations on this site; the 'A' station is powered by Magnox reactors and the 'B' station by AGRs. Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together. Dungeness A ceased generating electricity on the 31 December 2006 and will be decommissioned. The Environment Agency has reviewed the authorisations to dispose of radioactive waste from the nuclear power station at Dungeness B and produced a summary decision document in March 2007 (Environment Agency, 2007c). Habits surveys have been used to investigate aquatic and terrestrial exposure pathways. 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 2006 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the limits of detection. Concentrations of carbon-14 were generally within the range of activity concentrations observed for background. Low concentrations of tritium and sulphur-35 were detected in some samples. Concentrations of total alpha and gross beta activity in freshwater were within WHO screening levels for drinking water. Relatively high concentrations of argon-41 in air were predicted for this site (Appendix 1).

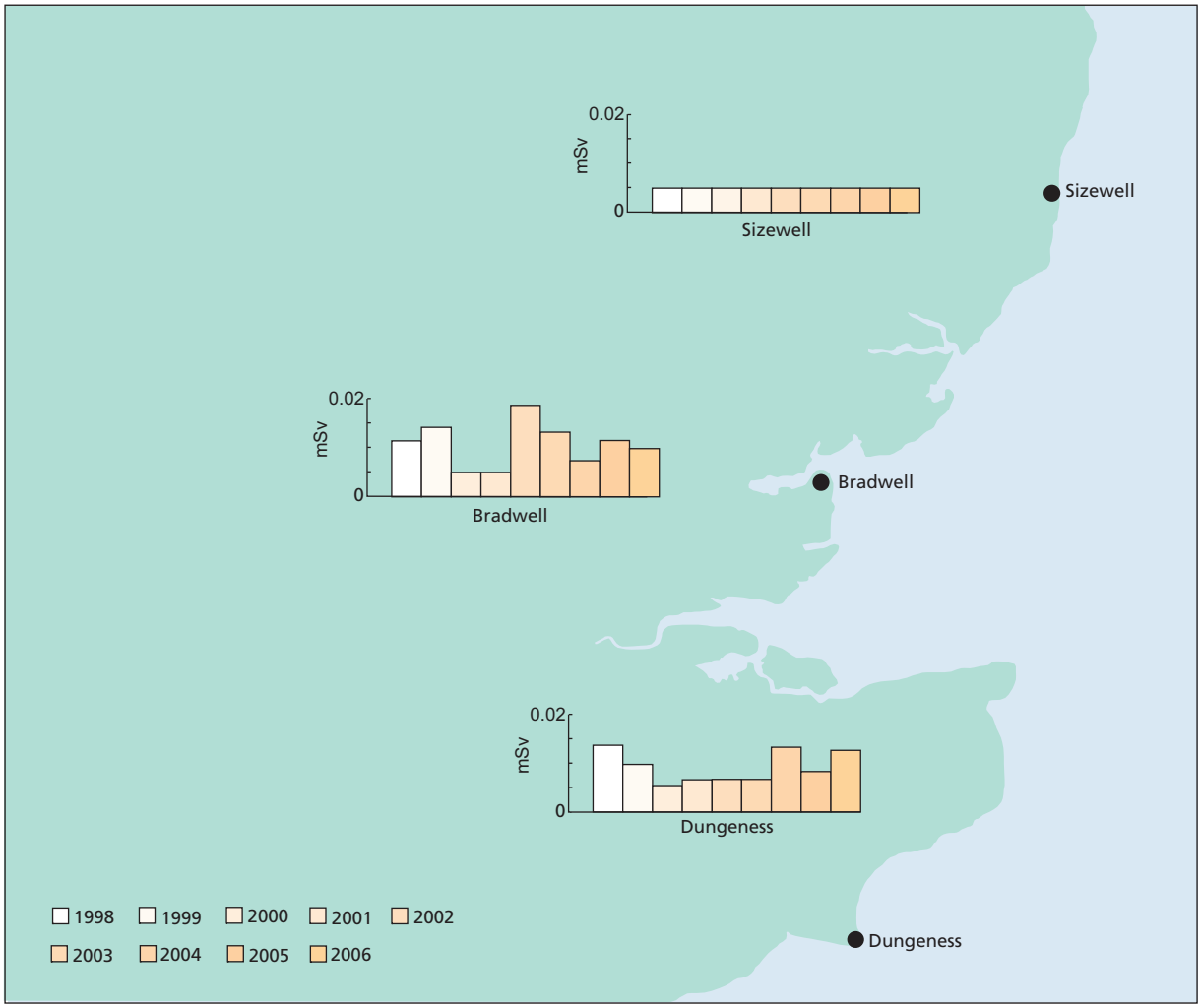


Figure 4.2. Individual radiation exposures to seafood consumers from artificial radionuclides in South-east England, 1998-2006. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Trials of atmospheric sampling have been undertaken, on behalf of the Environment Agency, to monitor radioactive substances in ambient air around the site. The primary remit of these studies was to determine the logistics and usefulness of deploying such techniques. Trials initially commenced at Dungeness power stations in December 2003 and finished in January 2005. Three high volume air samplers were deployed at designated points around the site. The positioning of these samplers was chosen to reflect public exposure, taking into account the outcome of atmospheric dispersion modelling calculations and local population distribution. The study concluded that there was considerable effort required in setting up sampling sites. Because of these factors, short-term air sampling campaigns are unlikely to be practical. High volume air sampling seems to be a reproducible way of detecting atmospheric radionuclides. Routine sampling around the sites does have merit. Concentrations of radionuclides in air were from time to time above the LoD. Monitoring of air around power stations is likely to be of value. However, because of the difficulties of setting up monitoring stations, short term campaigns are unlikely to be the most practical option. The ways of taking the findings forward are now being considered by the Radiological Monitoring Standards Working Group (RMSWG).

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 2006 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. 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 difficult to distinguish from the natural background; beta dose rates were not detected.

Doses to the public

The adult age group received the maximum dose due to gaseous disposals. Their dose in 2006 was estimated to be 0.13 mSv, which was 13% of the dose limit for members of the public. This represents a slight increase in the dose in comparison to the value obtained in 2005 (11%), in which the age group was prenatal children. The increase in dose is consistent with an increase in gaseous discharges from 1020 TBq (2005) to 1280 TBq (2006) of argon-41 from Dungeness A. As in 2005, the contribution from food pathways was less than 0.005 mSv. For seafood consumers, the critical group was represented by local bait diggers who also eat fish and shellfish. Their radiation dose was 0.013 mSv, which was approximately 1% of the dose limit for members of the public of 1 mSv (Table 4.1). The trend in doses to seafood consumers 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. The external radiation dose for local houseboat occupants was estimated to be 0.014 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.55 mSv or approximately 55% of the dose limit. The majority of the *total dose* was due to direct radiation from Dungeness 'A' power station.

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 reviewed the authorisations to dispose of radioactive waste from the nuclear power station and produced a summary decision document in March 2007 (Environment Agency, 2007c).

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 2006 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 levels in terrestrial samples were apparent. The 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. A habits survey has examined the potential pathways for radiation exposure due to liquid effluent disposals and this established that exposures could be represented by consumption of local fish and shellfish and external irradiation whilst digging for bait. Technetium analysis in *Fucus vesiculosus* is used as a specific indication of the far-field effects of disposals to sea from Sellafield. In 2004, the sampling and analytical schedule was extended to include new determinations of polonium-210 and other naturally-occurring radionuclides, to consider the possibility of local enhancement of naturally-occurring radionuclides from waste slag historically disposed of from the local iron and steel industries along parts of the River Tees. In 2006, a further assessment of polonium-210 and other naturally-occurring radionuclides was carried out, but with fewer samples than collected in 2005.

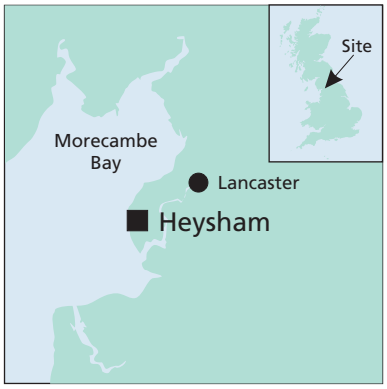
Results of the aquatic monitoring programme carried out in 2006 are shown in Tables 4.5(a) and (b). These include short-lived nuclides detected by gamma-ray spectrometry from the naturally-occurring decay series. Concentrations of carbon-14 were enhanced above a background of approximately 25 Bq kg^{-1} 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 reduced and less than the peak observed in 1998 (see also Figure 2.20). They are less than 1% of the equivalent concentrations near Sellafield. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. In 2006, the concentrations of lead-210 and polonium-210 found in winkles from Paddy's Hole (2.6 and 23 Bq kg^{-1}, respectively) were above those expected due to natural sources. These results are consistent with values for winkles from Paddy's Hole obtained from sampling and analysis undertaken in 2004 and 2005. 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 in sea defences, and/or the build up of naturally-occurring gamma-ray-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time. The critical occupancy group does not spend time at Paddy's Hole. Data for other naturally-occurring radionuclides, locations and species in the Hartlepool area were well within the range of concentrations expected for natural sources.

Doses to the public

The critical group dose from consumption of locally grown foodstuffs was estimated to be less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv. The radiation dose to local fish and shellfish consumers, including external radiation but excluding naturally-occurring radionuclides in seafood, was low, at less

than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (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 did not identify any consumption of molluscs from Paddy's Hole. However, in the unlikely event that some of these molluscs did enter the diet of the critical group of fish and shellfish consumers, it is estimated that an additional dose from naturally-occurring radionuclides of 0.060 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 2006. 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% 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 reviewed the authorisations to dispose of radioactive waste from the nuclear power station (Heysham 1 and 2) and produced a summary decision document in March 2007 (Environment Agency, 2007c). A habits survey was undertaken in September 2006. Variations in consumption and occupancy rates have been observed, including an increase in fish consumption and a decrease in mollusc consumption. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. Data for 2006 are presented in Table 4.6(a). The effects of gaseous disposals were also difficult to detect in 2006. Small enhancements of concentrations of carbon-14 were apparent in some samples.

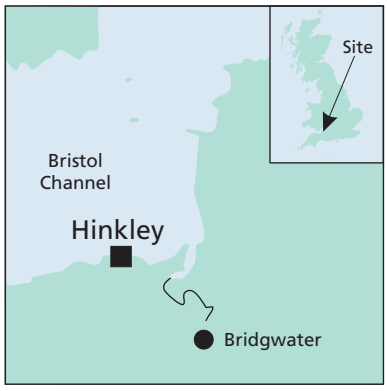
Liquid waste discharges and aquatic monitoring

The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates, but for completeness the data considered in this section include all of that for Morecambe Bay. A substantial part of the programme is therefore in place in order to monitor the effects of Sellafield disposals. The results for 2006 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2005 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

The critical group dose from consumption of locally grown foodstuffs was estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. The radiation dose in 2006 to the critical group of fishermen, including a component due to external radiation, was 0.038 mSv, which is well within the dose limit for members of the public of 1 mSv (Table 4.1) 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. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.037 mSv or less than 4% 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. The Environment Agency has reviewed the authorisations to dispose of radioactive waste from the nuclear power station at Hinkley Point B and produced a summary decision

document in March 2007 (Environment Agency, 2007c). A habits survey was undertaken in May/June 2006. Small variations in consumption rates 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. Environmental monitoring covers the effects of the two power stations together.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. Data for 2006 are presented in Table 4.7(a). Results indicate a small enhancement of radioactivity levels due to disposals of gaseous wastes. Activity concentrations of tritium and gamma emitters in terrestrial materials were all below the limits of detection. Concentrations of sulphur-35 showed the effects of the power stations and some of the concentrations of carbon-14 were higher than the default values used to represent background levels (Appendix 1). Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

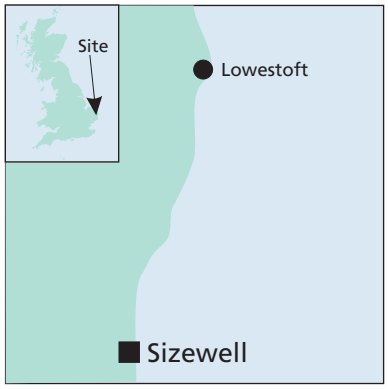
Authorised discharges of radioactive liquid effluent from both power stations are made via a common cooling water outlet to the Bristol Channel. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were also carried out. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the GE Healthcare plant at Cardiff. The environmental results for 2006 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 2005 (see also Figure 4.1). Concentrations of tritium and carbon-14 in cod and shrimps were similar to their levels in 2005. Further information of tritium levels 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 levels detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from GE Healthcare, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment, measured using portable instruments, increased by small amounts in some locations when compared with 2005.

Doses to the public

The estimated critical group dose due to radioactivity in the terrestrial environment was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. The critical group of local fishermen was estimated to receive a dose, including a component due to external radiation, of 0.040 mSv, which was 4% of the dose limit for members of the public of 1 mSv (Table 4.1). This estimate also includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1). The increase in dose, from 0.018 mSv in 2005, was mainly due to an increase in occupancy observed in the recent habits survey and to a smaller extent due to enhanced gamma dose rates, which, combined accounted for an external radiation dose of 0.038 mSv in 2006. There is no site related reason to account for the increase 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 0.048 mSv or less than 5% of the dose limit. Trends in doses in the area of the Severn Estuary are shown in Figure 6.4.

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 reviewed the authorisations to dispose of radioactive waste from the nuclear power station at Sizewell B and produced a summary decision document in March 2007 (Environment Agency, 2007c).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. The results of the terrestrial monitoring in 2006 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 2006. Concentrations of activity in local freshwater were all low. In April 2006, the site operators for the 'A' station reported that levels for total carbon-14 were close to exceeding the weekly advisory level. As a precautionary measure, the Food Standards Agency undertook extra analyses of carbon-14 in

samples of local milk but found no elevated concentrations of this radionuclide. The Environment Agency instigated *ad hoc* sampling and analysis of soil and grass. Three suitable sampling locations were identified. These were situated close to the perimeter fence and approximately 100 metres apart. In addition, a sample was also taken from the Visitor Centre for background purposes. Subsequent analysis of these samples revealed that all carbon-14 analyses were below the analytical detection limit apart from one grass sample. This was marginally above the LoD, but the concentration was of no radiological significance.

Liquid waste discharges and aquatic monitoring

Authorised discharges of radioactive liquid effluent from both power stations are made via adjacent 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 2006 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 levels in seafood were all below the limits of detection. Measured gamma dose rates in intertidal areas were difficult to distinguish from the natural background except at Sizewell Beach where direct radiation from the station is known to have a local effect.

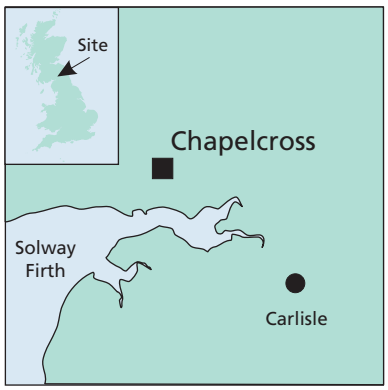
Doses to the public

The estimated dose to the critical group of consumers eating locally grown foodstuffs was less than 0.005 mSv. However, after making an allowance for concentrations of radionuclides in air using the methods and data in Appendix 1, the critical group dose in 2006 was 0.059 mSv or approximately 6% of the dose limit for members of the public of 1 mSv. The increase in dose, from 0.057 mSv in 2005, was due to the marginally higher discharges of argon-41 in 2006. In 2006, the radiation dose to local fish and shellfish consumers was low, at less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 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 assessment includes a contribution for external exposure based on a calculation using concentrations of radionuclides in sediment. The estimated dose to the critical group of consumers eating local foods 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 0.091 mSv or less than 10% of the dose limit.

SCOTLAND

4.8 Chapelcross, Dumfries and Galloway

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



Habits surveys have been used to investigate aquatic and terrestrial exposure pathways. The most recent habits survey was conducted during July 2005. This survey confirmed the existence of local fishermen who eat large quantities of local seafood and are also exposed to external radiation whilst tending stake nets. A further group was identified consisting of wildfowlers who were exposed to external radiation whilst on salt marshes.

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 2006. 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 air monitoring in 2006 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 2005. The maximum concentration of tritium in milk decreased from 160 Bq l^{-1} in 2005 to 38 Bq l^{-1} in 2006, and is consistent with values in previous years. 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 at locations near to the site were very low (Table 4.9(c)).

During 2006, SEPA undertook monitoring of water from in and around the Chapelcross Site. The sample points included several points along the Gullielands burn and a groundwater sample taken from a trial pit on the Site. Data are presented in Table 4.9(a). The analysis of these samples served as a comparison for similar samples routinely taken by the Site. Each sample was found to contain very low concentrations of tritium at levels consistent with those measured by the Site.

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 2006 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 and gamma dose rates in intertidal areas remained at similar levels to those detected in recent years. 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. This area is monitored frequently by Magnox Electric Limited. In 2006, this monitoring resulted in three items being detected with radioactivity levels above background. This compares with 95 items in 2005, 3 in 2004, 21 items in 2003, 3 in 2002, 1 in 2001 and 3 in 2000. The relatively high numbers found in 2005 were due to a series of incidents including a flooding event that was the result of exceptionally heavy rainfall in the area. All contaminated items detected are removed by Magnox Electric Limited and taken back to Chapelcross for analysis and appropriate disposal. SEPA carried out additional monitoring in the vicinity of the pipeline during 2005 and again in November 2006 and did not find any items above normal background levels. For a number of years there has been a plan to build a new filter house to reduce this problem. However, delays to the construction of this filter house and the nature of some of the incidents during 2005 have resulted in a review of all options for improving the pipeline such that the limescale problem is eliminated in the long term. During 2005, Magnox Electric Limited made several interim improvements, both physical and procedural, to the end of line strainer system. Additionally, improvements further up the pipeline have been made to reduce the risk of further flooding events. A project to de-scale the discharge pipeline will begin in the second quarter of 2007. This, combined with the changes in the volume and chemistry of the water in the discharge pipeline, will significantly reduce the probability of active debris being discharged in the future.

Doses to the public

The annual dose to the critical group of terrestrial food consumers was estimated to be 0.028 mSv, which was approximately 3% of the dose limit for members of the public of 1 mSv. The dose in 2005 was similar at 0.025 mSv. No argon-41 was discharged in 2006 and the entire dose is due 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 0.021 mSv in 2006, which was approximately 2% of the dose limit for members of the public of 1 mSv (Table 4.1). A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the dose to the local population; the greater proportion of the dose can be attributed to the emissions from Sellafield.

The habits survey in 2005 confirmed the existence of consumers of wildfowl and their occupancy over salt marsh. Samples of wildfowl were monitored in 2006 and an assessment has been undertaken using the new data. The total exposure to wildfowlers including external dose was 0.006 mSv, which is 0.6% of the dose limit for members of the public of 1 mSv (Table 4.1). The dose from consumption of wildfowl was less than 0.005 mSv. The annual dose from inhaling air containing caesium-137 at these concentrations was estimated to be much less than 0.005 mSv. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.024 mSv or approximately 2% 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 Generation Limited, while Hunterston 'A' is operated by Magnox Electric Limited (part of BNG). Hunterston 'A' was powered by twin Magnox reactors and Hunterston 'B' is powered by a pair of AGRs. Hunterston 'A' ceased electricity power production at the end of March 1990. Environmental monitoring in the area considers the effects of both sites together.

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

Changes were proposed for many of the limits in the certificates of authorisation in force at Hunterston. Historically it has been SEPA's practice to grant to the nuclear industry separate certificates of authorisation for each medium and this has required separate applications to be made for each certificate. SEPA has developed a multi-media certificate of authorisation that will encompass all radioactive waste disposal form the premises. The multi-media certificate for Hunterston Power Station came into effect on 1 June 2007. Following the statutory outage during the summer, problems were discovered with the boiler tubes which resulted in both reactors being shutdown for the remainder of 2006.

The most recent habits survey undertaken in 2001 resulted in three potential critical groups being identified: seafood consumers, terrestrial food consumers and a group of professional shellfish collectors who have a high occupancy time over intertidal areas. The results from the monitoring programme are used to quantify the dose to each critical group.

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 2006 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.

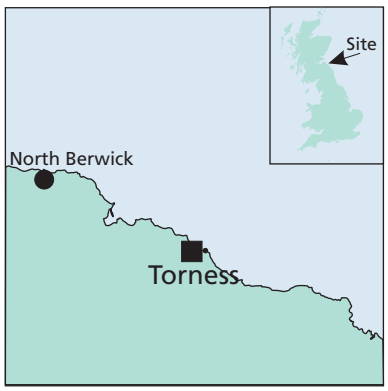
The results of aquatic monitoring in 2006 are shown in Tables 4.10(a) and (b). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs around Hunterston were similar to those in 2005. There was a decrease in technetium-99 concentrations in the common lobster from 2005 to 2006. 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.

Doses to the public

The radiation dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was estimated to be 0.023 mSv which was approximately 2% of the dose limit for members of the public of 1 mSv (Table 4.1). The estimated dose in 2005 was 0.010 mSv. The increase in dose was largely attributable to the inclusion of the LoD for americium-241 analysis in the food pathway assessment, which in line with the rules on use of results for dose calculations was included due to a small, but detectable, activity in soil. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. In 2006, the dose to the critical group from consumption of fish and shellfish was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 4.1). This includes a contribution from the Sellafield-derived technetium-99 in shellfish. The dose to a separate critical group of shellfish collectors who use local beaches was 0.009 mSv or approximately 1% of the dose limit. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.097 mSv or less than 10% 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.



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

In December 2005, British Energy Generation Limited requested that the Certificate of Authorisation for the on site waste oil burner be revoked. The waste oil burner had never been used to burn radioactively contaminated waste

oil. SEPA revoked this Certificate of Authorisation on 12 April 2006.

In December 2005, British Energy Generation Limited applied to SEPA to vary the Certificate of Authorisation to dispose of liquid solid and liquid combustible radioactive waste from Torness Power Station to an off-site incinerator. The purpose of the variation is to remove specific reference to Rechem International Limited, the named operator of the incinerator at Hythe. This variation was granted on 1 June 2006.

In March 2006, SEPA issued a public consultation on the six applications from British Energy Generation Limited for the authorisation to dispose of radioactive wastes from Torness Power Station (Scottish Environment Protection Agency, 2006b). Changes are being proposed for many of the limits in the certificates of authorisation currently in force at Torness. Historically it has been SEPA's practice to grant to the nuclear industry separate certificates of authorisation for each medium and this has required separate applications to be made for each certificate. SEPA has developed a multi-media certificate of authorisation that will encompass all radioactive waste disposal form the premises. The multi-media certificate for Torness Power Station came into effect on 1 June 2007.

A habits survey was undertaken in July 2006. Consumption rates of fish and handling rates of fishing gear decreased, whilst consumption of crustacean and occupancy rates increased. The consumption of winkles was also identified. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1. 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 2006 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.

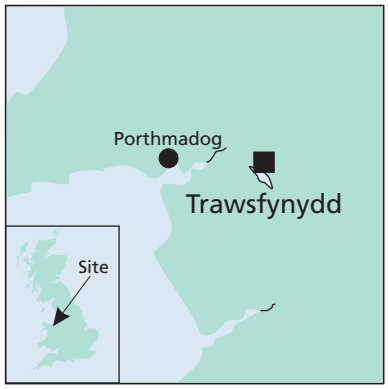
The results of the aquatic monitoring in 2006 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout, although trace concentrations of activation products were detected which were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2005, except in lobster where a small positive result was measured. Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates on beaches were generally indistinguishable from natural background though data for St Abbs and Dunbar were higher.

Doses to the public

The dose to the critical group of terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout was 0.016 mSv, which was less than 2% of the dose limit for members of the public of 1 mSv. The decrease in dose from 0.027 mSv in 2005 was due to the lower LoD for americium-241 in milk in 2006. 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% of the dose limit for members of the public of 1 mSv (Table 4.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.024 mSv or approximately 2% 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 2006 under an authorisation granted by the Environment Agency. Monitoring is carried out 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. The most likely source of radiocaesium in the one terrestrial food (blackberries) where a value above

the LoD was found is fallout from Chernobyl and weapon tests though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also carried out in crop and animal samples. Detected activities were low and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was no evidence of resuspension of activity in sediment from the lakeshore contributing to increased exposure from transuranic radionuclides in 2006.

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 2006 are presented in Tables 4.8(a) and (b). Concentrations of radiocaesium in fish in 2006 were similar to those in 2005. The activity concentrations in sediments and the activity in the fish that result from discharges from earlier years (and maintained in the water column by processes such as remobilisation) predominate at this stage. Low concentrations of other radionuclides including actinides are also detected, particularly in lake sediments. However, the actinide concentrations in fish are very low and it is the effects of caesium-137 which dominate the fish consumption and external radiation pathways.

In 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 2005. The predominant radionuclide is caesium-137. The time trend of concentrations of caesium-137 in sediments is shown in Figure 4.3. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. The observed levels now are mainly affected by sample variability.

Doses to the public

The critical group for terrestrial foods at Trawsfynydd in 2006 received doses of 0.007 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to the critical group of anglers was 0.008 mSv in 2006, which was less than 1% of the dose limit for members of the public of 1 mSv. The observed concentrations in lake sediments are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels. 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% of the dose limit.

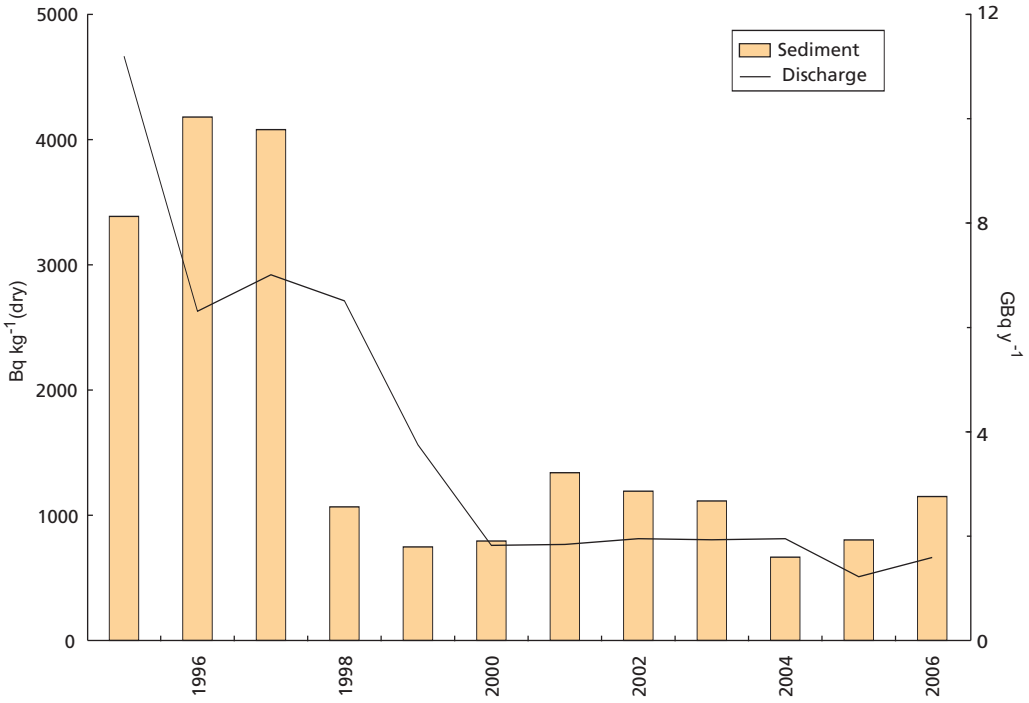
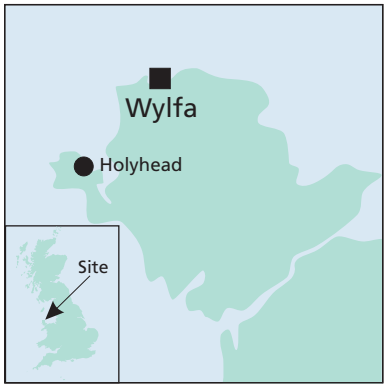


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake

4.12 Wylfa, Isle of Anglesey



Wylfa power station is located on the north coast of Anglesey and generates electricity from two Magnox reactors. It is scheduled for closure in 2010. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is carried out on behalf of the Welsh Assembly Government. In June 2006, the site operators reported that the weekly advisory levels had been exceeded. The Food Standards Agency undertook extra analyses of tritium and carbon-14 in samples of local milk but found no elevated concentrations of either radionuclide.

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. Data for 2006 are presented in Table 4.13(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 levels slightly above background values. Overall the effects of discharges are very low. Total alpha and total beta concentrations in surface waters were less than the WHO screening levels.

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 2006 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 2005, and continued to show the effects of technetium-99 from Sellafield. Gamma dose rates, measured using portable instruments, were similar to those found in 2005.

Doses to the public

The dose received by high-rate terrestrial food consumers remained low at 0.005 mSv which was 0.5% of the dose limit for members of the public. The dose to the critical group of high-rate fish and shellfish consumers was low, at 0.006 mSv, which was less than 1% of the dose limit for members of the public of 1 mSv (Table 4.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.009 mSv or less than 1% of the dose limit.

Table 4.1. Individual radiation exposures – nuclear power stations, 2006

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	0.012	<0.005	-	0.010	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005
Bradwell	Seafood consumers	0.010	<0.005	-	0.008	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
Dungeness	Seafood consumers	0.013	<0.005	-	0.010	-
	Houseboat occupants	0.014	-	-	0.014	-
	Inhabitants and consumers of locally grown food	0.13	-	<0.005	-	0.13
	All sources[d]	0.55	-	-	-	-
Hartlepool	Seafood consumers[c]	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	All sources[d]	0.021	-	-	-	-
Heysham	Seafood consumers	0.038	0.015	-	0.023	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	All sources[d]	0.037	-	-	-	-
Hinkley Point	Seafood consumers	0.040	<0.005	-	0.038	-
	Consumers of locally grown food[b]	<0.005	-	<0.005	-	-
	All sources[d]	0.048	-	-	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.059	-	<0.005	-	0.058
	All sources[d]	0.091	-	-	-	-
Scotland						
Chapelcross	Seafood consumers	0.021	<0.005	-	0.019	-
	Wildfowlers	0.006	-	<0.005	0.005	-
	Consumers of locally grown food[b]	0.028	-	0.028	-	-
	All sources[d]	0.024	-	-	-	-
Hunterston	Seafood consumers	<0.005	<0.005	-	-	-
	Beach occupants	0.009	-	-	0.009	-
	Consumers of locally grown food[b]	0.023	-	0.023	-	-
	All sources[d]	0.097	-	-	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	0.016	-	0.016	-	-
	All sources[d]	0.024	-	-	-	-
Wales						
Trawsfynydd	Anglers	0.008	<0.005	-	<0.005	-
	Consumers of locally grown food[b]	0.007	-	0.007	-	-
	All sources[d]	0.022	-	-	-	-
Wylfa	Seafood consumers	0.006	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	0.005	-	<0.005
	All sources[d]	0.009	-	-	-	-

[a] *Adults are the most exposed age group unless stated otherwise*
[b] *Children aged 1y*
[c] *Excluding possible enhancement of naturally occurring radionuclides. See Section 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, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{134}Cs	^{137}Cs	^{155}Eu	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25		<0.11	0.14	<0.17	
Bass	River Severn	1	870		<0.24	3.6	<0.49	
Cod	River Severn	1			<0.18	0.71	<0.23	
Elvers	River Severn	1	<25		<0.11	0.18	<0.25	
Shrimps	Guscar	2	380	38	<0.20	<0.41	<0.35	0.00021
Sediment	Hills Flats	2[E]				24		
Sediment	1 km south of Oldbury	2[E]				36		
Sediment	2 km south west of Berkeley	1[E]				40		
Sediment	Sharpness	2[E]				32		
Seawater	Local beach	2[E]			<0.17	<0.15		

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	Total alpha	Total beta
Marine samples								
Salmon	Beachley	2		<0.09				
Bass	River Severn	1		<0.66				
Cod	River Severn	1		<0.12				
Elvers	River Severn	1		<0.22				
Shrimps	Guscar	2	0.0014	0.0012	0.000020	0.000012		
Sediment	Hills Flats	2[E]		<1.2				
Sediment	1 km south of Oldbury	2[E]		<1.8				
Sediment	2 km south west of Berkeley	1[E]		<1.9				
Sediment	Sharpness	2[E]		<1.7				
Seawater	Local beach	2[E]					<1.6	11

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	Total alpha	Total beta
Terrestrial samples									
Milk		9	<4.8	16	<0.30	<0.19	<0.20		
Milk	max		<5.0	20	<0.40	<0.20			
Apples		1	<4.0	14	<0.20	<0.20	<0.20		
Blackberries		1	<5.0	20	0.50	<0.20	<0.20		
Honey		1	<8.0	69	<0.20	<0.20	<0.10		
Lettuce		1	<4.0	<2.0	0.80	<0.20	<0.20		
Onions		1	<5.0	3.0	0.30	<0.20	<0.20		
Potatoes		1	<5.0	22	0.40	<0.20	<0.30		
Runner beans		1	<5.0	9.0	0.50	<0.20	<0.20		
Wheat		1	<8.0	84	2.4	<0.20	<0.20		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.0		<1.4	<0.21	<0.18	<0.060	<0.22
Freshwater	Public supply	2[E]	<4.0		<1.1	<0.29	<0.25	<0.040	0.26

[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*

[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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
1 km south of Oldbury	Grass and mud	1	0.086
1 km south of Oldbury	Grass and salt marsh	1	0.080
2 km south west of Berkeley	Mud and stones	1	0.075
2 km south west of Berkeley	Mud and rock	1	0.072
Guscar Rocks	Mud and salt marsh	1	0.080
Guscar Rocks	Salt marsh	1	0.081
Lydney Rocks	Mud and salt marsh	1	0.098
Lydney Rocks	Salt marsh	1	0.094
Sharpness	Grass and mud	1	0.075
Sharpness	Grass and salt marsh	1	0.081
Hills Flats	Mud and sand	1	0.087
Hills Flats	Grass and mud	1	0.076
Aust Rock	Mud	2[F]	0.084

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

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2006

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			<0.09	0.80		
Bass	Pipeline	1			<0.20	1.0		
Mullet	Pipeline	1			<0.07	0.91		
Lobsters	West Mersea	1			<0.08	0.33		
Native oysters	Tollesbury N. Channel	1			<0.11	0.40	0.00037	0.0019
Pacific oysters	Goldhanger Creek	2			<0.09	0.29		
Winkles	Pipeline	2			<0.17	0.83		
Winkles	Heybridge Basin	2			<0.17	0.62		
Seaweed	Bradwell	2[E]		13	<0.73	<1.9		
Leaf beet	Tollesbury	1			<0.06	<0.05		
Samphire	Tollesbury	1			<0.02	0.20		
Sediment	Pipeline	2[E]	<2.0			11		
Sediment	Waterside	2[E]	<1.5			36		
Sediment	West Mersea Beach Huts	2[E]	<1.0			3.7		
Sediment	West Mersea 2	2[E]	<1.0			15		
Sediment	Maldon	2[E]	<1.5			67		
Sediment	N side Blackwater Estuary	2[E]	<2.0			31		
Seawater	Bradwell	2[E]			<0.30	<0.29		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples							
Sole	Bradwell	2	<0.15				
Bass	Pipeline	1	<0.12				
Mullet	Pipeline	1	<0.27				
Lobsters	West Mersea	1	<0.07				
Native oysters	Tollesbury N. Channel	1	0.0040	*	0.00018		
Pacific oysters	Goldhanger Creek	2	<0.12				
Winkles	Pipeline	2	<0.11				
Winkles	Heybridge Basin	2	<0.11				
Seaweed	Bradwell	2[E]	<1.1				
Leaf beet	Tollesbury	1	<0.04				
Samphire	Tollesbury	1	<0.02				
Sediment	Pipeline	2[E]	<2.6				
Sediment	Waterside	2[E]	<2.1				
Sediment	West Mersea Beach Huts	2[E]	<2.2				
Sediment	West Mersea 2	2[E]	<1.9				
Sediment	Maldon	2[E]	<2.0				
Sediment	N side Blackwater Estuary	2[E]	<2.2				
Seawater	Bradwell	2[E]	<0.57			<1.7	20

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	Total alpha	Total beta
Terrestrial samples								
Milk		5	<4.8	15		<0.20		
Milk	max		<5.0	17				
Apples		1	<4.0	8.0		<0.30		
Blackberries		1	<5.0	14		<0.30		
Cabbage		1	<5.0	7.0		<0.20		
Carrots		1	<5.0	6.0		<0.30		
Lucerne		1	<4.0	5.0		<0.30		
Potatoes		1	<5.0	20		<0.30		
Rabbit		1	8.0	16		<0.30		
Wheat		1	<8.0	81		<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.23	<0.040	0.38
Freshwater	Coastal ditch 3	1[E]	31		<1.5	<0.090	<0.80	16

* *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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Sand and shingle	2	0.068
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.068
Beach opposite power station, N side of estuary	Salt marsh	1	0.071
Waterside	Mud	1	0.052
Waterside	Mud and salt marsh	1	0.066
Maldon	Mud	1	0.063
Maldon	Mud and salt marsh	1	0.062
West Mersea Beach Huts	Mud and sand	1	0.053
West Mersea Beach Huts	Sand and shingle	1	0.056
West Mersea	Mud and shingle	2	0.058

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2006

Material	Location	No. of sampling observations	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		<0.13			<0.13
Cod	Pipeline	1		<25		<0.06			0.19
Whiting	Pipeline	1		<25		<0.05			0.21
Bass	Pipeline	1		<25		<0.06			0.34
Sole	Pipeline	1	<25	<25		<0.05			0.12
Crabs	Eastbourne/ Folkestone landed	1				<0.07			<0.07
Shrimps	Pipeline	2	<25	<25	34	<0.08			0.11
Scallops	Pipeline	2				<0.10	<0.043		<0.09
Sea kale	Dungeness Beach	1				<0.03			0.10
Seaweed	Copt Point	2[E]				<1.3		2.8	<1.1
Mud and sand	Rye Harbour	2				<0.60			1.2
Sediment	Rye Harbour 1	2[E]				<0.48			1.1
Sediment	Rye Harbour 2	2[E]				<0.70			<0.83
Sediment	Camber Sands	2[E]				<0.32			<0.33
Sediment	Pilot Sands	1[E]				<0.32			<0.25
Seawater	Pipeline	2		3.8					
Seawater	Dungeness South	2[E]				<0.14			<0.11

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	1			<0.27				
Cod	Pipeline	1			<0.06				
Whiting	Pipeline	1			<0.23				
Bass	Pipeline	1			<0.06				
Sole	Pipeline	1			<0.25				
Crabs	Eastbourne/ Folkestone landed	1			<0.20				
Shrimps	Pipeline	2			<0.20				
Scallops	Pipeline	2	0.00046	0.0021	0.0011	*	0.000052		
Sea kale	Dungeness Beach	1			<0.03				
Seaweed	Copt Point	2[E]			<1.9				
Mud and sand	Rye Harbour	2	0.065	0.33	0.31	*	0.013		
Sediment	Rye Harbour 1	2[E]			<0.68				580
Sediment	Rye Harbour 2	2[E]			<2.2				440
Sediment	Camber Sands	2[E]			<1.1				
Sediment	Pilot Sands	1[E]			<0.50				
Seawater	Dungeness South	2[E]			<0.28			<2.8	21

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	Total alpha	Total beta
Terrestrial Samples									
Milk		2	<4.9	14	<0.23	<0.21	<0.20		
Milk	max		<5.0		<0.25	<0.23			
Blackberries		1	<4.0	15	<0.20	<0.20	<0.30		
Cabbage		1	<4.0	9.0	1.1	<0.20	<0.20		
Onions		1	<5.0	5.0	0.40	<0.20	<0.20		
Potatoes		1	<4.0	12	0.40	<0.30	<0.30		
Sea kale		1	<4.0	10	2.3	<0.10	0.30		
Wheat		1	<8.0	63	0.70	<0.10	<0.30		
Grass		1				<0.30	<0.30		
Freshwater	Long Pits	2[E]	<4.3		<1.0	<0.21	<0.18	<0.045	0.25
Freshwater	Pumping station Well number 1	1[E]	<4.0		<1.0	<0.33	<0.27	<0.020	0.29
Freshwater	Pumping station Well number 2	1[E]	<4.0		<1.0	<0.16	<0.13	<0.030	0.40
Freshwater	Reservoir	1[E]	<4.0		<1.6	<0.34	<0.27	<0.020	0.12

** Not detected by the method used*

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

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

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

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

Table 4.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2006

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	1	0.051
Littlestone-on-Sea	Shingle	1	0.053
Greatstone-on-Sea	Sand	1	0.060
Greatstone-on-Sea	Sand and shingle	1	0.060
Dungeness East	Sand and shingle	2	0.058
Dungeness South	Shingle	2	0.051
Jury's Gap	Sand and shingle	2	0.056
Rye Bay	Sand and shingle	2	0.057
Rye Harbour	Mud and sand	2[F]	0.068
Mean beta dose rates			μSv h^{-1}
Rye Harbour	Mud and sand	2[F]	<0.025

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

Table 4.5(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{7}Be	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{208}Tl
Marine samples											
Plaice	Pipeline	2	<25	<26		29	<0.11		*	0.23	
Cod	Pipeline	2					<0.05		*	0.27	
Crabs	Pipeline	2				44	<0.06		*	<0.06	
Winkles	Paddy's Hole	1	<25	<25			<0.05		*	0.38	
Winkles	South Gare	1	<25	<25			<0.07		*	0.24	
Mussels	South Gare	2					<0.05		*	0.06	
Mussels	Seal Sands	1				230					
Fucus vesiculosus	Pilot Station	2					<0.05	30	*	0.11	
Seaweed	Pilot Station	2[E]					<1.1	43	20	<0.81	
Sediment	Old Town Basin	2[E]					<0.39			2.5	
Sediment	Seaton Carew	2[E]					<0.30			<0.42	
Sediment	Paddy's Hole	2[E]			<28		<0.97			16	15
Sediment	North Gare	2[E]			<5.4		<0.43			<0.36	2.0
Sediment	Greatham Creek	2[E]			<32		<0.36			9.1	17
Sea coal	Old Town Basin	2[E]					<0.62			<0.53	
Sea coal	Carr House Sands	2[E]					<0.42			<0.41	
Seawater	North Gare	2		<3.4							
Seawater	North Gare	2[E]					<0.31			<0.25	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{210}Pb	^{210}Po	^{212}Pb	^{212}Bi	^{214}Pb	^{214}Bi	^{228}Ac	^{234}Th	^{234}Pa
Marine samples											
Plaice	Pipeline	2			*			*	*	*	
Cod	Pipeline	2			<0.03			*	*	*	
Crabs	Pipeline	2			*			<0.08	*	*	
Winkles	Paddy's Hole	1	2.6	23	1.1			0.79	1.0	*	
Winkles	South Gare	1		10	*			*	*	*	
Mussels	South Gare	2			<0.14			0.19	*	*	
Fucus vesiculosus	Pilot Station	2			0.19			0.41	1.1	*	
Sediment	Paddy's Hole	2[E]			46	55	34	33	40	640	<80
Sediment	North Gare	2[E]			5.8	<23	6.9	7.1	6.5	<56	<21
Sediment	Greatham Creek	2[E]			53	60	32	31	44	190	<16

Table 4.5(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	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.10				
Cod	Pipeline	2			<0.06				
Crabs	Pipeline	2	0.00023	0.0015	0.0017	*	0.000012		
Winkles	Paddy's Hole	1	0.011	0.071	0.035	*	0.000072		
Winkles	South Gare	1			<0.08				
Mussels	South Gare	2			<0.10				
Fucus vesiculosus	Pilot Station	2			<0.11				
Seaweed	Pilot Station	2[E]			<1.4				
Sediment	Old Town Basin	2[E]			<0.67				
Sediment	Seaton Carew	2[E]			<0.55				
Sediment	Paddy's Hole	2[E]			<1.6				1200
Sediment	North Gare	2[E]			<0.71				220
Sediment	Greatham Creek	2[E]			<1.2				800
Sea coal	Old Town Basin	2[E]			<1.0				
Sea coal	Carr House Sands	2[E]			<0.84				
Seawater	North Gare	2[E]			<0.38			<2.2	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	Total alpha	Total beta
Terrestrial samples								
Milk		6	<4.5	15	<0.23	<0.21		
Milk	max		<4.8	20	<0.28	<0.23		
Apples		1	16	4.0	<0.20	<0.30		
Beetroot		1	<5.0	11	0.30	<0.30		
Blackberries		1	<4.0	13	<0.20	<0.20		
Cabbage		1	<5.0	23	<0.30	<0.20		
Honey		1	<7.0	74	<0.20	<0.30		
Potatoes		1	<5.0	16	0.20	<0.20		
Runner beans		1	<5.0	12	0.40	<0.30		
Wheat		1	<8.0	110	1.3	<0.30		
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.17	<0.055	0.15
Freshwater	Borehole, Dalton Piercy	2[E]	<4.0		<1.0	<0.10	<0.075	0.15

** 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, 2006

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
Fish Sands	Sand	1	0.066
Fish Sands	Rock and sand	1	0.066
Old Town Basin	Mud and sand	1	0.073
Old Town Basin	Sand	1	0.058
Carr House	Sand	2	0.060
Seaton Carew	Sand	2	0.065
Seaton Sands	Sand	2	0.061
North Gare	Sand	2	0.061
Paddy's Hole	Mud and pebbles	2	0.17
Greatham Creek Bird Hide	Mud	1	0.084
Greatham Creek Bird Hide	Salt marsh and mud	1	0.078

Table 4.6(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2006

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	3			110	<0.18			<1.8
Plaice	Flookburgh	1				<0.12			<1.0
Plaice	Morecambe	4	<30	48		<0.13	0.10	0.46	<1.5
Bass	Morecambe	2				<0.10			<1.2
Whitebait	Sunderland Point	1				<0.09	0.11		<0.89
Shrimps	Flookburgh	4			89	<0.09		1.8	<0.85
Cockles	Middleton Sands	2				1.3			<0.65
Cockles[b]	Flookburgh	1			97	1.6	0.37	5.8	<0.50
Winkles	Red Nab Point	4				0.45			<1.0
Mussels	Morecambe	4	<110	140	99	0.41		160	<1.4
Fucus vesiculosus	Half Moon Bay	4				0.38		670	<0.92
Seaweed	Half Moon Bay	2[E]				<0.97		280	<6.2
Sediment	Flookburgh	1[E]				<0.51			<3.7
Sediment	Half Moon Bay	2[E]				<1.3			
Sediment	Pott's Corner	2[E]				<0.61			
Sediment	Heysham pipelines	2[E]				<0.84			
Sediment	Morecambe Central Pier	2[E]				2.2			
Sediment	Sunderland Point	4[E]				<1.1			<3.4
Sediment	Conder Green	4[E]				1.5			<4.5
Sediment	Sand Gate Marsh	4[E]				<0.97			<4.3
Turf	Conder Green	4				3.6			<11
Turf	Sand Gate Marsh	4				<1.0			<9.7
Samphire	Cockerham Marsh	1				<0.04			<0.42
Seawater	Pipeline	1		20					
Seawater	Heysham Harbour	2[E]				<0.18			<1.5

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	3	<0.48	<0.19	13	<0.34	0.00032	0.0016	
Plaice	Flookburgh	1	<0.26	<0.12	5.6	<0.19			
Plaice	Morecambe	4	<0.35	<0.14	4.8	<0.33			
Bass	Morecambe	2	<0.30	<0.11	16	<0.25			
Whitebait	Sunderland Point	1	<0.23	<0.09	5.3	<0.24	0.039	0.25	1.9
Shrimps	Flookburgh	4	<0.22	<0.09	5.2	<0.19	0.0041	0.025	0.11
Cockles	Middleton Sands	2	0.43	<0.07	3.3	<0.12	0.39	2.3	
Cockles[b]	Flookburgh	1	0.42	<0.05	4.4	<0.15	0.43	2.4	18
Winkles	Red Nab Point	4	0.56	<0.07	3.8	<0.16	0.19	1.1	
Mussels	Morecambe	4	0.50	<0.06	2.5	<0.15	0.26	1.4	
Fucus vesiculosus	Half Moon Bay	4	0.68	<0.11	5.2	<0.22			
Seaweed	Half Moon Bay	2[E]	<5.0	<0.83	5.5				
Sediment	Flookburgh	1[E]	<4.0	<0.44	110	<1.1			
Mud and sand	Half Moon Bay	1					12	67	
Sediment	Half Moon Bay	2[E]			24				
Sediment	Pott's Corner	2[E]			30				
Sediment	Heysham pipelines	2[E]			24				
Sediment	Morecambe Central Pier	2[E]			150				
Sediment	Sunderland Point	4[E]	<3.6	<0.45	66	<1.3			
Sediment	Conder Green	4[E]	<3.8	<2.3	120	<1.2			
Sediment	Sand Gate Marsh	4[E]	<3.8	<0.43	150	<1.4			
Turf	Conder Green	4	7.0	<1.1	270	<2.8			
Turf	Sand Gate Marsh	4	<3.2	<1.1	150	<2.7			
Samphire	Cockerham Marsh	1	<0.11	<0.04	0.91	0.13			
Seawater	Half Moon Bay	1		*	0.20				
Seawater	Heysham Harbour	2[E]		<0.18	<0.20				

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	Total alpha	Total beta
Marine samples							
Flounder	Flookburgh	3	0.0027	*	*		
Plaice	Flookburgh	1	<0.11				
Plaice	Morecambe	4	<0.36				
Bass	Morecambe	2	<0.28				
Whitebait	Sunderland Point	1	0.45	*	0.00046		
Shrimps	Flookburgh	4	0.042	*	0.000025		
Cockles	Middleton Sands	2	5.8	*	0.0072		
Cockles[b]	Flookburgh	1	6.3	*	0.0077		
Winkles	Red Nab Point	4	2.3	*	0.0034		
Mussels	Morecambe	4	2.5	*	0.0026		
Fucus vesiculosus	Half Moon Bay	4	0.90				
Seaweed	Half Moon Bay	2[E]	<4.1				
Sediment	Flookburgh	1[E]	45			180	460
Mud and sand	Half Moon Bay	1	120	*	0.14		
Sediment	Half Moon Bay	2[E]	21				
Sediment	Pott's Corner	2[E]	17				
Sediment	Heysham pipelines	2[E]	24				
Sediment	Morecambe Central Pier	2[E]	140				
Sediment	Sunderland Point	4[E]	55			330	580
Sediment	Conder Green	4[E]	95			450	600
Sediment	Sand Gate Marsh	4[E]	98			430	520
Turf	Conder Green	4	190				
Turf	Sand Gate Marsh	4	92				
Samphire	Cockerham Marsh	1	0.46				87
Seawater	Heysham Harbour	2[E]	<0.46			<2.3	18

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	^{106}Ru	^{137}Cs	Total alpha	Total beta
Terrestrial samples										
Milk		7	<4.8	16	<0.28	<0.24	<1.6	<0.21		
Milk	max		<5.3	18	0.45	<0.25	<1.8	<0.25		
Apples		1	<5.0	4.0	<0.20	<0.30	<1.6	<0.20		
Blackberries		1	<5.0	12	<0.20	<0.30	<1.6	<0.20		
Cabbage		1	<4.0	7.0	<0.30	<0.30	<1.7	<0.20		
Honey		1	<8.0	71	<0.20	<0.20	<1.3	<0.20		
Onions		1	<5.0	7.0	0.20	<0.30	<1.2	<0.20		
Potatoes		1	<5.0	19	<0.20	<0.40	<1.8	<0.30		
Sprouts		1	<5.0	<2.0	0.90	<0.20	<1.0	<0.20		
Wheat		1	<8.0	94	1.2	<0.30	<1.8	<0.30		
Freshwater	Lancaster	2[E]	<4.0		<1.0	<0.22		<0.18	<0.045	<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 12 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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate			
Greenodd Salt Marsh	Salt marsh	2	0.073
Sand Gate Marsh	Salt marsh	4[F]	0.084
Sand Gate Marsh	Salt marsh	3	0.089
Sand Gate Marsh	Grass and mud	1	0.091
Flookburgh	Salt marsh	1	0.080
High Foulshaw	Salt marsh	4	0.079
Arnside 1	Mud and sand	2	0.080
Arnside 1	Sand	2	0.080
Arnside 2	Salt marsh	4	0.094
Morecambe Central Pier	Sand	2	0.076
Half Moon Bay	Rock and sand	2	0.073
Heysham pipelines	Mud and sand	1	0.081
Heysham pipelines	Sand	1	0.079
Middleton Sands	Salt marsh and sand	1	0.075
Middleton Sands	Sand	1	0.077
Sunderland	Mud	3	0.089
Sunderland	Mud and sand	1	0.094
Sunderland Point	Mud	2	0.090
Sunderland Point	Mud and sand	2	0.093
Colloway Marsh	Salt marsh	2	0.10
Lancaster	Grass and mud	4	0.080
Aldcliffe Marsh	Salt marsh	4	0.10
Conder Green	Mud	2	0.086
Conder Green	Grass and mud	2	0.086
Conder Green	Salt marsh	4[F]	0.097

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

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2006

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{54}Mn	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Marine samples												
Cod	Stolford	2	100	120	27	<0.10	<0.10			<0.21	<0.10	0.72
Shrimps	Stolford	2	160	200	36	<0.05	<0.05			<0.13	<0.06	0.36
Whelks	Stolford	1		2000	60	<0.13	<0.12			<0.27	<0.13	0.36
Seaweed	Pipeline	2[E]					<1.2	<0.040	24	<5.9	<0.98	<1.5
Mud	Watchet Harbour	2[E]					<0.68	<1.0				5.7
Sediment	Pipeline	2[E]					<0.50	<2.4				10
Sediment	Stolford	2[E]					<1.2	<2.4				27
Sediment	Steart Flats	2[E]					<1.1	<3.3				16
Sediment	River Parrett	2[E]					<1.2	<4.9				33
Sediment	Weston-Super-Mare	2[E]					<0.42	<2.5				4.7
Sediment	Burnham-On-Sea	2[E]					<0.48	<3.5				5.9
Sediment	Kilve	2[E]					<0.67	<2.0				16
Sediment	Blue Anchor Bay	2[E]					<0.35	<1.8				3.2
Seawater	Pipeline	2[E]					<0.19	<0.030				<0.15

Material	Location	No. of sampling observations	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	Total alpha	Total beta
Marine samples											
Cod	Stolford	2	<0.40	<0.15			<0.08				
Shrimps	Stolford	2	<0.34	<0.15	0.00017	0.00070	0.00079	*	0.0000091		
Whelks	Stolford	1	<0.49	<0.18			<0.10				
Seaweed	Pipeline	2[E]	<3.8				<1.6				
Mud	Watchet Harbour	2[E]					<2.3				
Sediment	Pipeline	2[E]					<0.91				
Sediment	Stolford	2[E]					<1.4				
Sediment	Steart Flats	2[E]					<1.2				
Sediment	River Parrett	2[E]					<3.0				
Sediment	Weston-Super-Mare	2[E]					<1.9				
Sediment	Burnham-On-Sea	2[E]					<1.2				
Sediment	Kilve	2[E]					<1.2				
Sediment	Blue Anchor Bay	2[E]					<1.4				
Seawater	Pipeline	2[E]					<0.46			<2.0	10

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	Total alpha	Total beta
Terrestrial samples								
Milk		6	<4.9	16	<0.35	<0.22		
Milk	max		<5.0	17	<0.53	<0.23		
Apples		1	<5.0	13	0.40	<0.30		
Barley		1	<8.0	79	0.80	<0.30		
Blackberries		1	<4.0	15	1.1	<0.30		
Cabbage		1	<5.0	<3.0	3.2	<0.30		
Honey		1	<7.0	54	<0.20	<0.20		
Onions		1	<5.0	9.0	1.3	<0.20		
Potatoes		1	<4.0	19	1.2	<0.30		
Runner beans		1	<5.0	5.0	0.60	<0.40		
Freshwater	Durleigh Reservoir	2[E]	<4.0		<1.7	<0.14	0.035	0.17
Freshwater	Ashford Reservoir	2[E]	<4.0		<1.3	<0.17	<0.045	<0.17

** Not detected by the method used*

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

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

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

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

Table 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2006

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Mud and sand	1	0.066
Weston-Super-Mare	Sand	3	0.068
Burnham	Mud and sand	1	0.061
Burnham	Sand	3	0.063
River Parrett	Mud and sand	2[F]	0.074
River Parrett	Mud and stones	1	0.071
River Parrett	Mud and rock	3	0.073
Steart Flats	Mud	2	0.079
Steart Flats	Mud and sand	2	0.081
Stolford	Mud and sand	1	0.093
Stolford	Mud and pebbles	1	0.10
Stolford	Mud and slate	1	0.093
Stolford	Mud and rock	1	0.092
Hinkley Point	Mud and pebbles	1	0.094
Hinkley Point	Mud and slate	1	0.095
Hinkley Point	Pebbles and sand	1	0.098
Hinkley Point	Rock	1	0.076
Kilve	Mud and pebbles	2	0.082
Kilve	Pebbles and rock	1	0.087
Kilve	Rock	1	0.099
Watchet Harbour	Pebbles and sand	1	0.097
Watchet Harbour	Pebbles and rock	2	0.10
Watchet Harbour	Rock	1	0.11
Blue Anchor Bay	Mud and sand	1	0.071
Blue Anchor Bay	Pebbles and sand	1	0.064
Blue Anchor Bay	Pebbles and shingle	2	0.071

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

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{110m}Ag	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Aquatic samples									
Cod	Sizewell	2	<25		<0.09	<0.05	0.64		
Sole	Sizewell	2	<25		<0.28	<0.13	0.34		
Crabs	Sizewell	2		31	<0.30	<0.15	0.42	0.000097	0.00065
Lobsters	Sizewell	1			<0.17	<0.08	0.41	0.000051	0.00040
Oysters	Blyth Estuary	1			<0.17	<0.10	0.14		
Pacific oysters	Butley Creek	1			<0.19	<0.09	0.08		
Mussels	River Alde	2	<25		<0.28	<0.14	<0.13		
Sediment	Rifle range	2[E]					<0.39		
Sediment	Aldeburgh	1[E]					<0.51		
Sediment	Southwold	2[E]					12		
Seawater	Aldeburgh	2	8.0						
Seawater	Sizewell	2[E]			<0.23	<0.17	<0.15		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Aquatic samples							
Cod	Sizewell	2	<0.09				
Sole	Sizewell	2	<0.18				
Crabs	Sizewell	2	0.0010	*	0.000024		
Lobsters	Sizewell	1	0.00078	*	0.000036		
Oysters	Blyth Estuary	1	<0.07				
Pacific oysters	Butley Creek	1	<0.17				
Mussels	River Alde	2	<0.35				
Sediment	Rifle range	2[E]	<0.39				
Sediment	Aldeburgh	1[E]	<0.93				
Sediment	Southwold	2[E]	<0.91				
Seawater	Sizewell	2[E]	<0.33			<2.5	21

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	Total alpha	Total beta
Terrestrial samples								
Milk		6	<4.9	15	<0.25	<0.20		
Milk	max		<5.8	18	<0.33			
Apples		1	<5.0	14	0.80	<0.30		
Cabbage		1	<5.0	<3.0	0.70	<0.20		
Carrots		1	<5.0	<3.0	<0.20	<0.30		
Honey		1	<7.0	56	<0.20	<0.20		
Potatoes		1	<4.0	13	0.40	<0.30		
Rabbit		1	<6.0	14	2.1	<0.20		
Runner beans		1	<4.0	<3.0	<0.20	<0.30		
Strawberries		1	<4.0	12	<0.20	<0.30		
Wheat		1	<8.0	90	1.8	<0.30		
Freshwater	Nature Reserve	2[E]	<4.0		<1.0	<0.18	<0.040	0.23
Freshwater	The Meare	2[E]	<4.0		<1.0	<0.11	<0.030	0.49
Freshwater	Leisure Park	2[E]	<4.0		<1.0	<0.23	<0.025	0.30

** Not detected by the method used*

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

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

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

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

Table 4.8(b). Monitoring of radiation dose rates near Sizewell, 2006

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	1	0.12
Sizewell Beach	Shingle	1	0.14
Dunwich	Sand and shingle	2	0.054
Rifle Range	Sand and shingle	1	0.060
Rifle Range	Shingle	1	0.052
Aldeburgh	Sand and shingle	1	0.059
Aldeburgh	Shingle	1	0.050
Southwold Harbour	Mud	1	0.065
Southwold Harbour	Salt marsh and mud	1	0.066

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2006

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	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Marine samples											
Flounder	Inner Solway	4		74	<0.12	<0.40	<0.10	<3.2	0.88	<1.3	<0.21
Salmon	Inner Solway	1	<5.0		<0.10	<0.25		<1.2		<0.66	<0.10
Sea trout	Inner Solway	1	6.0		<0.17	<0.61		<5.4		<1.7	<0.27
Shrimps	Inner Solway	2	<5.2		<0.18	<0.41	<0.10	<0.31	1.9	<1.5	<0.23
Cockles	North Solway	5[F,S]		92	1.9	<0.21	0.77	<0.56	9.9	<0.97	<0.14
Mussels	North Solway	8[F,S]	<5.3	100	<0.54	<0.17	1.1	<0.47	150	<1.2	<0.20
Winkles	Southerness	4	<19		0.84	<0.67	0.22	<1.2	110	<1.9	<0.30
Fucus vesiculosus	Pipeline	4			0.81	<0.21		<0.31	2000	<0.60	<0.13
Fucus vesiculosus	Redkirk	4			0.57	<0.25		<0.59		<0.71	<0.13
Sediment	Southerness	1			0.24	<0.24		<0.15		<0.65	<0.10
Sediment	Pipeline	4	<5.2		1.5	<0.51		<7.5		3.4	<0.21
Seawater	Pipeline	4	9.1		<0.10	<0.10		<0.11		<0.16	<0.10
Seawater	Southerness	4	6.7		<0.10	<0.10		<0.11		<0.18	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples											
Flounder	Inner Solway	4	<0.32	<0.11	16	<0.81	<0.15	<0.28	0.0028	0.017	
Salmon	Inner Solway	1	<0.16	<0.10	0.32	<0.44	<0.10	<0.14			
Sea trout	Inner Solway	1	<0.41	<0.16	2.8	<1.1	<0.18	<0.35			
Shrimps	Inner Solway	2	<0.42	<0.16	4.5	<0.85	<0.21	<0.39	0.0021	0.011	
Cockles	North Solway	5[F,S]	0.59	<0.08	5.0	<0.44	<0.17	<0.19	1.0	5.5	42
Mussels	North Solway	8[F,S]	<0.67	<0.10	<2.8	<0.46	<0.16	<0.21	0.82	2.6	33
Winkles	Southerness	4	<0.81	<0.22	1.0	<1.3	<0.27	<0.52	0.20	1.2	
Fucus vesiculosus	Pipeline	4	<0.84	<0.11	13	<0.37	<0.12	<0.36	1.0	6.0	
Fucus vesiculosus	Redkirk	4	<0.26	<0.10	17	<0.46	<0.12	<0.31			
Sediment	Southerness	1	0.81	<0.10	14	<0.64	<0.16	<0.27	2.0	11	
Sediment	Pipeline	4	2.1	<0.13	140	<1.4	<0.47	<0.87	19	62	
Seawater	Pipeline	4	<0.10	<0.10	<0.17	<0.12	<0.10	<0.10			
Seawater	Southerness	4	<0.10	<0.10	<0.13	<0.11	<0.10	<0.10	<0.00025	0.0011	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Marine samples							
Flounder	Inner Solway	4	0.040				
Salmon	Inner Solway	1	<0.14				
Sea trout	Inner Solway	1	0.19				
Shrimps	Inner Solway	2	0.026				
Cockles	North Solway	5[F,S]	15	*	0.021		
Mussels	North Solway	8[F,S]	9.9	*	0.019		
Winkles	Southerness	4	2.5				
Fucus vesiculosus	Pipeline	4	8.4			22	510
Fucus vesiculosus	Redkirk	4	10			23	290
Sediment	Southerness	1	19				
Sediment	Pipeline	4	120				
Seawater	Pipeline	4	<0.10				
Seawater	Southerness	4	0.00045				

Table 4.9(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			12	<13	<16	<1.1	<0.05	<0.10	<0.55
Milk		max		38	25	<3.1		<0.11	<0.64
Apples			2	<7.2	<15	<0.53	<0.05	<0.53	<0.14
Apples		max		9.3		<1.0		0.95	<0.23
Cabbage			1	6.0	<15	<0.22	<0.05	0.47	<0.10
Crab Apples			1	5.0	16	<0.07	<0.05	0.50	<0.05
Elderberries			1	5.7	<15	<0.50	<0.05	0.11	<0.15
Honey			1	100	68	<0.50	<0.05	<0.10	<0.05
Mallard			1	<5.0	33	<1.6	<0.05	0.21	<0.06
Partridge			1	<5.0	29	<1.5	<0.11	0.23	<0.17
Pheasant			1	<5.0	36	<1.1	<0.05	<0.10	<0.06
Potatoes			2	<5.0	<15	<0.40	<0.05	<0.10	<0.26
Potatoes		max				<0.71			<0.43
Rosehips			1	19	38	<0.50	<0.05	1.2	<0.15
Rowan berries			1	22	27	<0.50	<0.05	0.20	<0.24
Turnips			1	<5.0	<15	<0.40	<0.05	0.39	<0.10
Wheat			1	<5.0	100	0.90	<0.05	<0.10	<0.08
Widgeon			1	<5.0	31	<1.1	<0.05	0.10	<0.06
Grass			4	<9.4	<15	<0.50	<0.05	0.26	<0.38
Grass		max		22		0.66		0.33	<0.65
Soil			4	<12	<16	<1.3	<0.06	1.8	<0.42
Soil		max		26	18	<2.3		3.2	0.65
Freshwater	On-site		1	160					
Freshwater	Burn A - Top Gullie		1	240					
Freshwater	After oil interceptor, Gullielands		1	250					
Freshwater	Burn C, Gullielands		1	160					
Freshwater	Coolig Tower Basin		1	230					
Freshwater	R-3 Cable basement		1	420					
Freshwater	R-3 Blower Pit E		1	140					

Material	Selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Terrestrial samples								
Milk			12	<0.05	<0.29	<0.06		
Milk		max		<0.06				
Apples			2	<0.05	<0.25	<0.07		
Apples		max			<0.33	<0.08		
Cabbage			1	<0.05	<0.27	<0.07		
Crab Apples			1	<0.05	<0.16	<0.09		
Elderberries			1	<0.05	<0.24	<0.06		
Honey			1	1.3	<0.22	<0.19		
Mallard			1	0.33	<0.22	<0.11		
Partridge			1	0.25	<0.55	<0.16		
Pheasant			1	0.68	<0.22	<0.11		
Potatoes			2	0.07	<0.27	<0.07		
Potatoes		max		0.08				
Rosehips			1	<0.05	<0.25	<0.06		
Rowan berries			1	<0.05	<0.26	<0.06		
Turnips			1	0.08	<0.24	<0.07		
Wheat			1	<0.05	<0.27	<0.15		
Widgeon			1	1.2	<0.22	<0.11		
Grass			4	0.23	<0.22	<0.08	3.3	360
Grass		max		0.39	<0.25	<0.09	4.9	460
Soil			4	11	<0.54	0.46	170	580
Soil		max		13	<0.58	0.57	230	750
Freshwater	On-site		1	<10				
Freshwater	Burn A - Top Gullie		1	<11				
Freshwater	After oil interceptor, Gullielands		1	<12				
Freshwater	Burn C, Gullielands		1	<13				
Freshwater	Coolig Tower Basin		1	<14				
Freshwater	R-3 Cable basement		1	<15				
Freshwater	R-3 Blower Pit E		1	<16				

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

Table 4.9(b). Monitoring of radiation dose rates near Chapelcross, 2006

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.060
Glencaple Harbour	Mud and sand	4	0.076
Priestside Bank	Salt marsh	4	0.062
Powfoot Merse	Mud	4	0.073
Pipeline	Sand	4	0.082
Pipeline	Salt marsh	4	0.086
Battlehill	Sand	4	0.075
Dornoch Brow	Mud and sand	4	0.071
Dornoch Brow	Salt marsh	4	0.081
Browhouses	Sand	4	0.074
Redkirk	Sand	4	0.074
East of pipeline close to salt marsh	Sand	1	0.089
East of pipeline outflow	Sand	1	0.073
Pipeline outflow	Sand and stones	1	0.14
Alternative pipeline outflow (western side)	Sand	1	0.065
West of pipeline outflow	Sand	1	0.077
Mean beta dose rates			μSv h^{-1}
Pipeline 500m east	Sand	4	<1.0
Pipeline 500m west	Sand	4	<1.0
Pipeline	Stake nets	3	<1.0

Table 4.9(c). Radioactivity in air near Chapelcross, 2006

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Eastriggs	11	<0.010	<0.0088	0.13
Kirtlebridge	11	<0.010	<0.0061	0.12
Brydekirk	9	<0.011	<0.013	0.13

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2006

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	^{95}Nb	^{99}Tc	^{110m}Ag
Marine samples										
Cod	Millport	2		<0.14	<0.28	<0.13		<0.82		<0.18
Hake	Millport	2		<0.19	<0.40	<0.17		<1.1		<0.19
Crabs	Millport	2		<0.10	<0.13	<0.10	<0.10	<0.29	4.8	<0.10
Nephrops	Millport	2		<0.12	<0.21	<0.12		<0.49		<0.14
Lobsters	Largs	1		<0.10	<0.11	<0.10		<0.26	120	<0.10
Squat lobsters	Largs	4		<0.11	<0.18	<0.10		<0.49	9.1	<0.11
Winkles	Pipeline	2		1.1	<0.66	0.58	<0.10	<1.4		<0.31
Scallops	Largs	4		<0.18	<0.92	<0.15	<0.10	<13		<0.20
Oysters	Hunterston	1		<0.11	<0.69	<0.10		<8.2		<0.13
Fucus vesiculosus	N of pipeline	2		3.4	<0.18	0.42		<0.42		<0.13
Fucus vesiculosus	S of pipeline	2		1.1	<0.10	0.29		<0.18		<0.10
Sediment	Fairlie	1		<0.10	<0.10	<0.10		<0.10		<0.10
Sediment	Millport	1		<0.10	<0.10	<0.10		<0.14		<0.10
Seawater	Pipeline	2	4.1							

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	<0.30	1.9	<0.81	<0.33			<0.21
Hake	Millport	2	<0.36	<1.3	<0.29	<0.30			<0.24
Crabs	Millport	2	<0.15	0.45	<0.32	<0.14	0.0092	0.016	0.022
Nephrops	Millport	2	<0.23	0.82	<0.58	<0.24			<0.17
Lobsters	Largs	1	<0.15	0.49	<0.37	<0.18			<0.14
Squat lobsters	Largs	4	<0.19	0.44	<0.46	<0.18	0.0036	0.025	0.014
Winkles	Pipeline	2	<0.54	0.65	<1.3	<0.48	0.033	0.14	0.52
Scallops	Largs	4	<0.31	<0.45	<0.92	<0.31	0.039	0.026	0.030
Oysters	Hunterston	1	<0.20	0.33	<0.58	<0.17			<0.10
Fucus vesiculosus	N of pipeline	2	<0.19	0.65	<0.36	<0.18			<0.13
Fucus vesiculosus	S of pipeline	2	<0.25	0.63	<0.19	<0.10			<0.10
Sediment	Fairlie	1	0.33	7.4	<0.52	<0.21			<0.28
Sediment	Millport	1	<0.16	5.8	<0.47	<0.24			0.48

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	<5.2	<15	<0.88	<0.06	<0.11	<1.5
Milk	max		<5.7	<16	<1.0	<0.07	<0.17	<2.7
Blackberries		2	<5.0	17	0.28	<0.05	0.47	<0.18
Blackberries	max						0.49	
Cabbage		1	<5.0	<15	<0.50	<0.05	0.63	<0.08
Carrots		3	<5.0	<15	<0.55	<0.08	0.46	<0.10
Carrots	max				<0.60		0.55	
Eggs		1	<5.0	30	<2.1	<0.06	<0.10	<0.57
Honey		1	6.6	59	1.3	<0.05	<0.10	<0.05
Nettles		1	<5.0	23	<4.3	<0.10	<0.10	<0.10
Onions		1	<5.0	<15	<0.50	<0.10	<0.10	<0.10
Potatoes		1	<5.0	22	<0.50	<0.10	<0.10	<0.10
Rabbit		2	<5.0	29	<4.1	<0.09	<0.17	<0.23
Rabbit	max			33	<7.4	<0.11	0.23	<0.24
Rosehips		1	<5.0	33	<0.50	<0.06	<0.10	<0.09
Rowan berries		1	<5.0	<17	0.15	<0.06	0.23	<0.21
Turnips		1	<5.0	<15	<0.50	<0.05	1.8	<0.08
Grass		3	<5.0	<17	<0.62	<0.05	0.36	<0.29
Grass	max			20	1.1		0.52	<0.40
Soil		3	<5.0	<15	<0.96	<0.05	1.0	<0.21
Soil	max				<1.2	<0.06	1.8	<0.26

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{110m}Ag	^{137}Cs	^{241}Am	Total alpha	Total beta
Terrestrial Samples							
Milk		6	<0.07	<0.09	<0.07		
Milk	max		<0.08	0.15	<0.08		
Blackberries		2	<0.05	<0.05	<0.07		
Cabbage		1	<0.05	<0.05	<0.06		
Carrots		3	<0.08	0.11	<0.08		
Carrots	max		<0.10	0.16	<0.10		
Eggs		1	<0.07	<0.05	<0.09		
Honey		1	<0.05	0.96	<0.08		
Nettles		1	<0.10	<0.10	<0.13		
Onions		1	<0.10	<0.10	<0.10		
Potatoes		1	<0.10	<0.10	<0.10		
Rabbit		2	<0.10	0.76	<0.14		
Rabbit	max		<0.12	0.85	<0.16		
Rosehips		1	<0.06	0.18	<0.08		
Rowan berries		1	<0.07	<0.06	<0.09		
Turnips		1	<0.05	<0.05	<0.07		
Grass		3	<0.05	0.17	<0.08	2.7	220
Grass	max		<0.06	0.29	<0.11	4.8	350
Soil		3	<0.08	13	<0.23	140	350
Soil	max			14	0.29	170	480

[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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Largs Bay	Stones	2	0.062
Kilchatten Bay	Sand	2	<0.048
Millport	Sand	2	<0.049
Gulls Walk	Mud	2	<0.057
0.5 km north of pipeline	Sand	2	0.058
0.5 km south of pipeline	Sand and stones	2	0.060
Ardneil Bay	NA	2	0.051
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, 2006

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Fencebay	12	<0.012	0.0094	0.11
West Kilbride	10	<0.011	<0.010	0.14
Crosbie Mains	8	<0.016	<0.0078	0.12

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{54}Mn	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{110m}Ag
Marine samples										
Cod	White Sands	1		18	<0.21	<0.15	<0.60	<12		<0.24
Crabs	Cove	2			<0.10	<0.10	<0.18	<0.32	0.86	<0.10
Lobsters	Cove	1			<0.14	<0.15	<0.35	<0.26	23	<0.14
Nephrops	Dunbar	1			<0.10	0.10	<0.16	<0.35		<0.10
Winkles	Pipeline	2			<0.19	<0.20	<0.51	<5.1		<0.41
Fucus vesiculosus	Pipeline	2			0.50	0.18	<0.19	<0.30		<0.10
Fucus vesiculosus	Thornton Loch	2			<0.44	<0.11	<0.26	<0.81	100	<0.11
Fucus vesiculosus	White Sands	2			<0.20	<0.13	<0.24	<0.39		<0.11
Fucus vesiculosus	Pease Bay	2			<0.10	<0.10	<0.15	<0.55		<0.10
Fucus vesiculosus	Coldingham Bay	1			<0.12	<0.11	<0.37	<1.6		<0.13
Fucus serratus	Coldingham Bay	1			<0.12	<0.10	<0.40	<0.50		<0.13
Sediment	Dunbar	1			<0.10	<0.10	<0.24	<0.74		<0.10
Sediment	Barns Ness	1			<0.10	<0.10	<0.13	<0.54		<0.10
Sediment	Thornton Loch	1			<0.10	<0.10	<0.19	<0.33		<0.10
Sediment	Heckies Hole	1			<0.12	<0.10	<0.68	<56		<0.27
Sediment	Eyemouth	1			<0.10	<0.10	<0.23	<0.41		<0.10
Salt marsh	Belhaven Bay	1			<0.10	<0.10	<0.28	<0.46		<0.11
Seawater	Pipeline	2	4.9		<0.10	<0.10	<0.11	<0.26		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{144}Ce	^{155}Eu	^{239}Pu+ ^{238}Pu	^{240}Pu	^{241}Am	Total alpha	Total beta
Marine samples										
Cod	White Sands	1	0.30	<1.3	<0.38			<0.18		
Crabs	Cove	2	<0.11	<0.36	<0.16			<0.11		
Lobsters	Cove	1	0.20	<0.77	<0.34			<0.21		
Nephrops	Dunbar	1	0.21	<0.40	<0.17	0.00056	0.0024	0.034		
Winkles	Pipeline	2	0.14	<0.98	<0.38			<0.23	3.1	73
Fucus vesiculosus	Pipeline	2	0.20	<0.36	<0.16			<0.11		
Fucus vesiculosus	Thornton Loch	2	0.26	<0.40	<0.17			<0.15		
Fucus vesiculosus	White Sands	2	0.28	<0.37	<0.18			<0.16		
Fucus vesiculosus	Pease Bay	2	<0.15	<0.22	<0.11			<0.14		
Fucus vesiculosus	Coldingham Bay	1	0.16	<0.58	<0.23			<0.14		
Fucus serratus	Coldingham Bay	1	<0.10	<0.60	<0.18			<0.11		
Sediment	Dunbar	1	3.4	<0.56	0.75			<0.23		
Sediment	Barns Ness	1	2.3	<0.46	0.99			<0.19		
Sediment	Thornton Loch	1	1.3	<0.41	0.35			<0.17		
Sediment	Heckies Hole	1	9.0	<1.3	0.99			<0.29		
Sediment	Eyemouth	1	1.8	<0.54	0.63			<0.21		
Salt marsh	Belhaven Bay	1	0.83	<0.73	<0.46			<0.34		
Seawater	Pipeline	2	<0.10	<0.14	<0.10			<0.10		

Table 4.11(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial samples								
Milk		1	<5.3	<16	<1.2	<0.05	<0.10	<0.22
Goats' milk		1	<5.0	<15	<1.5	<0.05	<0.10	<0.17
Beetroot		1	<5.0	17	<1.1	<0.05	<0.10	<0.08
Broccoli		1	<5.0	<15	0.82	<0.07	0.19	<0.43
Cabbage		2	<5.0	<19	<1.6	<0.05	<0.10	<0.07
Cabbage	max			24	2.5			<0.09
Carrots		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Eggs		1	<5.0	17	<0.82	<0.05	0.44	<0.06
Elderberries		1	<5.0	<15	0.13	<0.05	<0.10	<0.07
Leeks		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Nettles		1	<5.0	<15	<2.5	<0.05	0.63	<0.44
Pigeon		1	79	23	<1.5	<0.05	<0.10	<0.15
Potatoes		1	<5.0	17	<0.50	<0.05	<0.13	<0.05
Rabbit		1	<5.0	30	<1.4	<0.15	0.14	<0.26
Rosehips		1	<5.0	23	<0.64	<0.05	0.15	<0.18
Rowan berries		1	<5.0	30	<0.20	<0.05	<0.10	<0.20
Grass		3	<5.0	<16	<0.76	<0.05	0.24	<0.46
Grass	max			16	<0.98		0.32	<0.48
Soil		3	<5.0	<15	<1.3	<0.06	0.99	<0.23
Soil	max				<1.6		1.7	<0.37

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Terrestrial samples								
Milk		1	<0.05	<0.05	<0.24	<0.06		
Goats' milk		1	<0.05	<0.05	<0.25	<0.06		
Beetroot		1	<0.05	<0.05	<0.25	<0.13		
Broccoli		1	<0.07	0.17	<0.37	<0.09		
Cabbage		2	<0.05	<0.06	<0.17	<0.09		
	max			0.06	<0.24	<0.11		
Carrots		1	<0.05	<0.05	<0.19	<0.05		
Eggs		1	<0.05	<0.05	<0.29	<0.12		
Elderberries		1	<0.05	0.19	<0.26	<0.07		
Leeks		1	<0.05	<0.05	<0.10	<0.05		
Nettles		1	<0.05	<0.05	<0.30	<0.12		
Pigeon		1	<0.05	<0.05	<0.32	<0.13		
Potatoes		1	<0.05	<0.05	<0.09	<0.05		
Rabbit		1	<0.15	<0.15	<0.85	<0.19		
Rosehips		1	<0.05	<0.05	<0.25	<0.06		
Rowan berries		1	<0.05	<0.05	<0.24	<0.06		
Grass		3	<0.05	<0.06	<0.22	<0.11	2.2	370
Grass	max		<0.06	0.07	<0.33	<0.12	3.1	460
Soil		3	<0.09	7.3	<0.54	<0.52	250	710
Soil	max		<0.10	11	<0.60	0.69	270	800

[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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Heckies Hole	Sediment	2	0.068
Dunbar Inner Harbour	Sand	2	0.097
Belhaven Bay	Salt marsh	2	0.057
Barns Ness	Mud, sand and stones	2	0.063
Skateraw	Sand	2	<0.049
Thornton Loch	Sand	2	<0.047
Pease Bay	Sand	2	0.057
St Abbs Head	Mud	2	0.081
Coldingham Bay	Sand	2	0.050
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, 2006

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Total alpha	Total beta
Innerwick	12	<0.010	<0.0073	0.12
Cockburnspath	10	<0.010	<0.0068	<0.13

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples											
Brown trout	Trawsfynydd Lake	6		56		<0.16	2.8	<0.56	<0.17	40	<0.48
Rainbow trout	Trawsfynydd Lake	6				<0.09		<0.22	<0.10	1.4	<0.30
Perch	Trawsfynydd Lake	6				<0.21	1.7	<0.79	<0.23	95	<0.62
Rudd	Trawsfynydd Lake	1				<0.20		<0.64	<0.19	59	<0.59
Mud	Pipeline	1				7.1		<7.0	<1.7	1000	<4.3
Sediment	Lake shore	2[E]				<0.59	<1.0	<12	<0.90	1400	
Sediment	Bailey Bridge	2[E]				<5.5	35	<37	<2.7	2200	
Sediment	Fish farm	2[E]				4.2	8.0	<8.3	<0.67	580	
Sediment	Footbridge	2[E]				<0.58	<1.0	<5.1	<0.48	290	
Sediment	Cae Adda	2[E]				<0.72	<1.0	<11	<0.91	620	
Freshwater	Cold Lagoon	2							*	0.01	
Freshwater	Public supply	2[E]	<4.0		<1.0	<0.13			<0.13	<0.12	
Freshwater	Gwylan Stream	2[E]	<4.0		<1.0	<0.29			<0.29	<0.24	
Freshwater	Diversion culvert	2[E]	<4.0		<1.0	<0.16			<0.17	<0.15	
Freshwater	Hot Lagoon	2[E]	<4.0		<1.4	<0.13			<0.14	<0.11	
Freshwater	Afon Prysor	2[E]	<4.0		<1.1	<0.28			<0.28	<0.25	
Freshwater	Trawsfynydd Lake	2[E]	<4.0		<2.0	<0.16			<0.17	<0.15	

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	Total alpha	Total beta
Freshwater samples										
Brown trout	Trawsfynydd Lake	6	<0.40	0.00014	0.00045	0.00091	0.000035	0.000018		
Rainbow trout	Trawsfynydd Lake	6	<0.20			<0.17				
Perch	Trawsfynydd Lake	6	<0.52	0.000055	0.00018	0.00039	0.000027	0.000012		
Rudd	Trawsfynydd Lake	1	<0.35			<0.19				
Mud	Pipeline	1	<3.6	6.5	18	29	0.19	1.1		
Sediment	Lake shore	2[E]		0.95	2.7	10				
Sediment	Bailey Bridge	2[E]		5.9	21	52				
Sediment	Fish farm	2[E]		5.6	15	32				
Sediment	Footbridge	2[E]		0.78	2.7	5.6				
Sediment	Cae Adda	2[E]		1.1	4.3	14				
Freshwater	Public supply	2[E]							<0.020	<0.10
Freshwater	Gwylan Stream	2[E]							<0.020	0.20
Freshwater	Diversion culvert	2[E]							<0.025	<0.13
Freshwater	Hot Lagoon	2[E]							<0.025	<0.10
Freshwater	Afon Prysor	2[E]							<0.021	<0.15
Freshwater	Trawsfynydd Lake	2[E]							<0.020	<0.10

Table 4.12(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs
Terrestrial Samples							
Milk		2	<4.8	16	<0.16	0.070	
Milk	max			17	<0.18	0.081	
Blackberries		1	<4.0	15	<0.10		0.50
Carrots		1	<4.0	<2.0	<0.20		<0.30
Eggs		1	<6.0	33	<0.30		
Potatoes		1	<5.0	14	<0.20		<0.20
Runner beans		1	<5.0	<3.0	<0.20		<0.30
Spinach/broccoli		1	<5.0	<3.0	<0.30		<0.30
Sheep muscle		2	<6.0	14	<0.20	<0.022	
Sheep muscle	max			18		0.034	
Sheep offal		2	<8.0	11	<0.20	0.11	
Sheep offal	max			13		0.15	

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples						
Milk		2	0.45			
Milk	max		0.69			
Blackberries		1		<0.00010	0.00010	0.00030
Carrots		1		<0.00020	<0.00020	0.00050
Eggs		1		<0.00010	<0.00010	0.00040
Potatoes		1		<0.00010	0.00020	0.00030
Runner beans		1		<0.00020	<0.00020	0.00050
Sheep muscle		2	5.6	<0.00020	<0.00020	0.00055
Sheep muscle	max		10			0.00070
Sheep offal		2	0.68	<0.00015	<0.00030	0.00040
Sheep offal	max		0.71	<0.00020	<0.00040	

[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 4.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2006

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Mud and stones	1	0.096
Footbridge	Pebbles and sand	1	0.099
Lake shore	Sand and stones	1	0.11
Lake shore	Rock and sand	1	0.10
Bailey Bridge	Rock and sand	1	0.086
Bailey Bridge	Grass and rock	1	0.095
Fish Farm	Sand and stones	1	0.11
Fish Farm	Rock	1	0.11
Cae Adda	Mud and stones	1	0.084
Cae Adda	Pebbles and sand	1	0.093

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2006

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	74		<0.30	2.0	
Bass	Outfall	1					<0.10	5.5	
Crabs	Pipeline	2				4.0	<0.22	0.55	0.0061
Lobsters	Pipeline	2				110	<0.14	0.59	
Winkles	Cemaes Bay	2	<25	<25	43		<0.23	0.27	0.018
Fucus vesiculosus	Cemaes Bay	2				140	<0.13	0.77	
Seaweed	Cemaes Bay	2[E]				590	<15	<2.4	
Sediment	Cemaes Bay	2[E]						4.4	
Sediment	Cemlyn Bay	2[E]						2.3	
Seawater	Cemaes Bay	2[E]						<0.11	
Seawater	Cemlyn Bay	2[E]						<0.23	

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	Total alpha	Total beta
Marine samples									
Plaice	Pipeline	2			<0.18				
Bass	Outfall	1			<0.10				
Crabs	Pipeline	2	0.033		0.11	0.00010	0.00011		
Lobsters	Pipeline	2			<0.34				140
Winkles	Cemaes Bay	2	0.10	0.71	0.14	*	0.00029		
Fucus vesiculosus	Cemaes Bay	2			<0.08				
Seaweed	Cemaes Bay	2[E]			<3.4				
Sediment	Cemaes Bay	2[E]			<0.48				
Sediment	Cemlyn Bay	2[E]			2.2				
Seawater	Cemaes Bay	2[E]			<0.26			<1.9	12
Seawater	Cemlyn Bay	2[E]			<0.37			<2.4	17

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	Total alpha	Total beta
Terrestrial samples								
Milk		5	<4.8	18	<0.40	<0.21		
Milk	max		<5.0	25	<0.50	<0.23		
Apples		1	<5.0	10	0.30	<0.30		
Barley		1	<7.0	58	3.4	<0.30		
Beetroot		1	<5.0	6.0	<0.20	<0.30		
Blackberries		1	<4.0	35	4.5	<0.20		
Broad beans		1	<4.0	10	1.0	<0.30		
Honey		1	<8.0	80	<0.20	<0.20		
Potatoes		1	<5.0	23	0.50	<0.20		
Spinach		1	<5.0	4.0	0.70	<0.20		
Freshwater	Public supply	1[E]	5.5		<1.0	<0.11	<0.030	0.11

** 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, 2006

Location	Ground type	No. of sampling observa-tions	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Rock and sand	2	0.062
Cemlyn Bay	Sand and stones	1	0.068
Cemlyn Bay	Pebbles and sand	1	0.063

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 carried out by the MoD (DSTL, 2006).

Key points

- Generally, concentrations and dose rates similar to 2005 for all establishments (including Barrow, Derby, Faslane and Coulport, Holy Loch, Rosyth and Vulcan NRTE)
- New survey of local diet and occupancy habits at Faslane carried out

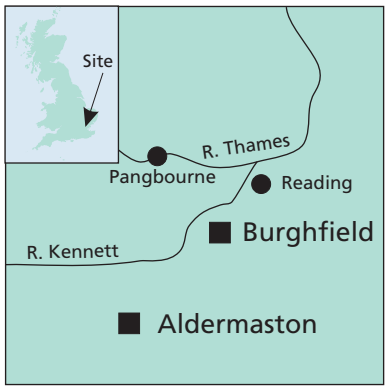
Aldermaston, Berkshire

- Atmospheric sampling trials undertaken
- Explanatory document for the review process issued in May 2006 by Environment Agency following request for variation of existing authorisation to dispose of radioactive waste from the site
- Discharges, concentrations and dose rates similar to 2005
- Radiation doses (Table 5.1) were less than 0.5% of the dose limit

Devonport, Devon

- Explanatory and draft Decision document for the HM Naval Base were issued by the Environment Agency for consultation following request for variation of existing approval to dispose of radioactive waste from the site
- Concentrations and dose rates similar to 2005
- Radiation doses (Table 5.1) were less than 0.5% 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. The site is authorised to discharge aqueous radioactive waste to the sewage works at Silchester and to Aldermaston Stream. The Pangbourne pipeline, which previously discharged aqueous waste to the River Thames at Pangbourne, closed on 16 March 2005. The new liquid effluent treatment plant came on-line in 2005 and uses evaporation technology to eliminate the need to discharge liquid radioactive waste to the environment. Samples of milk, other terrestrial foodstuffs, freshwater, fish and sediments were collected. The sampling locations are shown in Figure 3.1. Monitoring of the aquatic environment at Newbridge is undertaken to indicate control or background levels upstream of nuclear establishments located in the Thames catchment.

The results of measurements of radionuclides concentrations are shown in Tables 5.2(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2005. Concentrations of tritium were generally below the LoD though some enhancements were observed in sediments collected from road gullypots very close to the site. Caesium-137 concentrations were detected in sediment from the Thames and water courses near the site and were similar to those observed in recent years. Currently, routine discharges from AWE do not include significant 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 habit 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 year^{-1}.

The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was much less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). Consumption of locally harvested crayfish was also considered as a pathway for radiation exposure. Exposures were much less than 0.005 mSv using consumption data from the habits survey. The total alpha and total beta activity concentrations in the freshwater samples were below the WHO screening levels for drinking water. The drinking water pathway has been shown to be insignificant (Environment Agency, 2002a).

The concentrations of radioactivity in milk, 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 2005. Natural background or weapon test fallout would have made a significant contribution to the levels detected. The reported results for caesium-137 in soils were broadly similar to the values observed in 2005. 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 to consumers of local food in 2006, including contributions from the natural and fallout sources, was less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv. 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% of the dose limit.

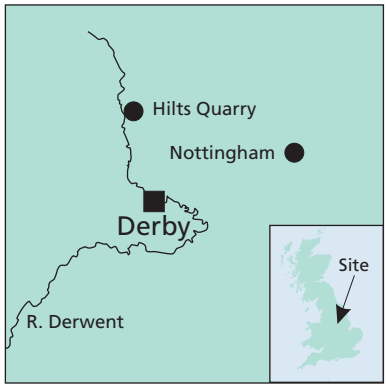
Early in 2006, the Environment Agency began a review of radioactive waste disposals from AWE. Public consultation on the limits and conditions under which AWE can dispose of radioactive waste at its two sites, at Aldermaston and Burghfield, was held between 15 May and October 2006 (Environment Agency, 2006j). The Environment Agency issued an explanatory document to assist the consultation process (Environment Agency, 2006k). A decision document on new authorisations for Aldermaston and Burghfield was issued in March 2007.

Trials of atmospheric sampling have been undertaken to monitor radioactive substances in ambient air around AWE Aldermaston. The primary remit of these studies was to determine the logistics and usefulness of deploying such techniques. A similar trial to that undertaken earlier at Dungeness (see Section 4.3 Gaseous discharges and terrestrial sampling) was carried out around the site, commencing in June 2005 and concluding in August 2006. Observations and conclusions were similar to that described for Dungeness. The way of taking the findings forward is now being considered by the Radiological Monitoring Standards Working Group (RMSWG).

5.2 Barrow, Cumbria

Discharges from submarine related operations at the site are very low. The Food Standards Agency's monitoring of Barrow is limited to grass sampling. In 2006, no tritium activity was detected (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 2006.

5.3 Derby, Derbyshire

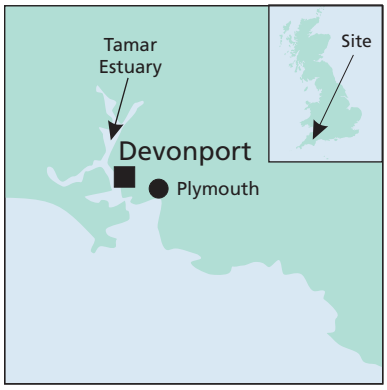


Rolls-Royce Marine Power Operations Ltd (RRMPOL) carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Megaloughton Lane Sewage Treatment Works to the River Derwent and very low 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. The total alpha and total beta activity levels in river water from the River Derwent were less than the WHO screening levels for drinking water and doses from using the river as a source of drinking water would be much less than 0.005 mSv per year (Table 5.1).

Table 5.3(a) also includes the results of monitoring of water from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for controlled burial of solid low level radioactive waste. Isotopes of uranium detected in the stream water were at levels similar to those seen elsewhere in Derbyshire (Table 8.16).

5.4 Devonport, Devon

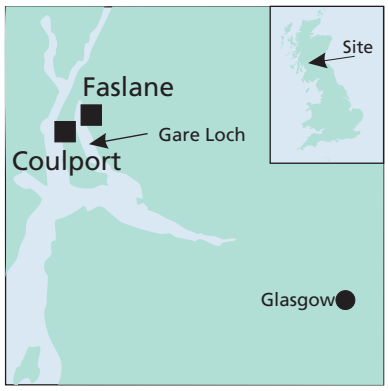


Devonport consists of two parts: the Naval Base which is owned and operated by the MoD, and Devonport Royal Dockyard which is owned by Devonport Royal Dockyard Limited (DRDL) and operated by Devonport Management Ltd. (DML). DML refits, refuels, repairs and maintains the Royal Navy's nuclear powered submarines 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.

In July 2006, the Environment Agency issued an explanatory document to assist the consultation to revise the existing arrangements for the disposal of radioactive waste from HM Naval Base at Devonport (Environment Agency 2006l). Following the consultation process, a decision document was issued (Environment Agency, 2007d) and the approval was issued in April 2007 and became effective in June 2007.

The routine monitoring programme in 2006 consisted of measurements of gamma dose rate and analysis of fish, shellfish, fruit, sediments and seawater. The results given in Tables 5.3(a) and (b) were similar to those in 2005 where comparisons can be drawn. 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. A habits survey in 2004 has established that there are two dominant critical groups for marine pathways, (i) fish and shellfish consumers and (ii) occupants of houseboats. Taking account of relevant consumption of marine foods and occupancy times, doses to both groups were estimated to be less than 0.005 mSv which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1). Similarly the dose to high-rate consumers of fruit 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 less than 0.005 mSv or 0.5% 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 Naval Services, a subsidiary of Babcock Support Services Limited, operate at HMNB Clyde in partnership with MoD. However, MoD remains in control of the undertaking, through the Naval Base Commander, Clyde, in relation to radioactive waste disposal.

Work on the new effluent plant that the MoD plans to build at Faslane has been subject to delays and the MoD are currently reconsidering the long-term strategy for the base. Consequently, SEPA has not progressed the determination of the application made by MoD in 2003, which relates to the disposal of liquid and gaseous wastes from the proposed plant.

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD. The discharges made during 2006 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 2006.

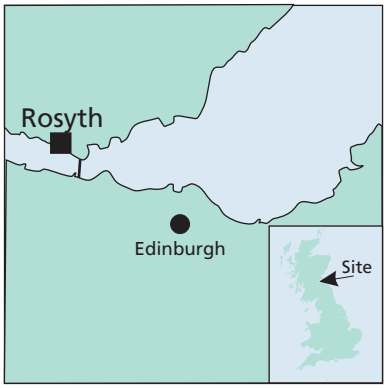
A habit survey was undertaken during late summer of 2006 and identified shellfish consumers, in addition to fish consumers and external radiation from the shore, as the major pathways of exposure. Fish consumption rates nearly doubled whilst occupancy rates slightly decreased. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1. The scope of the monitoring programme reflects the pathways, prior to the 2006 habit survey, and included the analysis of seawater, sediment and seaweed samples. Samples of non-migratory fish species were not available. Results are given in Tables 5.3(a) and (b). These show that caesium-137 concentrations were consistent with the distant effects of discharges from Sellafield, and to weapons testing and Chernobyl fallout. Additionally, measurements of gamma dose rates made in the surrounding area were difficult to distinguish from natural background. Taking into account the new occupancy and consumption rate data from the 2006 habit survey, and seafood concentration data from 2005, 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% 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% 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 levels detected were low, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. As in 2005, 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 2006, which was 0.5% of the dose limit for members of the public of 1 mSv (Table 5.1).

5.7 Rosyth, Fife

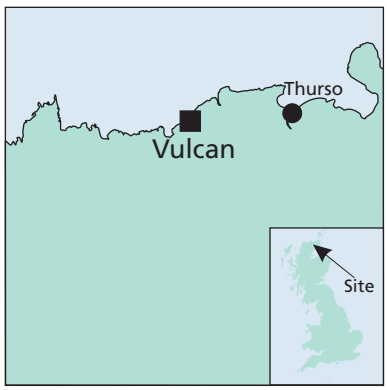


The site is operated by Babcock Engineering Services who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006 and is expected to be completed within four years. Radioactive waste produced during decommissioning will be disposed of under the conditions of an authorisation granted to Rosyth Royal Dockyard Limited in November 2004. Operational wastes continue to be discharged under separate, continuing, authorisations for such wastes. Rosyth Royal Dockyard Limited (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). During 2006, authorised discharges from Rosyth were below the LoD.

Small volumes of liquid radioactive waste associated with site decommissioning were discharged to the River Forth. In all cases the activity in the liquid discharged was well within authorised limits.

SEPA's routine monitoring programme included sampling and analysis of 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. A habit survey was undertaken in 2005. For marine pathways, the critical group remained as fish and shellfish consumers with an additional element of intertidal occupancy. Consumption and occupancy rates were increased (Appendix 1). The dose to the critical groups of local fishermen and beach users in 2006 were estimated to be less than 0.005 mSv, which were less than 0.5% 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% 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 UKAEA 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, 2006

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 or water
Aldermaston	Anglers	<0.005	<0.005	-	<0.005	-
	Consumers of locally harvested crayfish[b]	<0.005	<0.005	-	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-
	All sources[d]	<0.005	-	-	-	-
Derby	Consumers of drinking water[c]	<0.005	-	-	-	<0.005
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Houseboat occupants	<0.005	-	-	<0.005	-
	Prenatal children of consumers of locally grown food	<0.005	-	<0.005	-	-
	All sources[d]	<0.005	-	-	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-
	All sources[d]	<0.005	-	-	-	-
Holy Loch	Anglers	0.006	-	-	0.006	-
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, 2006

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{57}Co	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Pike	Newbridge	1	<25	<25	<0.03	<0.04			
Pike	Outfall (Pangbourne)	1	<25	<25	<0.05	0.15			
Pike	Staines	1	<25	<25	<0.04	0.15			
Pike	Shepperton	1	<25	<25	<0.04	0.18			
Pike	Teddington	1	<25	<25	<0.04	0.10			
Flounder	Beckton	1		<25	<0.08	0.20			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	<0.11	<0.13	0.035	0.0011	0.028
Nuphar lutea	Newbridge	1		<25	<0.05	0.07			
Nuphar lutea	Staines	1		<25	<0.04	0.06			
Sediment	Pangbourne	4[E]				20	11	<0.71	10
Sediment	Mapledurham	4[E]				8.0	9.9	<0.82	9.1
Sediment	Aldermaston	4[E]				2.5	10	<0.85	9.4
Sediment	Spring Lane	4[E]				<0.84	8.4	<0.94	9.0
Sediment	Stream draining south	4[E]				1.3	15	<0.80	15
Sediment	Reading (Kennet)	4[E]				2.6	12	<0.77	11
Gullypot sediment	Falcon Gate	1[E]		42		<0.89	18	0.60	19
Gullypot sediment	Main Gate	1[E]		32		<0.22	18	0.71	19
Gullypot sediment	Tadley Entrance	1[E]		42		3.9	16	<0.64	17
Gullypot sediment	Burghfield Gate	1[E]		53		2.5	17	0.86	17
Freshwater	Pangbourne	4[E]		<4.0		<0.24	<0.011	<0.0063	0.0093
Freshwater	Mapledurham	4[E]		<4.0		<0.20	0.014	<0.0050	<0.0088
Freshwater	Aldermaston	4[E]		6.4		<0.32	0.011	<0.0050	0.0083
Freshwater	Spring Lane	4[E]		<4.0		<0.18	<0.0063	<0.0050	<0.0065
Freshwater	Reading (Kennet)	4[E]		<4.0		<0.23	<0.013	<0.0090	<0.0063
Crude liquid effluent	Silchester treatment works	4[E]		<70		<0.23	<0.0083	<0.0050	<0.0055
Final Liquid effluent[d]	Silchester treatment works	4[E]		<63		<0.24	<0.0075	<0.0050	<0.0065
Sewage sludge	Silchester treatment works	4[E]		<27		<0.31	0.56	<0.043	0.51

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	Total alpha	Total beta
Freshwater samples									
Pike	Newbridge	1	0.000022	0.00015	0.00029	0.000020	*		
Pike	Outfall (Pangbourne)	1	0.000042	0.00019	0.00026	*	*		
Pike	Staines	1			<0.06				
Pike	Shepperton	1			<0.07				
Pike	Teddington	1			<0.07				
Flounder	Beckton	1			<0.15				
Signal crayfish	Ufton Bridge - Theale	1	0.00022	0.00019	0.00017	*	*		
Nuphar lutea	Newbridge	1			<0.13				
Nuphar lutea	Staines	1			<0.05				
Sediment	Pangbourne	4[E]	<0.59	<0.61	1.6			210	310
Sediment	Mapledurham	4[E]	<0.47	<0.91	2.2			200	250
Sediment	Aldermaston	4[E]	<0.69	3.5	3.0			210	380
Sediment	Spring Lane	4[E]	<0.72	<0.37	<1.4			170	300
Sediment	Stream draining south	4[E]	<0.68	0.37	<1.3			370	470
Sediment	Reading (Kennet)	4[E]	<0.67	<0.40	<0.98			130	250
Gullypot sediment	Falcon Gate	1[E]	<0.61	<0.26	<1.4			290	620
Gullypot sediment	Main Gate	1[E]	<0.78	<0.65	<0.52			370	510
Gullypot sediment	Tadley Entrance	1[E]	<0.72	0.69	<1.0			310	550
Gullypot sediment	Burghfield Gate	1[E]	<0.70	0.39	<1.4			230	490
Freshwater	Pangbourne	4[E]	<0.0090	<0.0050	<0.011			<0.050	0.25
Freshwater	Mapledurham	4[E]	<0.0085	<0.0063	<0.011			<0.044	0.26
Freshwater	Aldermaston	4[E]	<0.0088	<0.0050	<0.010			<0.041	0.19
Freshwater	Spring Lane	4[E]	<0.0075	<0.0050	<0.013			<0.038	0.17
Freshwater	Reading (Kennet)	4[E]	<0.019	<0.0058	<0.011			<0.042	<0.12
Crude liquid effluent	Silchester treatment works	4[E]	<0.012	<0.015	<0.34			<0.047	0.55
Final Liquid effluent[d]	Silchester treatment works	4[E]	<0.0082	<0.0050	<0.36			<0.065	0.57
Sewage sludge	Silchester treatment works	4[E]	<0.031	<0.021	<0.51			<5.1	<12

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			5	<4.7	<0.22				<0.0066
Milk		max		<5.0	<0.25				
Beetroot/carrots			1	<4.0	<0.30				<0.035
Blackberries			1	<5.0	<0.20				<0.032
Cabbage			1	<5.0	<0.30	0.0057	0.0013	0.0081	0.072
Honey			1	<8.0	<0.20				<0.028
Potatoes			1	<5.0	<0.30				<0.033
Rabbit			1	<6.0	<0.20	0.0035	<0.0010	0.0019	<0.034
Runner beans			1	<4.0	<0.30				<0.033
Wheat			1	<7.0	<0.20				0.071
Grass	Location 1		1[E]	68	<1.6	0.43	<0.19	0.50	
Grass	Location 2		1[E]	62	<2.2	0.20	<0.12	<0.14	
Grass	Location 3		1[E]	<25	<2.0	0.39	<0.15	0.23	
Grass	Location 4		1[E]	120	<6.2	1.6	<0.20	0.97	
Soil			1[#]			3.9	0.14	4.0	
Soil	Location 1		1[E]	<25	3.5	15	<0.70	15	
Soil	Location 2		1[E]	<25	5.6	16	0.61	15	
Soil	Location 3		1[E]	47	13	22	0.81	23	
Soil	Location 4		1[E]	55	9.2	17	0.92	18	

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	Total alpha	Total beta
Terrestrial samples								
Milk			5	<0.00010	<0.00010	<0.00013		
Milk		max				<0.00020		
Beetroot/carrots			1	<0.00020	<0.00020	0.00030		
Blackberries			1	0.00010	0.00020	<0.00020		
Cabbage			1	0.00030	<0.00030	0.00070		
Honey			1	<0.00010	<0.00020	0.00020		
Potatoes			1	<0.00010	<0.00020	<0.00020		
Rabbit			1	0.00030	<0.00040	0.00040		
Runner beans			1	<0.00010	<0.00010	0.00030		
Wheat			1	<0.00050	<0.00040	<0.00020		
Grass	Location 1		1[E]	<0.15	<0.060		16	310
Grass	Location 2		1[E]	<0.070	0.11		<5.0	140
Grass	Location 3		1[E]	<0.13	<0.16		4.0	110
Grass	Location 4		1[E]	<0.21	<0.060		15	140
Soil	Location 1		1[E]	<0.45	0.79		300	500
Soil	Location 2		1[E]	<0.51	0.52		190	360
Soil	Location 3		1[E]	<0.88	0.94		280	430
Soil	Location 4		1[E]	<0.40	1.1		180	410

** 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 wet concentrations

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

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

[d] An additional analysis gave a ^{3}H value of 130 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 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2006

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	4	0.065
Mapledurham, riverbank	Mud	2	0.061
Mapledurham, riverbank	Grass and mud	2	0.076

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2006

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	^{60}Co	^{65}Zn	^{106}Ru	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs
Barrow													
Grass	Barrow	2[F]		<6.0									
Derby													
Sediment	River Derwent, downstream	2					<1.2						
Sediment	River Derwent, upstream	1					<0.29						
Sediment	Fritchley Brook, downstream of Hilt's Quarry	1					<0.51						
Water	River Derwent, downstream	3					<0.27						
Water	River Derwent, upstream	1					<0.28						
Water	Fritchley Brook, downstream of Hilt's Quarry	1		<4.0			<0.48						<0.42
Devonport													
Skates/Rays	Plymouth Sound	2[F]				<0.14	<0.14	<0.36	<1.3	<0.29	*		0.21
Crabs	Plymouth Sound	2[F]			20	<0.12	<0.13	<0.33	<1.2	<0.26	*		<0.11
Shrimps/prawns	Lynher Estuary	1[F]			22	<0.17	<0.16	<0.41	<1.8	<0.35	*		<0.14
Winkles	Torpoint (South)	1[F]				<0.20	<0.17	<0.45	<2.0	<0.41	*		<0.14
Cockles	Southdown	1[F]				<0.08	<0.07	<0.22	<0.75	<0.15	*		0.10
Mussels	R Lynher	2[F]	<25	<25		<0.10	<0.08	<0.23	<0.95	<0.18	*		<0.07
Fucus vesiculosus[c]	Kinterbury	2[F]				<0.07	<0.07	<0.20	<0.55	<0.12	*		<0.07
Mud[d]	Kinterbury	2[F]				<0.76	<0.62	<1.6	<6.3	<1.7	*		3.6
Sediment	Torpoint (South)	2		<25			<0.92						1.7
Sediment	Lopwell	2		<41			<1.4						7.8
Seawater	Torpoint (South)	2		<4.0	<4.0		<0.30						
Seawater	Millbrook Lake	2		<4.0	<4.0		<0.30						
Beetroot		1[F]		<5.0			<0.30		<2.2			<0.20	<0.20
Blackberries		1[F]		<5.0			<0.10		<2.1			<0.20	<0.20
Courgettes		1[F]		<4.0			<0.30		<0.20			<0.20	<0.30
Lettuce		1[F]		<5.0			<0.20		<1.6			<0.20	<0.20
Faslane													
Seaweed	Rhu	1				<0.11	<0.10	<0.31		<0.24			0.49
Sediment	Carnban boatyard	1				<0.10	<0.10	<0.23		<0.17			6.6
Seawater	Carnban boatyard	2		<3.9		<0.10	<0.10	<0.10		<0.10			<0.10
Holy Loch													
Sediment	Mid Loch	1				<0.10	<0.10	<0.25	<0.57	0.37		<0.10	7.2
Rosyth													
Fucus vesiculosus	East of dockyard	1				<0.10	<0.10	<0.20	0.36	<0.10		<0.10	0.17
Sediment	East of dockyard	1				<0.10	<0.10	<0.26	<0.66	<0.20		<0.10	3.4
Sediment	Port Edgar	1				<0.26	<0.24	<1.3	<3.1	<0.67		<0.31	19
Sediment	West of dockyard	1				<0.10	<0.10	<0.22	<0.53			<0.10	1.0
Sediment	East Ness Pier	1				<0.10	<0.10	<0.26	<0.65	<0.19		<0.10	8.0
Sediment	Blackness Castle	1				<0.10	<0.10	<0.32	<0.68	<0.18		<0.10	2.2
Sediment	Charlestown Pier	1				<0.10	<0.10	<0.18	<0.47	<0.15		<0.10	1.6
Seawater	East of dockyard	1		<1.1		<0.10	<0.10	<0.10	<0.16	<0.10		<0.10	<0.10

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}										
			^{155}Eu	^{228}Th	^{230}Th	^{232}Th	Total U	^{234}U	^{235}U	^{238}U	^{241}Am	Total alpha	Total beta
Derby													
Sediment	River Derwent, downstream	2						51	1.5	43		510	690
Sediment	River Derwent, upstream	1						16	<0.70	17		410	390
Sediment	Fritchley Brook, downstream of Hilt's Quarry	1						20	<1.0	18		350	540
Grass		4[F]					0.33						
Grass	max						0.70	0.21	0.0077	0.18			
Soil		4[F]					110						
Soil	max						180	2.7	0.11	2.2			
Water	River Derwent, downstream	3										<0.043	<0.17
Water	River Derwent, upstream	1										0.18	0.72
Water	Fritchley Brook, downstream of Hilt's Quarry	1		<0.0080	<0.0090	<0.0050		0.067	<0.0050	0.044		<0.080	0.73
Devonport													
Skates/Rays	Plymouth Sound	2[F]	<0.21								<0.10		
Crabs	Plymouth Sound	2[F]	<0.18								<0.09		
Shrimps/prawns	Lynher Estuary	1[F]	<0.22								<0.11		
Winkles	Torpoint (South)	1[F]	<0.44								<0.61		
Cockles	Southdown	1[F]	<0.11								<0.05		
Mussels	R Lynher	2[F]	<0.18								<0.21		
Fucus vesiculosus[c]	Kinterbury	2[F]	<0.12								<0.08		
Mud[d]	Kinterbury	2[F]	<2.3								0.15		
Faslane													
Seaweed	Rhu	1	0.39								<0.14		
Sediment	Carnban boatyard	1	0.73								0.41		
Seawater	Carnban boatyard	2	<0.10								<0.10		
Holy Loch													
Sediment	Mid Loch Rosyth	1	0.65								<0.25		
Fucus vesiculosus	East of dockyard	1	<0.14								<0.13		
Sediment	East of dockyard	1	0.65								<0.31		
Sediment	Port Edgar	1	1.7								1.4		
Sediment	West of dockyard	1	<0.24								<0.19		
Sediment	East Ness Pier	1	<0.37								<0.29		
Sediment	Blackness Castle	1	0.55								<0.22		
Sediment	Charlestown Pier	1	<0.23								0.27		
Seawater	East of dockyard	1	<0.10								<0.10		

** Not detected by the method used*

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

[b] *Except for sediment where dry concentrations apply, and for water where units are Bq l^{-1}, and Total Uranium in soil which is dry*

[c] *The concentration of ^{99}Tc was 0.66 Bq kg^{-1}*

[d] *The concentrations of ^{238}Pu, $^{239+240}$Pu and $^{243+244}$Cm were 0.017, 0.42 and 0.0012 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, 2006

Establishment	Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1 m over substrate				
Devonport	Kinterbury	Mud	2[F]	0.075
Devonport	Torpoint South	Mud and shale	1	0.10
Devonport	Torpoint South	Shale and stones	1	0.11
Devonport	Lopwell	Salt marsh and mud	1	0.074
Devonport	Lopwell	Mud and shale	1	0.085
Faslane	Gareloch Head	Mud, sand and stones	2	0.055
Faslane	Gulley Bridge Pier	Sand and stones	2	0.067
Faslane	Rhu	Gravel	2	0.067
Faslane	Helensburgh	Sand	2	0.057
Faslane	Carnban boatyard	Gravel	2	0.077
Holy Loch	North Sandbank	Mud and sand	1	0.063
Holy Loch	Kilmun Pier	Sand and stones	1	0.065
Holy Loch	Mid-Loch	Sand	1	0.061
Rosyth	Blackness Castle	Mud and sand	2	0.048
Rosyth	Charlestown Pier	Sand	2	<0.052
Rosyth	East Ness Pier	Sand	2	<0.051
Rosyth	East of Dockyard	Sand	2	<0.057
Rosyth	Port Edgar	Mud	2	<0.058
Rosyth	West of Dockyard	Mud and sand	2	<0.051

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

6. Radiochemical production

GE Healthcare (formerly, Amersham plc) manufactures radioactively labelled materials for use in medicine, research and industry. The company's principal establishment is located in Amersham, Buckinghamshire and it also has facilities in Cardiff and on the Harwell site. The environmental effects of the Harwell facilities are covered by general monitoring of the Harwell site (Section 3). In February 2004, the Environment Agency launched a consultation exercise to consider an application from Amersham plc to vary the authorisation it holds for disposals from the Harwell site (Environment Agency, 2004c). The application reflects the progressive reductions in the company's operations involving radioactivity at the site and the extensive programme to decommission redundant facilities on the site. The revised authorisations came into effect in 2005.

Gaseous and liquid discharges from each of the sites are authorised by the Environment Agency. In 2006, gaseous and liquid discharges were below limits for each of the sites (see Appendix 2). Independent monitoring of the environment around each of the sites is carried out by the Food Standards Agency and the Environment Agency.

6.1 Grove Centre, Amersham, Buckinghamshire

Discharges of liquid radioactive wastes are made under authorisation to sewers serving the Maple Lodge sewage works; releases enter the Grand Union Canal and the River Colne. Discharges of gaseous wastes are also authorised. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials. The monitoring locations are shown in Figure 3.1. Monitoring at Newbridge, well upstream on the Thames, acts as a control site and gives an indication of background levels in the catchment.

Key points

GE Healthcare Ltd., Grove Centre, Amersham, Buckinghamshire

- Work continues to fully characterise the chemical form etc. of the tritium found in groundwater by operator in 2005. Radiological impact of the tritium in the groundwater is very low. Local drinking water supplies are not affected
- Contaminated soil with slightly elevated radium-226 concentrations found in a grass verge just off the site has been removed. Radiological impact off site is very low
- Discharges, concentrations and dose rates similar to 2005
- Radiation doses from discharges (Table 6.1) were less than 2% of the dose limit.
- The *total dose* from all sources was 22% of the dose limit

GE Healthcare Ltd., Maynard Centre, Cardiff, South Glamorgan

- Liquid tritium discharges reduced, others similar to 2005
- In December 2006, the Environment Agency reported that Project Paragon had been successful in developing a process to recycle tritium (but not carbon-14)
- Tritium levels in River Taff below LoD
- Reduction of tritium in fish and dose from fish consumption
- Dose determined for sewer workers from sewage and sludge (less than 0.5% of dose limit)
- The critical group were prenatal children receiving exposure as a consequence of adult seafood consumption but the doses were negligible at less than 2% of the dose limit (Table 6.1). The adult dose was similar with 0.012 mSv
- The *total dose* from all sources was approximately 1% of the dose limit

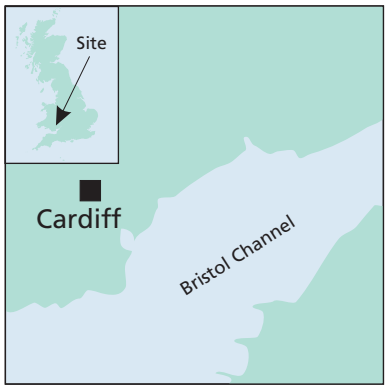
The results are presented in Table 6.2. The concentration of carbon-14 in fish was typical of the background level and its radiological significance was low. Tritium concentrations in biota in the Thames and the Grand Union Canal were below the LoD. Concentrations in material from Maple Lodge Sewage Works were similar to those in 2005. Total alpha and total beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates above the banks of the canal were indistinguishable from background. In 2005, GE Healthcare identified the presence of tritium in the groundwater some 70 metres below the site, at concentrations less than 1750 Bq l^{-1}. While work continues to fully characterise the source and extent of the contamination, environmental monitoring has confirmed the assessment that the impact off the site is very low and local drinking water supplies are not affected.

The activity concentrations in milk, grass and soil crops were generally lower than the limits of detection. However, low concentrations of sulphur-35 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. In 2005, GE Healthcare's environmental monitoring programme identified elevated concentrations of radium-226 in a grass verge just off the site. The radium-226 was present at levels slightly in excess of the naturally-occurring level of radium-226 in the Buckinghamshire area. Subsequent monitoring has confirmed that this issue is limited to the grass verge and adjacent land is not affected. GE Healthcare has removed the contaminated soil.

A consumption and occupancy habits survey in the vicinity of the site was undertaken in 2004. Considering pathways downstream of the release point for discharges of liquid effluents, no consumers of fish, shellfish or freshwater plants were identified directly. However, there was hearsay evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg $year^{-1}$ for fish has therefore been assumed. Occupancy of the river and canal banks by anglers and others was confirmed as continuing, and this pathway has also been assessed. The dose in 2006 from fish consumption and external radiation was less than 0.005 mSv, which was less than 0.5% of the dose limit for members of the public of 1 mSv (Table 6.1).

The dose to the critical group of local terrestrial food consumers was assessed as being less than 0.015 mSv, which was less than 2% of the annual dose limit for members of the public. This estimate includes a contribution of 0.011 mSv from estimates of concentrations of discharged radionuclides in air. The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.22 mSv or 22% of the dose limit.

6.2 Maynard Centre, Cardiff



A second laboratory, situated near Cardiff, produces radiolabelled compounds used in research and diagnostic kits used in medicine for the testing of clinical samples and radio-pharmaceuticals. Liquid wastes are discharged into the Ystradyfodwg and Pontypridd public sewer (YP). This joins the Cardiff East sewer, which after passing through a new waste water treatment works discharges into the Severn estuary near Orchard Ledges. During periods of high rainfall, effluent from the YP sewer has been known to overflow into the River Taff. In addition, there is run-off from the site into the river. The authorisation for OrthoClinical Diagnostics Ltd a tenant on the site was revoked in 2004 and consequently no discharges were made by them in 2006.

In April 2004, the Environment Agency issued a new authorisation for the site. Limits were reduced for all the radionuclides and the management conditions were improved. The new authorisation required the introduction of new technology to be developed to reduce the discharges of tritium and carbon-14 in the future.

In 2006, GE Healthcare applied to vary their existing authorisation to dispose of solid waste for processing and disposal at WMTL, Winfrith. In May 2006, the Environment Agency issued a consultation document to assist the process (Environment Agency, 2006m), and a decision document was issued in July 2006 (Environment Agency, 2006n).

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, their main radioactive waste (Environment Agency, 2006o). GE Healthcare also indicated that Project Paragon had been unable to develop a process for the recycling of liquid and gaseous carbon-14 wastes. Liquid carbon-14 wastes will continue to be stored until another recycling process or disposal route is developed.

At present some tritium effluent, which includes a significant proportion of the organic form, is withheld and stored on site pending the introduction of the plant. Once the new plant is commissioned, both the stored waste and future arisings of tritium will be treated (where practical) to recycle the radionuclide. This should significantly reduce the generation and subsequent discharges of tritium in the future. Discharges of organic tritium in 2006 were less than those in 2005. Levels of discharge in recent years are likely to be maintained until the plant becomes fully operational.

GE Healthcare continues to concentrate and contain high activity low volume waste liquids contaminated with carbon-14. This should ensure that their failure to develop a recycling process for their carbon-14 wastes should not result in a significant increase in liquid discharges to the River Taff. GE Healthcare has concluded that the Best Practicable Means of minimising their gaseous discharges of carbon-14 is to continue with their current arrangements; this will mean that their gaseous discharges of carbon-14 will be approximately proportionate to the scale of their manufacturing activities.

Routine monitoring, carried out on behalf of the Welsh Assembly Government, includes consideration of consumption of locally produced food and external exposure over muddy, intertidal areas (Figure 6.1). Measurements of external exposure are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, *Fucus* seaweed, soil and grass provide additional information. Earlier monitoring and research has targeted organic tritium in foodstuffs (Food Standards Agency, 2001b, Swift, 2001; Williams *et al.*, 2001; Leonard *et al.*, 2001 and McCubbin *et al.*, 2001). A full review of monitoring data for tritium bioaccumulation has been undertaken (Rowe *et al.*, 2001). A local habits survey was completed in 2003 and the assessment of exposures given below takes the results into account.

The results of routine monitoring in 2006 are presented in Tables 6.3(a) and (b). The main effect of liquid discharges is seen in enhanced tritium and carbon-14 activities in samples above background levels. The results of sample analyses show that virtually all of the total tritium in marine samples was associated with organic matter. The tritium is strongly bound to organic matter and has the potential to transfer through the marine foodchain from small organisms to accumulate in fish. The dose coefficients for this form of tritium differ from those for tritiated water (see Appendix 1) and the estimates of dose for members of the public take this into account. 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, we have taken a generic dose coefficient for organically bound tritium (OBT). 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. There were similar concentrations of carbon-14 in seafood in 2006, despite a small increase in the carbon-14 discharge. The lower tritium levels, in comparison

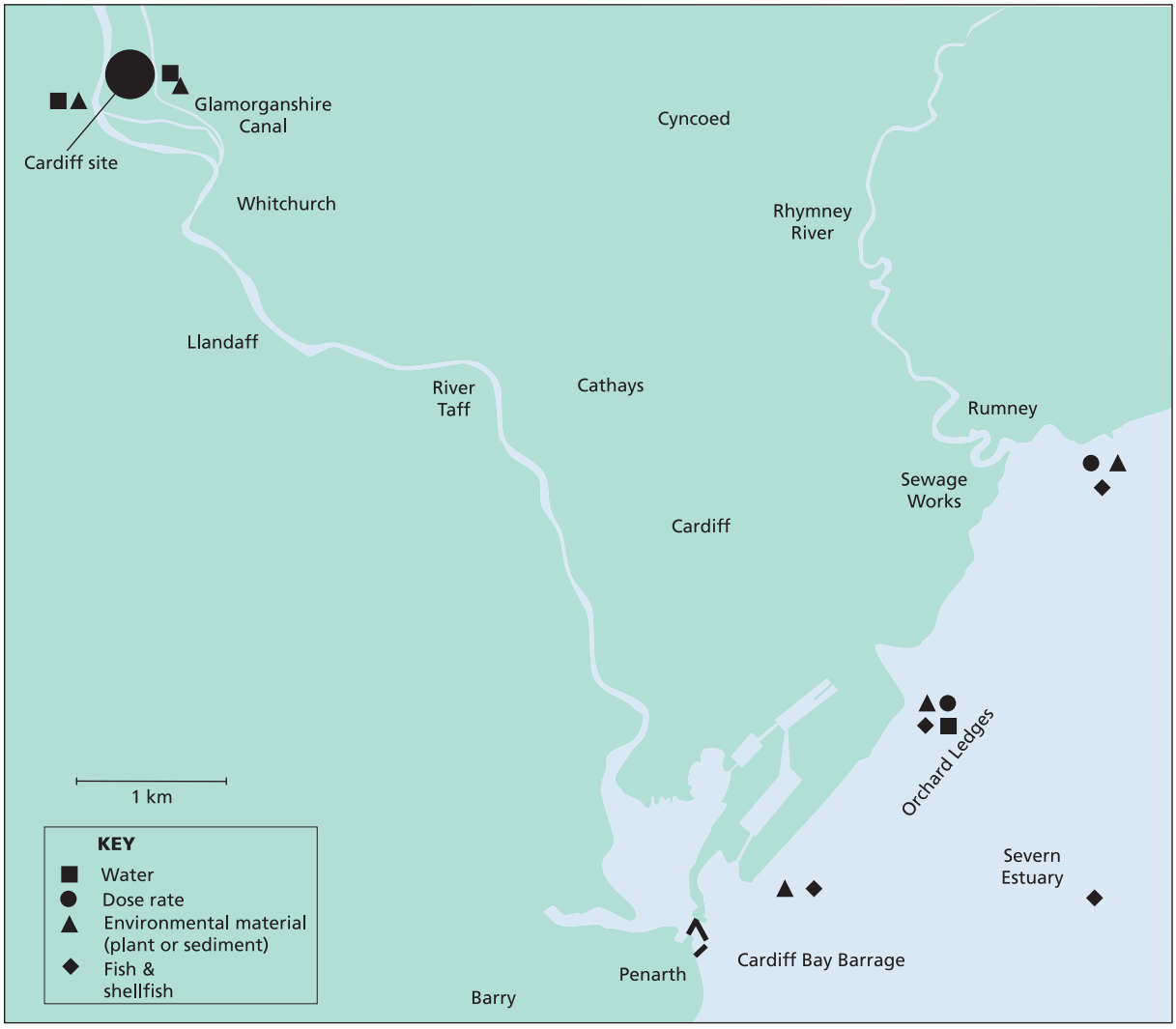


Figure 6.1. Monitoring locations at Cardiff (excluding farms)

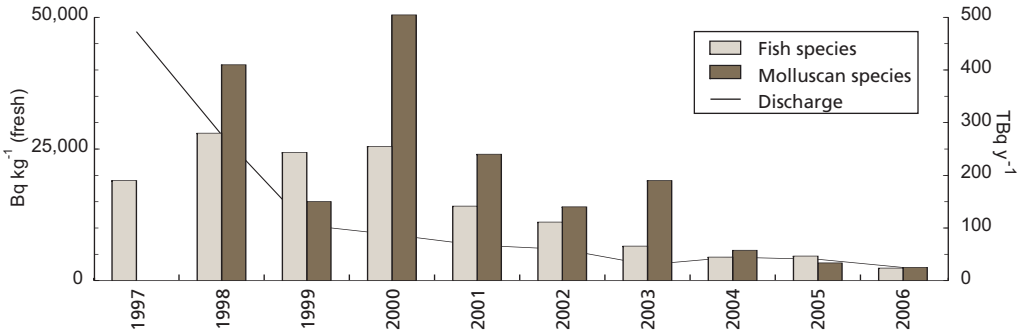


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

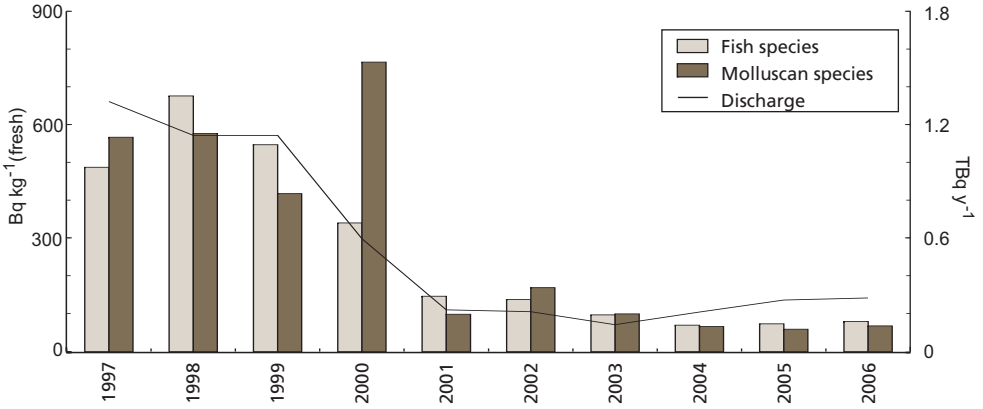


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

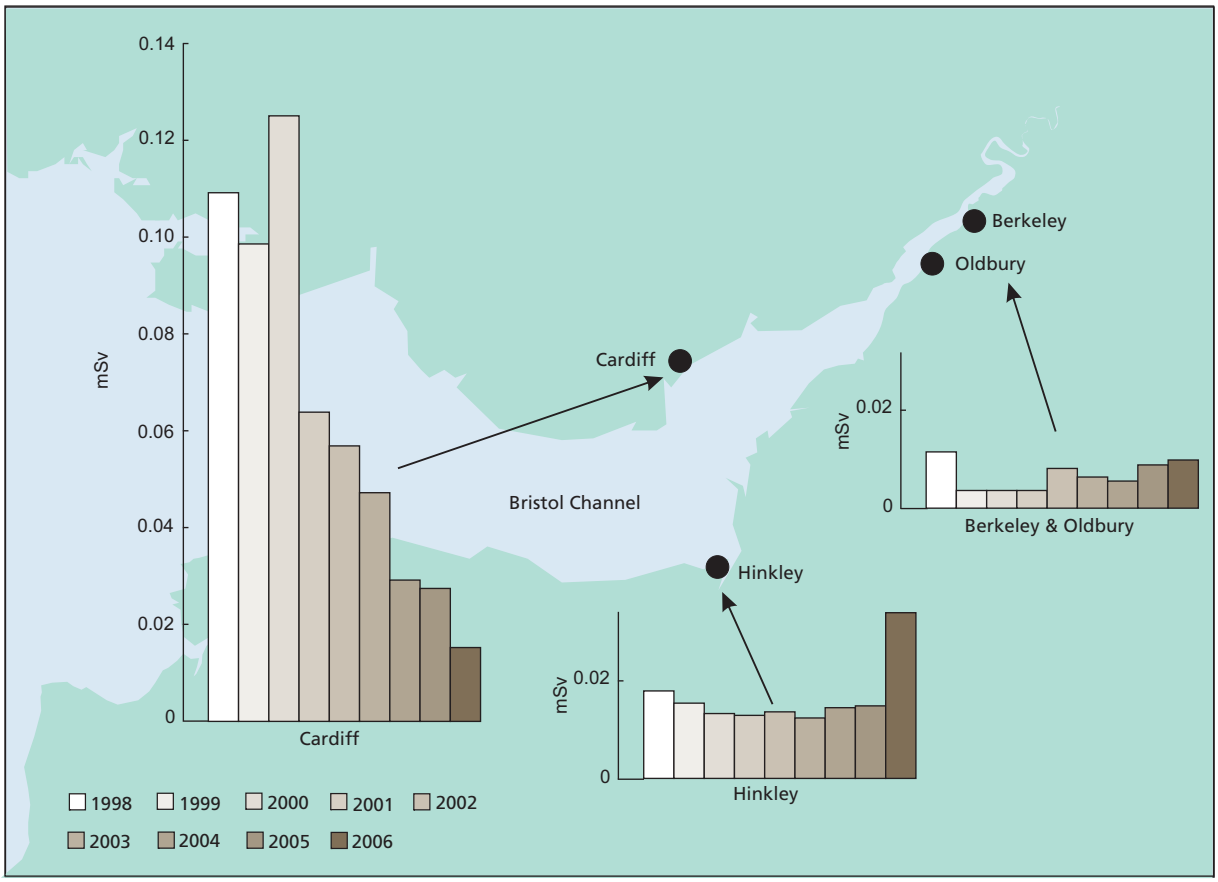


Figure 6.4. Individual radiation exposures to seafood consumers from artificial radionuclides in the Severn Estuary, 1998-2006. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv; an alternative tritium dose coefficient is applied for seafood in the Bristol Channel)

to previous years, were most probably due to a reduction in the organically bound components of the discharge.

Tritium continued to be detected in water from the Glamorganshire Canal, which is not used as a source of water for the public water supply. Concentrations in run-off from the site into the River Taff decreased in 2006 from 100 Bq 1^{-1} (2005) to below the LoD (<13 Bq 1^{-1}). Concentrations in sediment from the local canal were similar to those in 2005. 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. Concentrations of tritium in fish were generally lower in 2006 in comparison with 2005 (Figure 6.2). This is consistent with a reduction of liquid discharges, from ~ 40 TBq in 2005 to ~25 TBq in 2006. Gamma and beta dose rates over sediment, as measured using portable instruments, were generally difficult to distinguish from those expected from the natural background. Using an increased dose coefficient for tritium specifically derived for the OBT discharged from this site, the dose to the critical group of prenatal children of fish and shellfish consumers in 2006 was 0.015 mSv. This was less than 2% of the dose limit for members of the public of 1 mSv (Table 6.1). This estimate includes a small contribution due to external radiation. The reduction from 0.027 mSv in 2005 also reflects the lower concentrations of tritium in fish. The tritium dose coefficient was revised to account for the most recent evidence from an experiment involving the uptake and retention of tritium fed to rats (see Appendix 1). The prenatal age group was introduced in 2005 following the recommendations of the HPA. The dose to this age group in 2005 was 0.027 mSv. The dose to the next highest age group in 2006, adults, was 0.012 mSv. 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, the largest contribution was estimated from the inadvertent ingestion of iodine-131 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). Despite an increase in 2006, doses for Hinkley Point and Berkeley/Oldbury have remained relatively constant and low.

The habits survey in 2003 identified consumers of wildfowl collected near Cardiff. Although samples of wildfowl were not monitored in 2006, an assessment has been undertaken making use of data from an earlier RIFE report when levels in the aquatic environment were greater than in 2006 (Food Standards Agency and Scottish Environment Protection Agency, 2000). The dose from high-rate consumption of wildfowl on this basis was less than 0.005 mSv.

The main effects of gaseous discharges were also seen in results for tritium and carbon-14. The incidence of detection of enhanced carbon-14 and tritium activities in a wide range of terrestrial samples is relatively high in comparison with other nuclear sites. Sulphur-35, which is not discharged by GE Healthcare, was detected at levels similar to those found in the general diet survey (see Section 8). All these measurements were of low radiological significance.

The maximum estimated dose to local terrestrial food consumers was to the 1-year-old age group. This critical group received 0.010 mSv, which was 1% of the dose limit for members of the public of 1 mSv. The largest contribution was from carbon-14 in milk. The estimate includes a small contribution from modelled concentrations of radionuclides in air (Appendix 1). 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% of the dose limit.

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 2006, 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.

Table 6.1. Individual radiation exposures – radiochemical sites, 2006

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 or water	Gaseous plume related pathways
Amersham	Anglers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food[b]	0.015	-	<0.005	-	-	0.011
	All sources[c]	0.22	-	-	-	-	-
Cardiff	Prenatal children of seafood consumers	0.015	0.011	-	<0.005	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Consumers of locally grown food[b]	0.010	-	0.008	-	-	<0.005
	All sources[c]	0.011	-	-	-	-	-

[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, 2006[f]

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{32}P	^{35}S	^{57}Co	^{65}Zn	^{125}I	^{131}I
Freshwater samples											
Pike	Newbridge	1	<25	<25				<0.03	<0.13		*
Pike	Outfall (Grand Union Canal)	1	<25	<25	18			<0.03	<0.09		*
Pike	Staines	1	<25	<25				<0.04	<0.21		*
Pike	Shepperton	1	<25	<25				<0.04	<0.23		*
Pike	Teddington	1	<25	<25				<0.04	<0.22		*
Flounder	Beckton	1		<25				<0.08	<0.56		*
Nuphar lutea	Newbridge	1		<25				<0.05	<0.20		*
Nuphar lutea	Outfall (Grand Union Canal)	1		<25				0.10	0.42		*
Nuphar lutea	Staines	1		<25				<0.04	<0.21		*
Sediment	Outfall (Grand Union Canal)	2[E]						<2.1	<1.3	<0.61	<1.6
Sediment	Upstream of outfall (Grand Union Canal)	2[E]						<4.1	<2.3	<0.89	<1.3
Freshwater	Maple Cross	2[E]		<4.2				<1.2	<0.80	<0.20	<0.47
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]		<4.1				<0.69	<0.40	<0.20	<0.24
Freshwater	River Chess	1[E]		<4.0				<0.84	<0.39	<0.20	<0.31
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<30		<0.53	<1.0	<0.96	<0.55	<0.25	
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]		<36		<1.3	<2.2	<0.78	<0.48	<0.20	
Final effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<14		<1.1	<1.0	<0.85	<0.50	<0.23	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Total alpha	Total beta
Freshwater samples										
Pike	Newbridge	1	<0.04	0.000022	0.00015	0.00029	0.000020	*		
Pike	Outfall (Grand Union Canal)	1	0.22			<0.09				
Pike	Staines	1	0.15			<0.06				
Pike	Shepperton	1	0.18			<0.07				
Pike	Teddington	1	0.10			<0.07				
Flounder	Beckton	1	0.20			<0.15				
Nuphar lutea	Newbridge	1	0.07			<0.13				
Nuphar lutea	Outfall (Grand Union Canal)	1	<0.05			<0.12				
Nuphar lutea	Staines	1	0.06			<0.05				
Sediment	Outfall (Grand Union Canal)	2[E]	2.6						200	260
Sediment	Upstream of outfall (Grand Union Canal)	2[E]	7.1						240	420
Freshwater	Maple Cross	2[E]	<0.34						0.11	0.59
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<0.16						<0.047	0.25
Freshwater	River Chess	1[E]	<0.17						<0.040	<0.10
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<0.22			<0.34			<0.11	0.82
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<0.18			<0.29			<3.0	6.1
Final effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<0.19			<0.30			<0.050	0.63

Table 6.2. continued

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	Total alpha	Total beta
Terrestrial samples												
Milk		2	<4.6	<0.25			<0.29	<0.021	<0.0067	<0.20		
Milk	max		<4.8				<0.30	<0.022	<0.0069			
Apples		1	<5.0	<0.10			<0.20	<0.040		<0.20		
Beetroot		1	<5.0	0.30			<0.30	<0.054		<0.20		
Blackberries		1	<5.0	0.70			<0.20	<0.067		<0.20		
Carrots		1	<4.0	0.20			<0.30	<0.039		<0.20		
French beans		1	<4.0	0.50			<0.20	<0.049		<0.30		
Runner beans		1	<5.0	<0.20			<0.30	<0.047		<0.30		
Spinach		1	<5.0	1.0			<0.30	<0.024		<0.30		
Wheat		1	<7.0	1.3			<0.20	<0.078		<0.30		
Grass	Next to site	1[E]		6.9	<16	<8.4		<4.0	<5.3	<3.7	33	170
Grass	Orchard next to site	1[E]		7.8	<17	<8.6		<4.0	<6.7	<3.5	<5.0	170
Grass	Water Meadows (River Chess)	1[E]		6.5	<15	<7.6		<3.0	<4.3	<3.2	<5.0	170
Soil	Next to site	1[E]			<7.4	<5.7		<1.0	<4.7	11	300	420
Soil	Orchard next to site	1[E]			<2.2	<1.3		<0.50	<0.91	18	480	580
Soil	Water Meadows (River Chess)	1[E]			<2.4	<1.3		<0.50	<1.0	12	220	360

** Not detected by the method used*

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

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

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

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

[e] The concentration of ^{3}H as tritiated water was <15 Bq l^{-1}

[f] The gamma dose rate in air at 1 m over grass and mud on the bank of the Grand Union Canal was 0.053 μGy h^{-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(a). Concentrations of radionuclides in food and the environment near Cardiff, 2006

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	^{155}Eu
Marine samples											
Cod	East of new pipeline	2		780	52			*	<0.05	0.54	<0.09
Flounder	East of new pipeline	4	4000	4400	120			*	<0.12	0.47	<0.19
Sole	East of new pipeline	1		4600	100			*	<0.08	0.31	<0.14
Mullet	East of new pipeline	1		45	27			*	<0.22	0.46	<0.50
Lesser spotted dogfish	Off Orchard Ledges	2	2900	3300	93			*	<0.18	0.90	<0.29
Skates/Rays	Off Orchard Ledges	2	790	1100	71			*	<0.11	1.2	<0.23
Mussels	Orchard Ledges	2	2300	2500	68			*	<0.12	0.39	<0.23
Fucus vesiculosus	Orchard Ledges	2	54	77	17			*	<0.08	0.52	<0.19
Seaweed	Orchard Ledges	2[E]		<43	<30	17	<0.65				
Mud	Orchard Ledges East	2	66	81				*	<1.4	25	<1.9
Sediment	East of new pipeline	2[E]		<180	<28		<0.70			30	
Sediment	West of new pipeline	2[E]		<110	<25		<0.85			30	
Seawater	Orchard Ledges East	2		5.0							
Seawater[h]	Orchard Ledges	2[E]		<16	<4.0		<0.25				

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	Total alpha	Total beta
Terrestrial samples														
Milk			7	<5.9	<7.4	16	<0.40	<0.33	<0.021		<0.20	<0.21		
Milk		max		<11	<17	19	<0.48	<0.38	<0.027		<0.25	<0.23		
Barley			1		8.0	69		1.2	<0.059		<0.20	<0.20		
Beetroot			1	4.0	22	27		<0.20	<0.027		<0.20	<0.20		
Blackberries			1	24	84	23		<0.20	<0.035		<0.20	<0.20		
Cabbage			1	<8.0	8.0	<3.0		1.4	<0.024		<0.20	<0.20		
Honey			1		23	97		<0.20	<0.028		<0.20	<0.20		
Leeks			1	15	31	15		0.40	<0.059		<0.30	<0.30		
Onions			1	<5.0	<5.0	<2.0		0.40	<0.051		<0.30	<0.30		
Potatoes			1	6.0	14	24		0.30	<0.053		<0.30	<0.30		
Rape oil			1		<8.0	38		4.6	0.069		<0.30	<0.30		
Strawberries			1	1.0	59	17		<0.20	<0.028		<0.20	0.50		
Grass			5	96	330	42					<0.20	<0.20		
Grass		max		260	1200	47								
Silage			2	<6.5	<8.0	30								
Silage		max		7.0	10	32								
Soil			3								<0.20	5.0		
Soil		max										11		
Sediment	Canal		2[E]		330	<34			<1.0			12		
Freshwater[d]	Run off into River Taff		2[E]		<13	<4.0			<0.25	<1.7		<0.26	<0.045	0.25
Freshwater[e]	Canal		2[E]		25	<4.0			<0.30	<1.2		<0.33	<0.035	<0.10
Freshwater[f]	River Taff		2[E]		<19	<4.0			<0.30	<2.0		<0.22	<0.055	<0.22

** Not detected by the method used*

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

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

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

[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 30 Bq l^{-1}

[f] The concentration of ^{3}H as tritiated water was 4.8 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 6.0 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, 2006

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	1	0.069
East of Pipeline	Mud and pebbles	1	0.071
West of Pipeline	Pebbles and rock	1	0.10
West of Pipeline	Rock and sand	1	0.095
Peterstone Wentlooge	Mud	1	0.089
Peterstone Wentlooge	Salt marsh	1	0.085
Mean beta dose rates			µSv h^{-1}
Orchard Ledges East	Mud	2[F]	0.057

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

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.

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. In 2006 it was operated by Sellafield Ltd. but as from 29 July 2007 it is operated by LLW Repository Ltd.

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

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

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

The new 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 2006, be distinguished from those due to Sellafield.

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

Key points

- New Drigg authorisation issued in 2006
- Concentrations and dose rates at LLWR near Drigg were similar to those in 2005
- Doses for LLWR near Drigg were less than 2% 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% 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 24% of dose limit
- Contamination on Aberdeen Beach with naturally-occurring radionuclides continued but no restriction on access was required
- Radium-226 contamination found on beaches near Dalgety Bay, Fife
  - SEPA is unaware of any other potential sources of this contamination other than that originating from the former MoD site at Dalgety Bay
  - The likelihood of harm to a member of the public is considered to be low

dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2005. 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 2005 and were approximately the same as WHO screening values for drinking water. Low concentrations of tritium were detected.

Very low levels of gaseous wastes are discharged from LLWR near Drigg. As such the monitoring programme of terrestrial foodstuffs at the site is primarily directed at the potential migration of radionuclides from the waste burial site via ground water.

Results for 2006 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 0.016 mSv which was less than 2% 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 2006 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4. 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 y^{-1}) from the site with the highest observed concentration of tritium (Glasgow) would result in a dose of less than 0.005 mSv or less than 0.5% of the dose limit for members of the public of 1 mSv (Table 7.1).

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

Following an enquiry from a member of the public suggesting that natural radionuclides associated with the oil and gas industry were being leaked from the disused landfill site in Aberdeen, SEPA collected leachate and analysed its content for tritium, radium-226 and actinium- 228. The results are available in Table 7.3. No enhanced concentrations of radionuclides of natural origin associated with the oil and gas industry were detected but an elevated level of tritium was detected. SEPA will undertake further sampling during 2007.

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 2006 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.

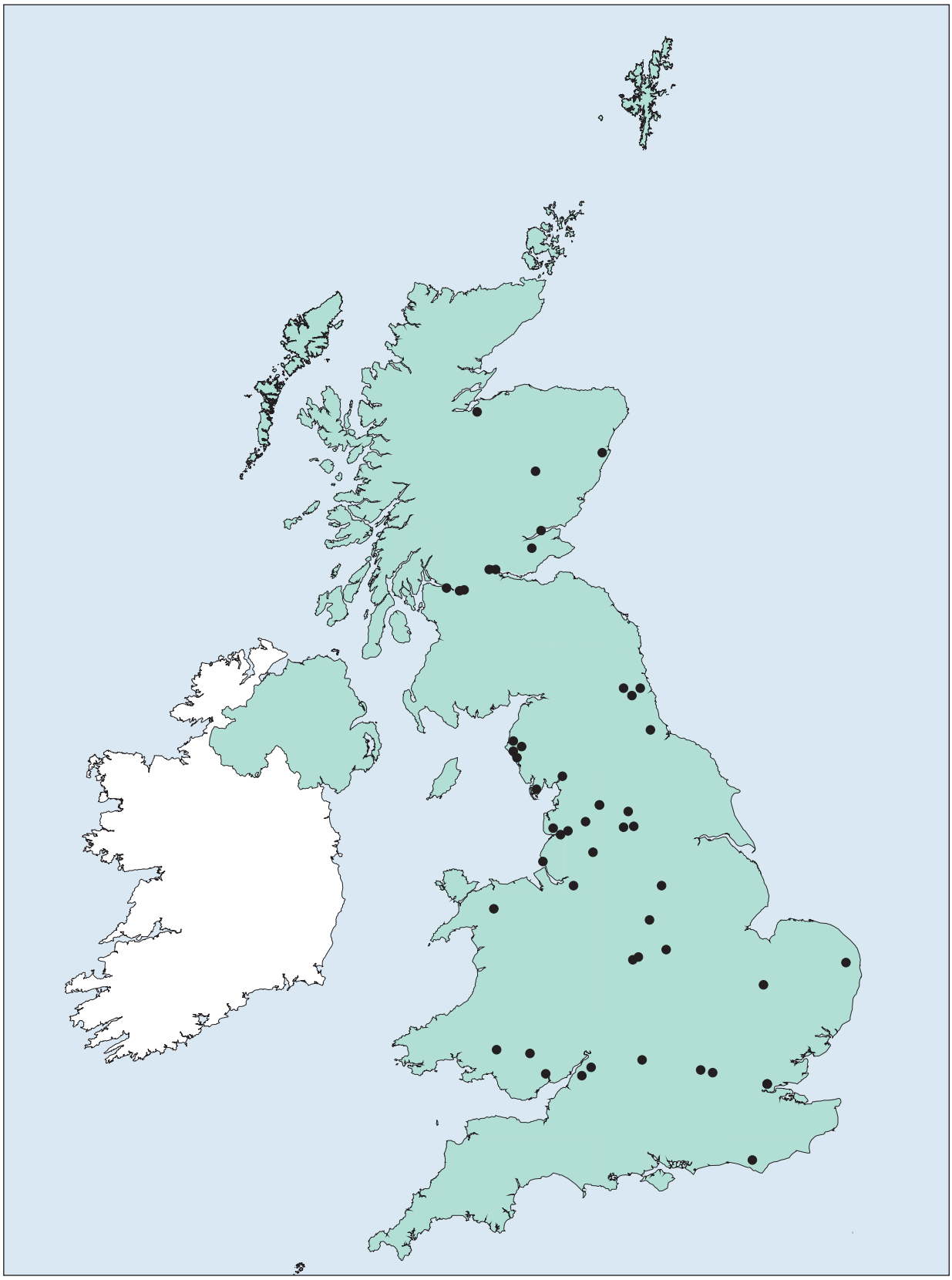


Figure 7.1. Landfill sites monitored in 2006

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 substantially since 1990, and more dramatically since 1992. These were small reductions in concentrations of polonium-210 in 2006 compared with 2005. 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. There were small enhancements for some samples above the expected natural background median levels for marine species, particularly in Saltom Bay, but the majority were within the ranges observed in the undisturbed marine environment. It is nevertheless considered prudent to continue to estimate doses based on the difference between observed concentrations and median levels indicative of natural background.

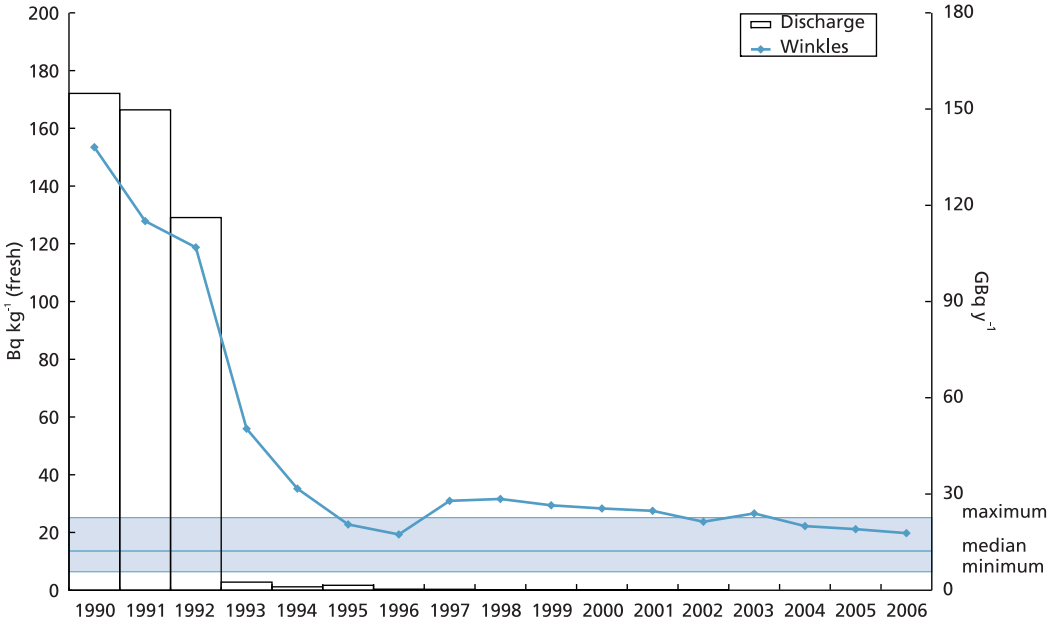


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton (maximum, median and minimum are taken to be natural values based on sampling and analysis from a detailed study – see Appendix 1, Table A4.1)

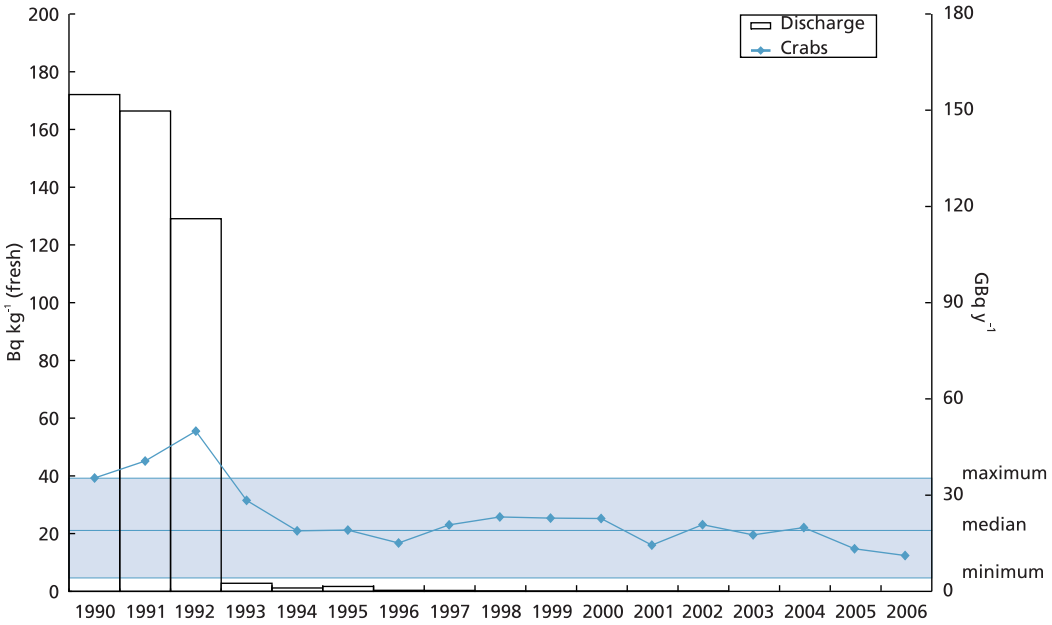


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton (maximum, median and minimum are taken to be natural values based on sampling and analysis from a detailed study – see Appendix 1, Table A4.1)

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 2006. The assessment is based on averaging the consumption rates over a five-year period from 2002 – 2006. Dose coefficients for polonium-210 were updated in 2004 to reflect new results from research involving the consumption of mussels and cockles containing natural concentrations of polonium-210 (Appendix 1). A conservative gut transfer factor of 0.8 is taken to apply to seafood generally, but we have adopted a value of 0.5 for molluscs where specific experimental evidence is available.

The critical group dose from enhanced naturally-occurring radionuclides from non-nuclear industrial activity (i.e. TNORM) was 0.24 mSv in 2006, similar to the estimate for 2005 (Table 7.1). The small decreases in concentrations of polonium-210 were balanced out by small increases in consumption rates. 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 2006, these exposures added a further 0.23 mSv to the doses above resulting in a total dose to this group of up to 0.47 mSv rounded to 2 significant figures. The estimated doses in 2006 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 carried out 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 against certain conditions contained in the variation notice.

Monitoring in the vicinity of discharges from Scotoil has included sampling of mussels from Aberdeen Harbour. It was concluded that it was unlikely that, should consumption occur, the dose from normal concentrations of naturally-occurring radiation would be enhanced due to Scotoil operations (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999). More recent surveys in 2004 found enhanced concentrations of lead-210 and radium-226 in sub-tidal samples from the Albert Basin and the River Dee (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2005). Further monitoring was undertaken in 2005 and the results showed that radiation dose rates and concentrations of radionuclides over the greater part of the beach were indistinguishable from the normal levels expected within the range of natural background. However, there was a localised area (about 50 metres by 25 metres) in the Footdee part of Aberdeen Beach where dose rates were up to about 10 times natural background and concentrations of polonium-210, radium-226 and actinium-228 in surface sediments were also enhanced. A multi-agency Incident Management Team involving the local authority, health board and government health and environment specialists was established to address the issue and an assessment was made of the potential risk to people in the area considering external exposure, inhalation and ingestion pathways (Scottish Environment Protection Agency, 2006c). The assessment suggested that the additional exposure by members of the public who regularly use the southern end of Aberdeen beach was less than 0.1 mSv in 2005. As a consequence Aberdeen City Council considered that it was not necessary to close any part of the beach on public health grounds.

Further monitoring will be undertaken by SEPA in 2007.

7.5 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected in Dalgety Bay in Fife since at least 1990. Contamination is likely to be due to past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959. The air station played a role as an aircraft repair, refitting and salvage yard. It is believed that waste was incinerated and the resultant ash and clinker was disposed of in an area of ground that, as a result of erosion, is now exposed and adjacent to the foreshore. Some of the incinerated material contained items which had been painted with luminous paint containing radium-226.

In June 1990, environmental monitoring showed elevated radiation levels in the Dalgety Bay area. The monitoring was undertaken as part of the routine environmental monitoring programme for Rosyth Nuclear Dockyard carried out in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material was removed for analysis, which indicated the presence of radium-226. Further investigation confirmed that the contamination could not have originated from the dockyard

and was most likely to be associated with past practices related to the nearby former 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 the most recent monitoring exercise, conducted during March 2006, was used to undertake a screening risk assessment. The monitoring survey report and screening risk assessment have recently been published (RWE Nukem (2006) and Scottish Environment Protection Agency (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.

During 2006, SEPA also carried out monitoring of winkles, mussels and cockles for radionuclides at Dalgety Bay. This served as a check that there had been no enhancement of radioactivity in seafood from the local area. The results are given in Table 7.6 and the positive determinations are within the normal ranges expected for natural radionuclides.

7.6 Other non-nuclear sites

Other small-scale studies of the effects of waste discharges from non-nuclear sites were carried out in 2006.

The first study looked into discharges of phosphorus-32 into freshwater systems in Cambridge. Phosphorus-32 behaviour in rivers has been of interest for some time because it may concentrate in fish. The generic concentration factor for phosphorus-32 between river water and fish is high, 5000 Bq t^{-1} per Bq m^{-3} which can lead to over-estimates of predictions of concentration and dose from phosphorus-32 in fish. The National Dose Assessment Working Group (NDAWG) has identified phosphorus-32 concentration factors for fresh water fish as an area of uncertainty that would benefit from further experimental work. Provisional measurements were undertaken in the River Cam where there are known discharges of small amounts of this nuclide. The results will be used as an input to a review of the available phosphorus concentration factors.

Two samples of water and two of fish were obtained in June 2006 (Shaw, 2006). In water, phosphorus-32 was not detected at <0.04 Bq l^{-1}. In pike, the result was < 0.07 Bq kg^{-1}. A positive determination was found for roach at 0.55 Bq kg^{-1}. It is not practical to calculate concentration factors from these data. The Environment Agency has therefore initiated further research into phosphorus-32 behaviour in freshwater rivers in a project that will begin 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. In addition, low concentrations of phosphorus-32 were detected. 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% of the dose limit.

Table 7.1. Individual radiation exposures – industrial and landfill sites, 2006

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]	0.016	-	-	0.016	-	-
	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]	0.47	0.19	0.24	-	0.036	-

[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, 2006

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	^{129}I
Milk		1	<5.0	15	<0.25	0.078	<0.43	<0.33	<0.0040	<1.6	<0.47	<0.0090
Blackberries		1	<5.0	13	<0.30	0.27	<0.40	<0.30		<2.0	<0.40	<0.038
Cabbage		1	<4.0	<2.0	<0.10	0.27	<0.30	<0.30	<0.012	<1.6	<0.70	<0.024
Deer muscle		1	12	18	<0.20	<0.0080	<0.40	<0.20	<0.011	<1.0	<0.50	<0.047
Eggs		1	6.0	19	<0.20	<0.0060	<0.30	<0.20		<1.7	<0.40	<0.028
Potatoes		1	<5.0	15	<0.30	0.042	<0.50	<0.30	<0.011	<1.7	<0.60	<0.023
Rabbit		1	<5.0	18	<0.30	0.011	<0.30	<0.30	<0.015	<2.1	<0.70	<0.034
Sheep muscle		1	6.0	16	<0.30	0.040	<0.40	<0.30	<0.023	<1.7	<0.50	<0.028
Sheep offal		1	<8.0	29	<0.10	0.16	<0.40	<0.30	<0.011	<1.8	<0.70	<0.029
Turnips		1	<5.0	10	<0.30	0.40	<0.40	<0.30		<1.6	<0.50	<0.032
Grass		2							<0.058			
Grass	max								0.091			
Sediment	Drigg Stream	4[E]			<0.90	<5.8	<2.7	<1.5		<6.3	<5.8	
Freshwater	Drigg Stream	4[E]	<7.8		<0.30	<0.10						
Freshwater	Railway Drain	1[E]	33		<0.48	3.1						

Material	Location	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.23	<0.26	0.25	<0.96				
Blackberries		1			0.089	<1.1				
Cabbage		1			1.2	<1.1				
Deer muscle		1			7.3	<0.90				
Eggs		1			0.10	<0.90				
Potatoes		1			0.54	<0.80				
Rabbit		1			2.2	<1.0				
Sheep muscle		1			2.0	<2.2				
Sheep offal		1			1.1	<2.4				
Turnips		1			0.30	<1.0				
Sediment	Drigg Stream	4[E]	<2.1	130		<3.1	14	16	12	11
Freshwater	Drigg Stream	4[E]	<0.27	<0.24			<0.0050	<0.0078	<0.0078	<0.0050
Freshwater	Railway Drain	1[E]	<0.46	<0.41			<0.0060	<0.0050	0.018	<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	Total alpha	Total beta
Milk		1					<0.00020	<0.00018	<0.026	<0.00018		
Blackberries		1					<0.00030	0.0010	<0.043	0.0014		
Cabbage		1					<0.00020	<0.00020	<0.041	0.00020		
Deer muscle		1					<0.00020	0.00060	<0.19	0.00020		
Eggs		1					0.00020	0.00030	<0.029	0.00050		
Potatoes		1					0.00030	0.00050	<0.070	0.0010		
Rabbit		1					<0.00040	<0.00060	<0.049	0.00030		
Sheep muscle		1					0.0010	0.0016	<0.11	0.0029		
Sheep offal		1					0.0029	0.017	0.076	0.018		
Turnips		1					<0.00020	0.00050	<0.065	0.00050		
Grass		2				0.089						
Grass	max		0.020	<0.0012	0.020	0.11						
Soil		1	5.2	0.22	4.8							
Sediment	Drigg Stream	4[E]	20	<0.84	20		3.4	19	110	20	420	730
Freshwater	Drigg Stream	4[E]	<0.012	<0.0050	<0.0088		<0.011	<0.0073	<1.3	<0.012	<0.043	0.58
Freshwater	Railway Drain	1[E]	0.073	<0.0050	0.068		<0.010	<0.0050	<1.0	<0.015	0.14	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 Total U in 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, 2006

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	24	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	310	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	1000	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	50	<15	<0.05	<0.05
Dunbartonshire	Birdstone	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	<5.0	<15	0.11	<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	46	<15	<0.05	<0.05
Fife	Melville Wood	1	180	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	210	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	5.7	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	88	<15	0.06	<0.05

Additional ad hoc sampling was conducted at a location in Aberdeen for which the results (in Bq l^{-1}) were 5500 for ^{3}H (liquid), <30 for ^{226}Ra (liquid), <10 for ^{226}Ra (solid) and <10 for ^{228}Ac (solid)

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2006

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}															
			Total ^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
City of Bristol																			
Crooks Marsh Farm, Avonmouth	Leachate	1		18	<4.0	<4.2	<0.19	<0.20	<0.52	<0.18								0.15	0.59
Cambridgeshire																			
Milton Landfill, Cambridge	Site borehole	1		120		51	<0.27			<0.19		<0.0050	<0.0050	<0.0050	<0.012	<0.0060	<0.0090	<1.3	46
Milton Landfill, Cambridge	Ground water borehole	1		<4.0		<9.9	<0.50			<0.39		<0.0060	0.011	<0.0050	<0.0050	<0.0050	<0.0050	<0.060	0.63
Milton Landfill, Cambridge	Phase 2 borehole 3.6	1		310		36	<0.49			<0.41		<0.013	<0.0050	<0.0050	<0.0080	<0.0060	<0.012	<0.41	32
Milton Landfill, Cambridge	Phase 2 borehole 3.7	1		4.0		21	<0.24			<0.19		<0.0070	<0.0050	<0.0050	<0.0070	<0.0080	<0.0070	<0.37	20
Carmarthenshire																			
Cefnbrynbrain	Liquid	1									<0.050								
Cheshire																			
Northwich Tip	Borehole WM5G	1		5.8		<4.3	<0.24			<0.19		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.35	4.1
Northwich Tip	Borehole WM6G	1		200		<4.6	<0.19			<0.18		<0.0070	<0.0060	<0.0050	0.0080	<0.0050	0.0050	<2.0	11
Northwich Tip	Borehole WM20G	1		<4.0		<6.1	<0.29			<0.26		<0.015	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<3.0	<5.0
Cleveland																			
Bewley ICI Tip	On-site stream (downstream)	1		4.5		11	<0.12			<0.11		<0.0050	<0.0070	<0.0050	0.033	<0.0050	0.027	<0.50	12
Bewley ICI Tip	On-site stream (upstream)	1		4.1		11	<0.10			<0.09		<0.0050	<0.0050	<0.0050	0.030	<0.0050	0.026	<0.50	15
Cumbria																			
Rhodia Consumer Specialties Ltd, Hut Bank Quarry	Borehole	1		<4.0		15	<0.22			<0.21		<0.0050	<0.0050	<0.0050	<0.0060	<0.0050	<0.0050	0.31	17
Rhodia Consumer Specialties Ltd, Ufex	Leachate	1		<4.0		59	<0.19			0.56		<0.0080	<0.0050	<0.0050	0.97	0.042	1.0	<8.0	56
Alco Landfill	Borehole	1		6.0	<4.0	<6.2	<0.30	<0.30	<0.54	<0.26								<0.13	1.2
BAE Systems Marine Ltd, Walney Island	Waste ponds water	1		<4.0		<4.0	<0.24			<0.20		<0.0070	<0.010	<0.0050	<0.010	<0.0050	<0.0080	<0.020	0.29
Greater London																			
Murex Ltd	Local water (East stream)	1		<4.0		<6.0	<0.28			<0.26		<0.0080	<0.0050	<0.0050	0.066	<0.0050	0.063	<0.52	2.5
Murex Ltd	Local water (West stream)	1		<4.0		<6.1	<0.28			<0.25		<0.0050	<0.0050	<0.0050	0.062	<0.0050	0.049	<0.91	3.5
Glamorgan																			
Trecatti Landfill , Merthyr Tydfil	Raw Leachate	2	530	490	<4.0														
Trecatti Landfill , Merthyr Tydfil	Treated leachate	2	800	770	<4.0														
Gwynedd																			
Cilgwyn Quarry	Leachate	1		370	<4.0	<6.1	<0.28	<0.30	<0.57	<0.25								<0.11	3.5
Cilgwyn Quarry	2nd pit	1		<4.0	<4.0	<4.0	<0.23	<0.20	<0.45	<0.20								<0.020	0.19

Table 7.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}														
			$^{3}H^{a}$	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Hertfordshire																	
Braziers Landfill	Borehole W2	1	4.8		<2.8	<0.15			<0.14	<0.0050	<0.0050	<0.0050	0.010	<0.0050	0.0090	<0.040	0.31
Braziers Landfill	Borehole W5	1	<4.0		<4.1	<0.19			<0.18	<0.0090	<0.0050	<0.0050	0.015	<0.0050	<0.0090	<0.060	0.15
Braziers Landfill	Borehole W9	1	<4.0		<5.9	<0.29			<0.26	<0.010	0.0070	<0.0060	0.010	<0.0050	<0.011	<0.040	0.13
Cole Green Landfill	Static borehole	1	40		<6.3	<0.29			<0.26	<0.0080	<0.0050	<0.0050	0.032	<0.0050	0.020	<0.26	6.7
Lancashire																	
Magnesium Elektron, Swinton	Local water	1	<4.0		<7.0	<0.35			<0.28	<0.0050	<0.0050	<0.0050	0.0090	<0.0050	<0.0060	<0.030	0.18
Belthorne Mine Shaft	Local water (brook)	1	<4.0		<9.8	<0.49			<0.38	<0.0070	0.0080	<0.0050	<0.0050	<0.0050	<0.0050	<0.030	0.47
Clifton Marsh	Borehole 6	2	<7.0		<9.7	<0.49			<0.41	<0.0090	<0.0050	<0.0050	0.067	<0.0055	0.059	<0.21	1.9
Clifton Marsh	Borehole 19	2	<4.1		<4.2	<0.23			<0.20	<0.012	<0.012	<0.0050	0.044	<0.0055	0.041	<0.15	1.0
Clifton Marsh	Borehole 40	2	<4.3		<6.4	<0.33			<0.26	<0.013	<0.011	<0.0090	0.0095	<0.0050	0.0085	<0.070	0.89
Clifton Marsh	Borehole 59	2	15		<4.3	<0.22			<0.19	<0.038	<0.0065	<0.0050	<0.0085	<0.0050	<0.0070	<0.095	3.1
Ulnes Walton	Pond	1	<4.0		<4.2	<0.24			<0.19	<0.0090	<0.0050	<0.0050	1.1	0.010	1.0	0.97	0.66
Near Whittle Hill Quarry	River Lostock	1	<4.0		<2.8	<0.16			<0.13	<0.0070	<0.010	<0.0050	0.0050	<0.0050	<0.0050	<0.020	0.26
River Yarrow	Local water	1	<4.0		<4.1	<0.25			<0.20	<0.0090	<0.0050	<0.0050	0.0070	<0.0050	0.0070	<0.030	0.16
Merseyside																	
Sefton Meadows Tip	Local water	1	<4.0	<4.0	<5.8	<0.27	<0.30	<1.3	<0.25							0.12	0.24
Arpley Landfill	Borehole 25 (groundwater)	1	57	<4.0	<7.0	<0.32	<0.20	<0.70	<0.28							0.41	0.90
Norfolk																	
Strumpshaw Landfill	Leachate (borehole BH2)	1	<40	<4.0												<0.050	0.11
Strumpshaw Landfill	Leachate (borehole BH3)	1	<4.0	<4.0												0.061	0.19
Nottinghamshire																	
School of Agriculture, Nottingham	Local water (stream)	1	<4.0		<4.2	<0.23			<0.19	<0.0060	<0.0050	<0.0050	0.046	<0.0050	0.024	0.13	0.23
Oxfordshire																	
Stanford in the Vale	Local water	1	<4.0		<10	<0.48			<0.40	<0.0060	<0.0050	<0.0050	<0.0080	<0.0050	<0.0090	<0.11	0.19
Stanford in the Vale	Borehole 15	1	<4.0		<2.7	<0.16			<0.13	<0.0050	<0.0050	<0.0050	0.013	<0.0050	0.010	0.16	0.18
South Glamorgan																	
Lamby Way Tip	Borehole 1A	2	53	<4.0	<6.2	<0.28	<0.30	<2.3	<0.24							<0.20	3.7

Table 7.4. continued

Area/ location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}														
			^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{125}I	^{131}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
South Gloucestershire																	
Berwick Lane Landfill, Hallen	Local water	1	48														
South Yorkshire																	
Beighton Tip, Sheffield	Local water	1	<4.0	<4.0	<2.8	<0.15	<0.20	<0.21	<0.13							<0.050	0.49
Beighton Tip, Sheffield	Borehole	1	50	<4.0	<6.0	<0.28	<0.30	<0.37	<0.24							<0.18	2.9
Sussex																	
Beddingham Quarry	Leachate (site 1)	1	18	<4.0	<4.2	<0.25	<0.20	<0.23	<0.20							<0.060	1.0
Beddingham Quarry	Stream (site 2)	1	<4.0	<4.0	<2.8	<0.15	<0.20	<0.16	<0.13							<0.060	0.20
Beddingham Quarry	Leachate (site 3)	1	300	<4.0	14	<0.20	<0.20	<0.19	<0.17							<0.37	17
Tyne and Wear																	
High Urpeth Tip	Local water (downstream)	1	<4.0		<1.2	<0.10			<0.080	<0.0050	<0.0050	<0.0050	<0.0080	<0.0050	<0.0050	<0.030	0.41
Kibblesworth Colliery	Liquid (sampling point)	1	<4.0		<1.4	<0.11			<0.10	<0.0050	<0.0050	<0.0050	0.030	<0.0050	0.0080	<0.23	1.3
Ryton Tip, Gateshead	Local water	1	<4.0	<4.0	<6.1	<0.29	<0.30	<0.59	<0.25							<0.080	0.61
West Yorkshire																	
Gelderd Road Tip, Leeds	Borehole	1	14	<4.0	<4.2	<0.23	<0.20	<0.28	<0.19							0.20	1.4
Dean House Farm Tip	Borehole	1	10	<4.0	<4.3	<0.19	<0.20	<0.19	<0.17							<0.24	3.2
Wilson Road Tip	Borehole	1	28	<4.0	25	<0.29	<0.30	<0.35	<0.26							<1.2	19

[a] *As tritiated water*

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2006

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	19	1.4						
Winkles	Parton	4	18	2.0	0.72	0.92	0.42	1.5	0.077	1.3
Winkles	North Harrington	1	14							
Winkles	Nethertown	4	17							
Winkles	Drigg	1			0.76	0.86	0.46			
Winkles	Tarn Bay	1	15							
Mussels	Parton	4	42	2.0						
Mussels	Nethertown	4	50	2.0						
Limpets	St Bees	2	18							
Cockles	Ravenglass	2	26							
Crabs	Parton	4	13	0.063	0.081	0.012	0.0050	0.037	0.00081	0.037
Crabs	Sellafield coastal area	4	13	<0.0026						
Lobsters	Parton	4	11	0.088	0.034	0.022	0.011			
Lobsters	Sellafield coastal area	3	12	<0.0026						
Cod	Parton	2	0.40	0.022	0.026	0.0087	0.0034	0.0090	0.00020	0.0095
Plaice	Whitehaven	1	2.6							
Other samples										
Winkles	South Gare (Hartlepool)	1	10							
Winkles	Paddy's Hole (Hartlepool)	1	23	2.6						
Winkles	Kirkcudbright	1	4.4							
Mussels	Ribble Estuary	2			0.27	0.29	0.089			
Limpets	Kirkcudbright	1	11							
Cockles	Southern North Sea	2			0.41	0.23	0.29			
Cockles	Flookburgh	1	12							
Crabs	Kirkcudbright	1	3.8							
Lobsters	Kirkcudbright	1	0.77							
Shrimps	Ribble Estuary	2			0.012	0.012	0.0027			
Sediment	Kirkcudbright	1						7.4	0.42	7.2
Sediment	Rascarrel Bay	1						8.9	0.52	9.0
Sludge 1	Dalmuir	1	0.64							
Sludge 2	Dalmuir	1	0.81							
Sludge 3	Dalmuir	1	0.72							
Sludge pellet	Daldowie	1	44							
Sludge pellet	Daldowie	1	44							

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

Table 7.6. Monitoring at Dalgety Bay, 2006

Material	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1} (fresh)			
		^{210}Po	^{226}Ra[a]	^{226}Ra[b]	^{228}Ac
Winkles	1	6.6	0.15	<10	<10
Winkles	1	7.5	0.15	<10	<10
Winkles	1	8.3	0.31	<10	<10
Mussels	1	43	<10	<10	<10
Mussels	1	37	<11	<11	<10
Mussels	1	41	<14	<14	<10
Cockles	1	30	<10	<10	<10

[a] *Counted by emanations*
[b] *Counted by gamma spectrometry*

Table 7.7. Monitoring in the River Clyde, 2006[a]

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{14}C	^{32}P	^{99}Tc	^{125}Sb	^{137}Cs	^{155}Eu	^{241}Am
Between Finlaystone and Woodhall	Mussels	1	25	9.1	11	<0.84	0.40	<0.85	<0.43
	Fucus vesiculosus	1		20	120	0.49	3.5	<0.13	<0.13
14 km downstream of Dalmuir	Sediment	1	<15	9.6		1.5	56	1.4	2.3
Downstream of Dalmuir	Freshwater	3		<0.74		<0.10	<0.10	<0.10	<0.10
Daldowie	Sludge pellets	4		<400		<1.0	8.6	<1.8	<0.60

[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}*

8. Chernobyl and regional monitoring

8.1 Chernobyl

This year, 2006, marked the 20th anniversary of the Chernobyl accident 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 radiocaesium, 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. Marked 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 2006 are given in Table 8.1

In the summer of 2006, whole flock monitoring surveys of sheep on selected farms in the post-Chernobyl restricted areas of England and Scotland were carried out with the aim of removing restrictions where controls are no longer necessary (Food Standards Agency, 2007a,b). The results of the survey in Scotland identified three farms where controls could be lifted and this decision was implemented in January 2007, leaving seven farms subject to restrictions. The results of the survey in England did not identify any farms where controls could be lifted. In Wales, scoping surveys were conducted on selected farms and it was recommended that it was not appropriate to undertake any whole flock surveys during 2006 (Food Standards Agency, 2007c). Further whole flock monitoring surveys are planned for restricted farms in all affected areas during the summer of 2007.

There remain a total of 371 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.

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% 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% of the limit
- Monitoring undertaken in London for polonium-210 in the environment from the Litvinenko incident
- Monitoring in Northern Ireland and the Isle of Man showed low concentration of man-made radionuclides from UK industry. Doses were less than 2% 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

Sampling locations for freshwater fish are now limited to Cumbria and southern Scotland, areas of relatively high deposition of fallout from Chernobyl. Samples from areas of low deposition in England were also obtained for completeness and comparison. Table 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 170 Bq kg^{-1} in perch, with overall levels generally similar to those in recent years and substantially less than the 1000 Bq kg^{-1} level reached shortly after the accident. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al.*, 2000) and the effective ecological half-life of

radiocaesium during the late 1990s has been shown to be between 6 and 30 years.

Radiation exposures have been estimated using a procedure based on cautious assumptions, as previously stated. A consumption rate of fish of 37 kg year^{-1}, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is conservative (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have much lower radiocaesium concentration. In 2006, estimated doses were less than 0.1 mSv.

8.2 The Litvinenko incident

In November 2006, the HPA announced that Alexander Litvinenko, a resident in London, had died from a radiation dose from a high body burden of polonium-210. Litvinenko had been ill for much of November and had been in hospital at two locations in London. Following the announcement the Environment Agency carried out some precautionary monitoring in river catchments in London that may have received polonium-210 from the incident. Water and sediment samples were taken from the catchment of the River Lee in north London including Salmon's Brook and at the confluence of Pymme's Brook and the River Lee. Polonium-210 concentrations in the water samples were very low and similar to those observed in natural uncontaminated water samples. Low concentrations of polonium-210 were detected in sediments in the range 15 to 92 Bq kg^{-1}. The HPA also carried out monitoring at a wide range of sites in London, including hotels, houses, eating places and market stalls. A significant number of premises in London were actually or potentially affected and a programme of decontamination was undertaken as necessary. This was largely complete at the time of writing.

8.3 Channel Islands

Marine environmental samples provided by the Channel Island States have continued to be analysed. The programme monitors the effects of radioactive discharges from the French reprocessing plant at Cap de la Hague and the power station at Flamanville; it also serves to monitor any effects of historical disposals of radioactive waste in the Hurd Deep. Fish and shellfish are monitored in relation to the internal irradiation pathway; sediment is analysed with relevance to external exposures. Sea water and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers.

The results for 2006 are given in Table 8.4. Nuclides, which can be attributed to routine releases from the nuclear industry, were detected in some samples (cobalt-60 and technetium-99). However, all concentrations of activity in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the critical group of high-rate fish and shellfish consumers gives a dose of less than 0.005 mSv in 2005, which is less than 0.5% of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources therefore continued to be of negligible radiological significance.

Results for milk and crop samples are given in Table 8.11 and Table 8.12, respectively, and form parts of the programme considered in Sections 8.6 and 8.7, respectively.

8.4 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 8.5).

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 2006.

The results are similar to those obtained in previous years. The dose to the critical group from consumption of terrestrial foodstuffs monitored in 2006 was 0.016 mSv (0.019 mSv in 2005) or less than 2% of the dose limit for members of the public of 1 mSv.

The effects of liquid discharges from BNG Sellafield in the Irish Sea are discussed fully in Section 2. The dose to the critical group of Manx fish and shellfish consumers was 0.007 mSv in 2006 (similar to 2005) or less than 1% of the dose limit.

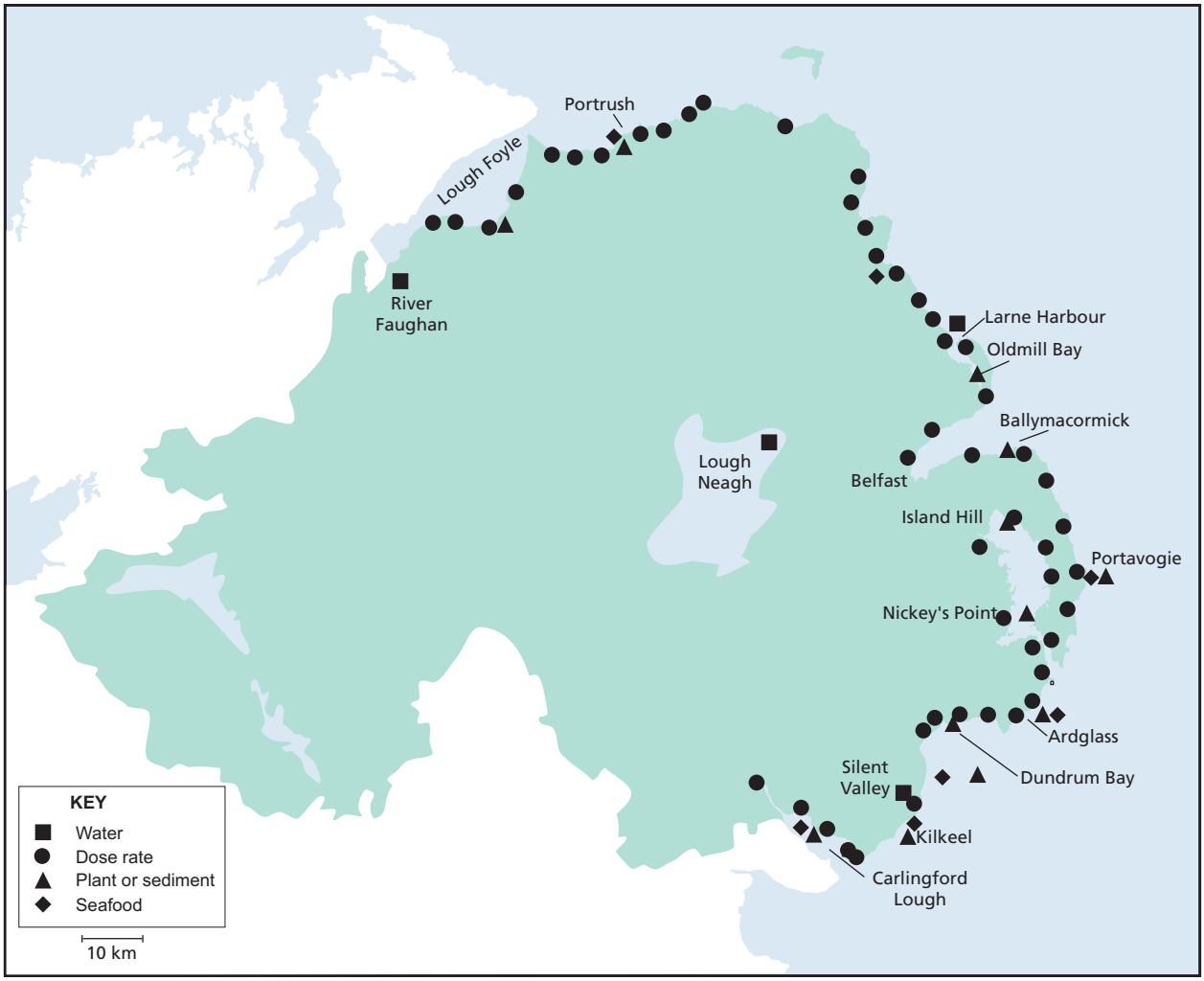


Figure 8.1. Monitoring locations in Northern Ireland

8.5 Northern Ireland

The EHS in Northern Ireland undertake monitoring of the far field effects of liquid discharges into the Irish Sea from Sellafield (Environment and Heritage Service, 2004). The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 8.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 8.6(a) and (b).

In 2006, 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 2005. 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 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 2006 was 0.018 mSv, which is less than 2% of the dose limit for members of the public.

8.6 General diet

As part of the Government's general responsibility for food safety, radioactivity in whole diet is determined on a regional basis. Measurements are made on samples of mixed diet from regions throughout the UK. Most samples are derived from the Food Standards Agency's TDS. The design of the UK TDS has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). The relative importance of each food category within a group reflects its importance in the diet and is based on an average of three previous years of consumption data from the National Food Survey (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). These samples are analysed for a range of food constituents including radioactivity. The system of sampling mixed diet rather than individual foodstuffs from specific locations, provides more accurate assessments of radionuclide intakes because people rarely obtain all their food from a local source (Mondon and Walters, 1990). Radionuclides of both naturally-occurring and man-made

origins were measured in samples in 2006. The results are provided in Tables 8.7 and 8.8.

There was some evidence for the effects of radioactive waste disposal into the environment reaching the general diet in the form of positively detected amounts of tritium being determined. However, all of the results for man-made radionuclides were low. Many were close to the limits of detection for the various analytical methods used. There was some variability from region to region, but in general no more than is usually detected from the programme. Concentrations of lead-210 and polonium-210 were higher at Anstruther in Fife than in other areas. Within the normal variability observed, there were no significant trends in concentrations.

Exposures as a result of consuming diet at average rates at the concentrations given in Tables 8.7 and 8.8 have been assessed for intakes by adults and summarised in Table 8.9. 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 0.049 mSv, less than the value for 2005 of 0.24 mSv. The reduction was due to there being no exceptionally high lead-210 or polonium-210 levels in any sample from England. In addition to potassium-40 the most important radionuclides continued to be lead-210 and polonium-210. The results demonstrate that radionuclides from natural sources are by far the most important source of exposure in the average diet of consumers and man-made radionuclides only contributed about 1% of the mean dose.

The maximum exposures from diet in each region are also provided in Table 8.9. The highest exposure in the UK was estimated to be 0.17 mSv based on sampling at Anstruther, with over 95% of the dose being derived from lead-210 and polonium-210. In 2005, the dose was given as 1.8 mSv from general diet for the mixed diet sample collected from Tonbridge. However, this dose was calculated assuming an infant ate the same amount as an average adult as the TDS is based on the average adult diet. This is considered too pessimistic so calculations are now only undertaken for adults. In 2005, the dose to adults was 0.44 mSv.

The concentrations found in a survey of radioactivity in canteen meals collected across the UK (Table 8.10) were generally similar to the mean concentrations found in UK diet.

8.7 Milk

The programme of milk sampling at dairies in the UK continued in 2006. 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 2006 were similar to those for previous years. These results are summarised in Table 8.11. Tritium results were close to or below their limits of detection. Mean and maximum values for carbon-14 from all dairies were generally similar and at expected background levels. There was a single result from a sample collected in North Yorkshire which was about twice that expected. 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 levels are now very low and it is less easy to distinguish this trend. Northern Ireland had the highest concentrations of caesium-137.
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%.

8.8 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2006 (Table 8.12). Tritium activity was below the LoD in all samples. The activities of carbon-14 detected in crop samples were mainly close to those expected from consideration of background sources. Within the normal variability observed, the concentrations of other radionuclides in crops were similar to those observed in 2005.

In 2006, 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. Three samples were analysed and the results are given in Table 8.13. The activity concentrations ranged from <2.0 – 1500 Bq kg^{-1}. No action on food restrictions was necessary.

8.9 Airborne particulate, rain and freshwater

Monitoring of radioactivity in air and rain took place at eight locations as part of a UK-wide monitoring programme of background sampling under the EURATOM Treaty. The results are given in Table 8.14. The routine programme

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

comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an *ad hoc* basis by gamma-ray spectrometry. Caesium-137 concentrations were all below or close to the limits of detection. These levels in air, typical of recent years, remain less than 0.01% of those observed in 1986, the year of the Chernobyl reactor accident. Concentrations of beryllium-7, a naturally-occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2005. Concentrations in air and rainwater are very low and do not currently merit radiological assessment.

Following an enquiry from a member of the public relating to radioactivity in Eskdalemuir, SEPA undertook monitoring of soil and grass and measured gamma dose rates in several locations. The results, combined with the UK air and rainwater programme in Table 8.14, showed no elevated concentrations of caesium-137 and did not give cause for concern.

During weekly checks on the nationwide automated radiation monitoring system, RIMNET, SEPA noticed elevated gamma dose rates at the RIMNET monitor at Applecross on the North West coast of Scotland. SEPA arranged for additional dose rate measurements and samples of soil and grass were taken and analysed. No further elevation in dose rate was found and the caesium-137 concentrations were very low, less than 5 Bq kg^{-1} (fresh).

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2006 (Figure 8.2). Sampling is designed to be representative of the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples are representative of natural waters before treatment and supply to the public water system. The results in Tables 8.15, 8.16 and 8.17, 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 values for drinking water of 0.5 and 1.0 Bq l^{-1}, respectively.

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

The mean annual dose from consumption of drinking water in the UK was assessed as 0.028 mSv in 2006 (Table 8.18). 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 0.046 mSv due to radionuclides in a source of drinking water from Silent Valley, Co Down.

8.10 Seawater surveys

The UK government is committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally-occurring radioactive substances, and close to zero for artificial radioactive substances (Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, National Assembly for Wales and Scottish Executive, 2002). Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling. The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2000b) and provide information that can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Evidence to help gauge progress towards achievement of the Government's vision for radionuclides and other hazardous substances is set out in a recent report (Department of Environment, Food and Rural Affairs, 2005a).

The research vessel programme on radionuclide distribution currently comprises of annual surveys of the Bristol Channel/ western English Channel and biennial surveys of the Irish Sea and the North Sea. The results of the 2006 cruises are presented in Figures 8.3 – 8.6. Shoreline sampling is also carried out 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 2006 caesium-137 data for the North Sea (Figure 8.3) show very low activities (<0.01 Bq l^{-1}) throughout the survey area that are only slightly above the global fallout levels in North Atlantic surface waters (~0.0012 Bq l^{-1} in 2002, Bailly du Bois pers. comm.). The distribution in the North Sea is typical of that observed in the last 5 years. The highest activities were observed at two stations close to the Norwegian coast, due to the input of Chernobyl-derived caesium-137 from the Baltic via the Skaggerak. In the previous three decades the impact of discharges from the reprocessing plants at Sellafield and La Hague has been readily apparent, carried by the prevailing residual currents from the Irish Sea and the Channel, respectively (Povinec *et al.*, 2003). The activity of caesium-137 in the North Sea has tended to follow the temporal trends of the discharges, albeit with a time lag. The maximum discharge of caesium-137 occurred at Sellafield in 1975 and caesium-137 activities of up to 0.5 Bq l^{-1} were

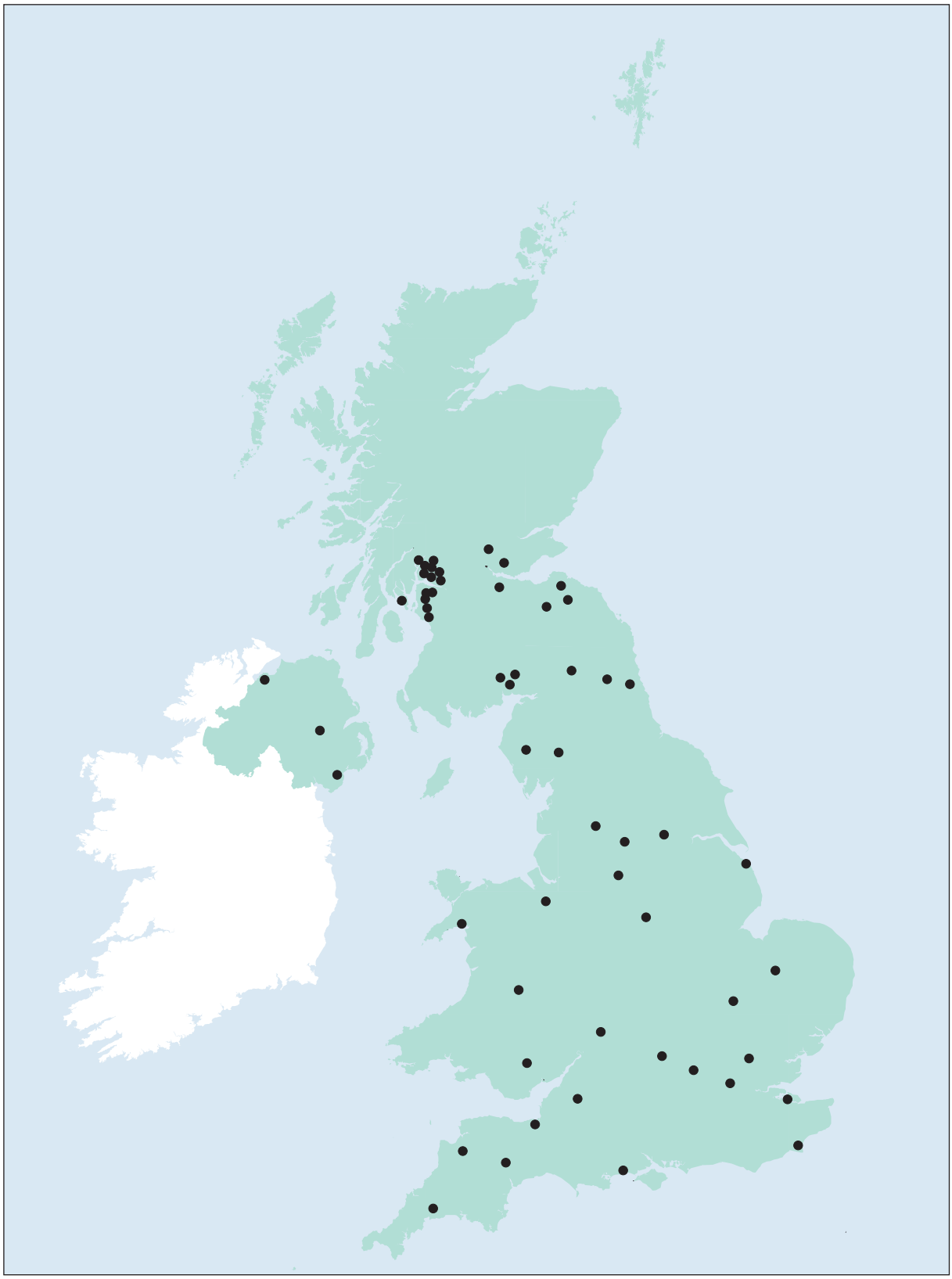


Figure 8.2. Drinking water sampling locations

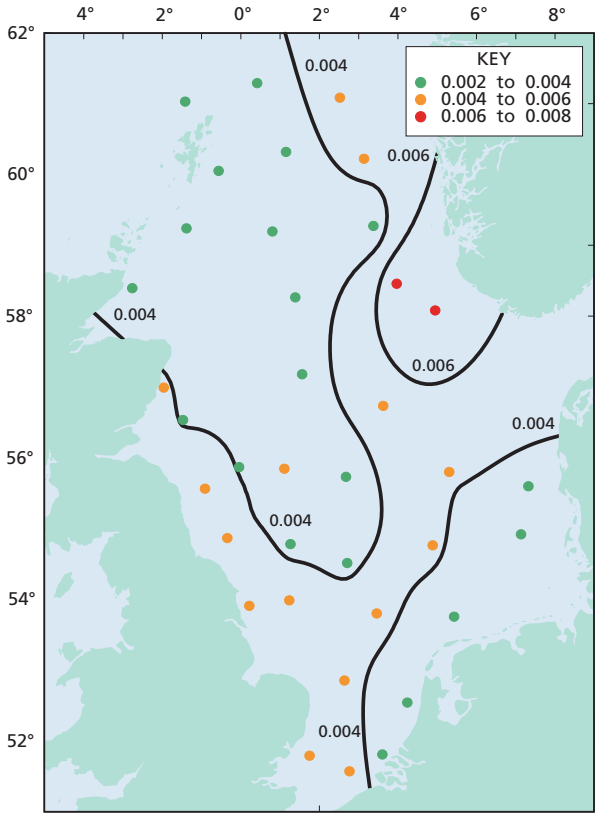


Figure 8.3. Concentrations (Bq l^{-1}) of caesium-137 in filtered seawater from the North Sea, August–September 2006

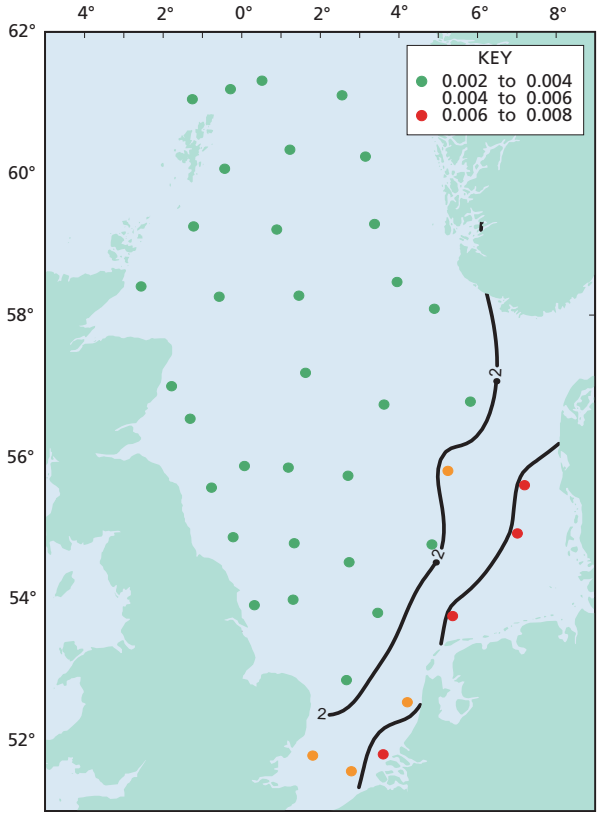


Figure 8.5. Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, August–September 2006

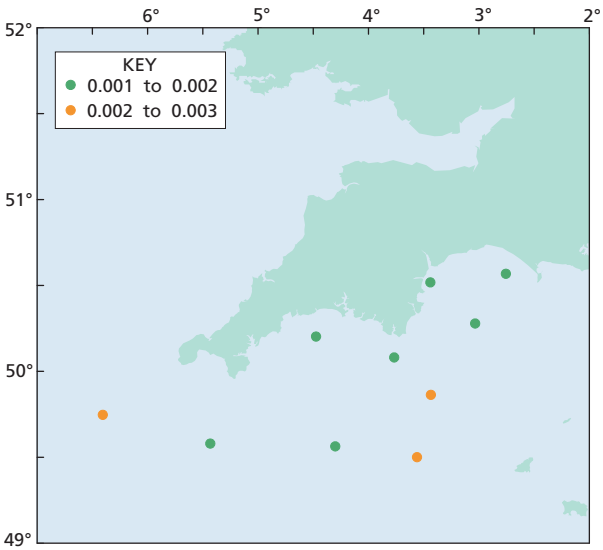


Figure 8.4. Concentrations (Bq l^{-1}) of caesium-137 filtered seawater from the Bristol Channel and western English Channel, September–October 2006

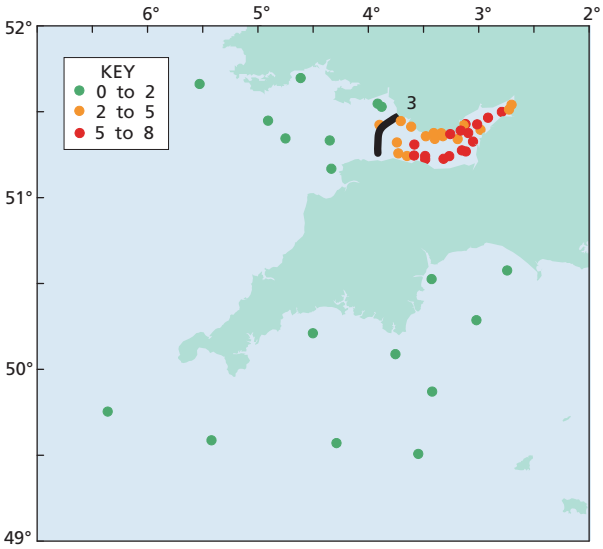


Figure 8.6. Concentrations (Bq l^{-1}) of tritium in surfacewater from the Bristol Channel and western English Channel, September–October 2006

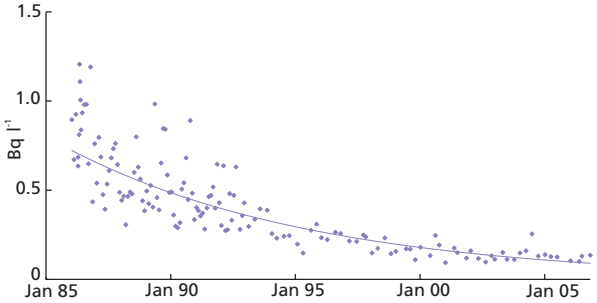


Figure 8.7. Temporal variation of dissolved caesium-137 in shoreline seawater close to Sellafield (at St Bees), 1986-2006

measured in the late 1970s. Due to significantly decreasing discharges after 1978, remobilisation of caesium-137 from contaminated sediments in the Irish Sea is now the dominant source of water contamination for most of the North Sea (McCubbin *et al.*, 2002).

Caesium-137 concentrations in the Irish Sea are only a small percentage of those prevailing in the late 1970s, typically up to 30 Bq l^{-1} (Baxter *et al.*, 1992), when discharges were substantially higher. The predominant source term is remobilisation into the water column of previously discharged activity that became associated with seabed sediments and, to a lesser extent, recent discharges from the Sellafield site. Consequently, levels in seawater have shown 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 8.7 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 8.8 (northern Irish Sea) and 8.9 (northern 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).

Figure 8.8. Concentrations of caesium-137 in the Northern Irish Sea, 1963-2006

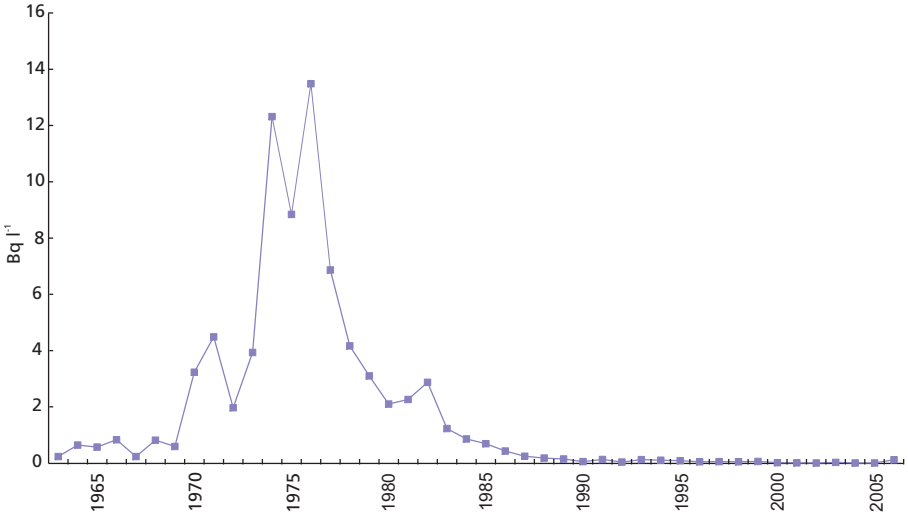
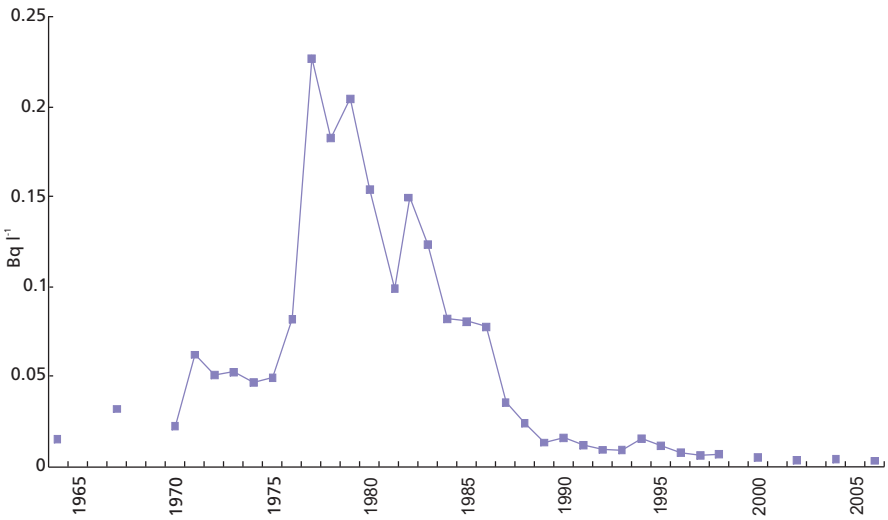


Figure 8.9. Concentrations of caesium-137 in the Northern North Sea, 1964–2006



A full assessment of long-term trends in Northern European seas is provided elsewhere (Povinec *et al.*, 2003).

The concentrations of tritium observed in the North Sea (Figure 8.5) were generally lower than those observed in the Irish Sea (Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2006) due to the influence of discharges from Sellafield and other nuclear sites. In the Bristol Channel, the extent of the combined effects of discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is evident (Figure 8.6). Levels in the western English Channel were below detection.

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

Measurements of beta and potassium-40 activity in water from the Clyde in 2006 gave results of less than 1 and less than 10 Bq kg^{-1}, respectively. These concentrations are similar to those for 2005. Caesium-137 was not detected.

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

Country	Number of sheep monitored	Number of sheep above action level	Percentage of sheep above action level
England	5266	0	0
Wales	96391	99	0.1
Scotland	5074	2685	53

Table 8.2. Concentrations of radiocaesium in the freshwater environment, 2006

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Rainbow trout	1	<0.08	0.27
Narborough[b]	Rainbow trout	1	<0.10	0.23
Low Wath	Rainbow trout	1	<0.08	0.20
Devoke Water	Brown trout	1	<0.09	25
Devoke Water	Perch	1	<0.31	170
Devoke Water	Water	1	*	0.007
Ennerdale	Brown trout	1	<0.30	8.2
Ennerdale	Water	1	*	0.002
Gilcrux	Rainbow trout	1	<0.07	0.18
Scotland				
Loch Dee	Brown trout	1	<0.27	95
Loch Dee	Water	1	*	0.01

** Not detected by the method used*
[a] Except for water where units are Bq l^{-1}
[b] The concentrations of ^{14}C, ^{238}Pu, $^{239+240}$Pu and ^{241}Am were 38, 0.000027, 0.000039 and 0.000050 Bq kg^{-1} respectively

Table 8.3. Concentrations of polonium-210 in the environment in relation to the Litvinenko incident, 2006

Location	Sample	No. of sampling observ-ations	Mean radioactivity concentration[a], Bq l^{-1}
			^{210}Po
England			
Salmon's Brook	Water	1	<0.010
Salmon's Brook	Particulate	1	<0.010
Salmon's Brook	Sediment	1	15
Pymme's Brook and River Lee	Water	1	<0.010
Pymme's Brook and River Lee	Particulate	1	<0.010
Pymme's Brook and River Lee	Sediment	1	25
River Lee	Water	1	<0.010
River Lee	Sediment	1	29
Lee Navigation, Keides Weir	Water	1	<0.010
Lee Navigation, Keides Weir	Sediment	1	92
Scotland[b]			
Dalmuir	Inlet influent 1	1	0.0042
Dalmuir	Inlet influent 2	1	0.0072
Dalmuir	Inlet influent 3	1	0.0052
Dalmuir	Final effluent 1	1	<0.0022
Dalmuir	Final effluent 2	1	<0.0016
Dalmuir	Final effluent 3	1	<0.0031

[a] Except for sediment where dry concentrations apply. Particulate is Bq l^{-1} equivalent
[b] Used for comparative purposes with England data

Table 8.4. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2006

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				<0.06			<0.67		0.14
Pollack	Jersey	1				<0.06			<0.56		0.16
Bass	Guernsey	1				<0.07			<0.58		0.29
Bass	Jersey	1				<0.06			<0.66		0.24
Edible crabs	Guernsey	1				<0.06			<0.55		<0.05
Edible crabs	Jersey	1				<0.07			<0.68		<0.06
Edible crabs	Alderney	2	<25	<25	33	<0.06		<0.68	<0.52		<0.05
Spiny spider crab	Jersey	1				<0.18			<1.6		<0.13
Spiny spider crab	Alderney	1				0.45			<0.43		<0.04
Lobsters	Guernsey	1				<0.07			<0.86		<0.06
Lobsters	Jersey	1				<0.03		0.41	<0.30		0.03
Lobsters	Alderney	1				<0.04			<0.42		0.06
Oysters	Jersey										
	La Rocque	1				<0.03			<0.36		<0.03
Limpets	Guernsey	1				<0.16			<1.9		<0.14
Limpets	Jersey										
	La Rozel	1				<0.07			<0.57		<0.05
Toothed winkle	Alderney	1	<25	<25	40	<0.17	0.42		<1.7		0.12
Scallops	Guernsey	1				<0.08			<0.68		<0.06
Scallops	Jersey	2				<0.05			<0.42		<0.04
Ormers	Guernsey	1				<0.07			<0.86		<0.07
Porphyra	Guernsey										
	Fermain Bay	2				<0.14			<1.5		<0.11
Porphyra	Jersey										
	Plemont Bay	4				<0.05			<0.58		<0.05
Fucus vesiculosus	Jersey										
	La Rozel	4				<0.07	0.022	3.5	<0.52		<0.05
Fucus vesiculosus	Alderney										
	Quenard Point	1								1.5	
Fucus serratus	Guernsey										
	Fermain Bay	2				<0.10	<0.057	1.4	<1.0		<0.08
Fucus serratus	Alderney										
	Quenard Point	2				<0.15	0.025	1.9	<0.89		<0.07
Laminaria digitata	Jersey										
	Verclut	4				<0.06			<0.54		<0.05
Laminaria digitata	Alderney										
	Quenard Point	2				<0.06			<0.63		<0.05
Mud	Guernsey										
	St. Sampson's Harbour	1				<0.23			<2.2		0.72
Mud	Jersey										
	St Helier	1				7.0			<3.6		2.6
Sand	Alderney										
	Lt. Crabbe Harbour	1				0.50			<2.4		1.4
Seawater	Guernsey	3									0.002
Seawater	Jersey	1									0.004
Seawater	Alderney East	3		5.9							0.002

Table 8.4. continued

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	^{242}Cm	^{243}Cm+ ^{244}Cm	Total beta
Mackerel	Guernsey	1	<0.19	<0.12	0.000068	0.00035	0.00063	*	0.000034	110
Pollack	Jersey	1	<0.21	<0.10			<0.06			130
Bass	Guernsey	1	<0.21	<0.11	0.000012	0.000068	0.000088	*	*	
Bass	Jersey	1	<0.21	<0.19			<0.28			100
Edible crabs	Guernsey	1	<0.17	<0.11	0.00027	0.00075	0.0026	*	0.00045	93
Edible crabs	Jersey	1	<0.20	<0.20	0.00039	0.0010	0.0026	0.000063	0.00034	83
Edible crabs	Alderney	2	<0.16	<0.15	0.00028	0.00090	0.0027	*	0.00037	82
Spiny spider crab	Jersey	1	<0.44	<0.22			<0.11			57
Spiny spider crab	Alderney	1	<0.11	<0.10	0.0013	0.0044	0.0051	0.000020	0.00047	72
Lobsters	Guernsey	1	<0.22	<0.13			<0.07			79
Lobsters	Jersey	1	<0.11	<0.06	0.00017	0.00053	0.0025	0.000025	0.00036	83
Lobsters	Alderney	1	<0.13	<0.08	0.00045	0.0013	0.013	0.000067	0.0019	87
Oysters	Jersey									
	La Rocque	1	<0.09	<0.09	0.0023	0.0066	0.0065	0.000049	0.00085	110
Limpets	Guernsey	1	<0.43	<0.35			<0.31			60
Limpets	Jersey									
	La Rozel	1	<0.18	<0.10	0.0023	0.0064	0.010	0.000032	0.0013	76
Toothed winkle	Alderney	1	<0.39	<0.23	0.0084	0.025	0.037	0.00020	0.0045	53
Scallops	Guernsey	1	<0.23	<0.12	0.00062	0.0021	0.0013	0.000044	0.00013	120
Scallops	Jersey	2	<0.13	<0.08	0.0055	0.020	0.015	0.000062	0.0016	110
Ormers	Guernsey	1	<0.21	<0.15			<0.08			65
Porphyra	Guernsey									
	Fermain Bay	2	<0.40	<0.29	0.0024	0.0088	0.011	0.000064	0.0011	100
Porphyra	Jersey									
	Plemont Bay	4	<0.17	<0.12			<0.12			130
Fucus vesiculosus	Jersey									
	La Rozel	4	<0.17	<0.11	0.0052	0.014	0.0061	0.000072	0.00072	160
Fucus vesiculosus	Alderney									
	Quenard Point	1								
Fucus serratus	Guernsey									
	Fermain Bay	2	<0.27	<0.22	0.0036	0.014	0.008	*	0.00090	120
Fucus serratus	Alderney									
	Quenard Point	2	<0.25	<0.22	0.0058	0.016	0.0052	0.000050	0.00082	130
Laminaria digitata	Jersey									
	Verclut	4	<0.18	<0.13			<0.12			170
Laminaria digitata	Alderney									
	Quenard Point	1	<0.20	<0.14			<0.16			230
Mud	Guernsey									
	St. Sampson's Harbour	1	<0.65	<0.57	0.033	0.13	0.17	*	0.021	460
Mud	Jersey									
	St Helier	1	<0.93	<0.82	0.67	2.5	3.3	0.012	0.33	630
Sand	Alderney									
	Lt. Crabbe Harbour	1	<0.80	<0.53			0.64			530

** 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. Concentrations of radionuclides in food and the environment from the Isle of Man, 2006[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	^{144}Ce
Aquatic samples										
Cod	4	<0.09	<0.64	<0.34		<0.96	<0.20	<0.10	2.4	<0.38
Herring	4	<0.10	<0.64	<1.4		<1.0	<0.22	<0.10	0.85	<0.46
Lobsters	4	<0.06	<0.41	<0.89	100	<0.63	<0.15	<0.06	0.44	<0.34
Scallops	4	<0.05	<0.48	<0.26		<0.54	<0.12	<0.05	0.36	<0.32
Fucus vesiculosus	4	<0.08	<0.42	<0.44	580	<0.60	0.24	<0.07	0.91	<0.36
Sediment	1[E]	<0.51	<1.2	<0.35		<2.9	<2.6	<0.43	9.4	<1.7

Material	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	Total alpha	Total beta
Aquatic samples								
Cod	4	0.000068	0.00036	0.00070	0.0000086	*		
Herring	4	0.0013	0.0086	0.013	*	*		
Lobsters	4			<0.13				170
Scallops	4	0.020	0.11	0.033	*	*		
Fucus vesiculosus	4			<0.20				
Sediment	1[E]						180	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	^{106}Ru	^{125}Sb
Terrestrial samples												
Milk		2	<4.9	17	<0.48	<0.28	0.038	<0.54	<0.55	0.0040	<1.7	<0.56
Milk	max		<5.0	18	<0.50		0.041	<0.58	<0.58		<1.9	<0.58
Cabbage		1	<5.0	9.0	0.90	<0.20	0.055	<0.30	<0.20	<0.033	<1.3	<0.50
Potatoes		1	<5.0	15	0.40	<0.20	0.028	<0.40	<0.30	<0.024	<1.7	<0.40
Raspberries		1	<5.0	26	0.50	<0.30	0.10	<0.50	<0.40		<1.5	<0.70

Material or selection[b]		No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{129}I	Total Cs	^{144}Ce	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples									
Milk		2	<0.0070	0.085	<1.1	<0.00010	<0.00020	<0.020	<0.00010
Milk	max			0.086	<1.2				
Cabbage		1	<0.029	0.075	<0.70	<0.00010	0.00020	<0.033	<0.00030
Potatoes		1	<0.026	0.14	<0.70	<0.00010	<0.00010	0.097	0.00020
Raspberries		1		0.10	<2.0				

** Not detected by the method used*

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

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

[c] *The gamma dose rate in air at 1m over sand at Douglas[E] was 0.099 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 8.6(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2006

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	3	55	<0.07		<0.17	2.9
Cod	North coast	1		<0.04		<0.10	2.4
Plaice	Kilkeel	1		<0.08		<0.17	2.7
Haddock	Kilkeel	2		<0.13		<0.27	0.84
Haddock	Portavogie	1		<0.07		<0.18	1.8
Herring	Ardglass	2		<0.09		<0.22	1.3
Spurdog	North coast	4		<0.07		<0.20	2.0
Spurdog	Kilkeel	2		<0.09		<0.22	1.2
Spurdog	Portavogie	1		<0.09		<0.24	2.6
Whiting	Kilkeel	1		<0.06		<0.12	0.36
Crabs	Kilkeel	3		<0.14		<0.33	0.33
Lobsters	Ballycastle	2		<0.15	110	<0.35	0.36
Lobsters	Kilkeel	2		<0.06	100	<0.14	0.38
Nephrops	Kilkeel	4		<0.09	34	<0.25	0.67
Winkles	Ards Peninsula	4		<0.13		<0.31	<0.34
Mussels	Carlingford Lough	2		<0.09	20	<0.24	0.62
Scallops	Co. Down	2		<0.05		<0.11	0.36
Ascophyllum nodosum	Ardglass	2		<0.10		<0.41	0.86
Ascophyllum nodosum	Carlingford Lough	1		<0.11		<0.27	0.76
Fucus spp.	Carlingford Lough	3		<0.12	1100	<0.46	0.95
Fucus spp.	Portrush	4		<0.07		<0.16	<0.10
Fucus vesiculosus	Ardglass	2		<0.20	1100	<0.45	0.84
Rhodymenia spp.	Strangford Lough	3		<0.14	16	<0.29	0.79
Mud	Carlingford Lough	2		<0.86		<3.5	91
Mud	Dundrum Bay	2		<0.67		<1.8	6.8
Mud	Oldmill Bay	2		<0.91		<2.5	48
Mud	Strangford Lough - Nicky's point	2		<0.61		<2.0	29
Mud	Ballymacormick	2		<0.52		<1.6	22
Sand	Carrichue	1		<0.40		<1.1	1.8
Sand	Portrush	2		<0.39		<1.1	<0.60
Shell and sand	Carrichue	1		<0.33		<0.86	3.0
Seawater	North of Larne	12			0.0086		0.02

Table 8.6(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	3			<0.16		
Cod	North coast	1			<0.10		
Plaice	Kilkeel	1			<0.07		
Haddock	Kilkeel	2			<0.10		
Haddock	Portavogie	1			<0.33		
Herring	Ardglass	2			<0.15		
Spurdog	North coast	4			<0.14		
Spurdog	Kilkeel	2			<0.09		
Spurdog	Portavogie	1			<0.10		
Whiting	Kilkeel	1			<0.06		
Crabs	Kilkeel	3			<0.28		
Lobsters	Ballycastle	2			0.43		
Lobsters	Kilkeel	2			<0.12		
Nephrops	Kilkeel	4	0.0017	0.0087	0.018	*	*
Winkles	Ards Peninsula	4	0.027	0.15	0.14	0.00032	*
Mussels	Carlingford Lough	2			<0.22		
Scallops	Co. Down	2			<0.13		
Ascophyllum nodosum	Ardglass	2			<0.22		
Ascophyllum nodosum	Carlingford Lough	1			0.28		
Fucus spp.	Carlingford Lough	3			<0.40		
Fucus spp.	Portrush	4			<0.23		
Fucus vesiculosus	Ardglass	2			<0.44		
Rhodymenia spp.	Strangford Lough	3	0.058	0.31	0.42	*	0.00080
Mud	Carlingford Lough	2	2.1	14	9.3	*	0.0063
Mud	Dundrum Bay	2			<2.8		
Mud	Oldmill Bay	2			26		
Mud	Strangford Lough - Nicky's point	2			9.6		
Mud	Ballymacormick	2			16		
Sand	Carrichue	1	0.024	0.20	0.22	*	*
Sand	Portrush	2			<2.0		
Shell and sand	Carrichue	1			<0.62		

** Not detected by the method used*

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

Table 8.6(b). Monitoring of radiation dose rates in Northern Ireland, 2006

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lisahally	Mud	1	0.072
Eglington	Shingle	1	0.064
Carrichue	Mud	1	0.060
Bellerena	Mud	1	0.064
Benone	Sand	1	0.064
Castlerock	Sand	1	0.062
Portstewart	Sand	1	0.058
Portrush, Blue Pool	Sand	1	0.065
Portrush, White Rocks	Sand	1	0.066
Portballintrea	Sand	1	0.061
Giant's Causeway	Sand	1	0.062
Ballycastle	Sand	1	0.060
Cushendun	Sand	1	0.062
Cushendall	Sand and stones	1	0.061
Red Bay	Sand	1	0.064
Carnlough	Sand	1	0.060
Glenarm	Sand	1	0.054
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.060
Drains Bay	Sand	1	0.054
Larne	Sand	1	0.063
Whitehead	Sand	1	0.062
Carrickfergus	Sand	1	0.062
Belfast Lough	Sand	1	0.061
Helen's Bay	Sand	1	0.064
Groomsport	Sand	1	0.065
Millisle	Sand	1	0.065
Ballywalter	Sand	1	0.066
Ballyhalbert	Sand	1	0.066
Cloughy	Sand	1	0.071
Portaferry	Shingle and stones	1	0.097
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.092
Ards Maltings	Mud	1	0.090
Island Hill	Mud	1	0.074
Nicky's Point	Mud	1	0.067
Strangford	Shingle and stones	1	0.087
Kilclief	Sand	1	0.069
Ardglass	Mud	1	0.087
Killough	Mud	1	0.085
Rocky Beach	Sand	1	0.076
Tyrella	Sand	1	0.080
Dundrum	Mud	1	0.094
Newcastle	Sand	1	0.090
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.090
Greencastle	Sand	1	0.090
Mill Bay	Mud	1	0.11
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.10

Table 8.7. Concentrations of radionuclides in regional diet (TDS survey), 2006[a]

Country	Town	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{40}K	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
England	Banstead	1	<2.6	40	<0.14	70	0.037	<0.04	0.043	0.060
England	Blackpool	1	<2.0	20	<0.16	80	0.040	0.04	0.035	0.031
England	Chelmsley Wood	1	<2.5	40	<0.14	80	0.029	0.06	<0.015	0.035
England	Keynsham	1	<2.6	30	<0.16	80	0.048	0.07	0.059	0.050
England	Leicester	1	4.3	30	<0.21	80	0.033	<0.11	0.046	0.027
England	Newmarket	1	<2.6	40	<0.14	70	0.032	<0.06	0.024	0.030
England	Paignton	1	<2.5	30	<0.13	70	0.060	0.04	0.032	0.030
England	Pudsey	1	<2.5	60	0.18	80	0.041	0.07	0.025	0.050
England	Sunderland	1	<2.5	50	<0.14	80	0.036	<0.06	<0.015	0.040
Wales	Bangor	1	3.1	40	<0.15	70	0.030	<0.05	0.028	0.027
Northern Ireland	Newtownards	1	<3.0	40	<0.18	80	0.030	<0.05	0.045	0.040
Mean			<2.7	38	<0.16	76	0.038	<0.06	<0.033	0.038

Country	Town	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{226}Ra	^{232}Th	Total U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
England	Banstead	1	0.052	0.00080	0.026	<0.00015	0.00030	0.00030
England	Blackpool	1	0.040	0.0015	<0.023	<0.00010	0.00010	0.00019
England	Chelmsley Wood	1	0.032	0.00098	<0.023	<0.00013	0.00030	<0.00020
England	Keynsham	1	0.028	0.0014	<0.023	<0.00024	0.00056	0.00020
England	Leicester	1	0.040	0.00097	<0.022	<0.00018	0.00026	0.00020
England	Newmarket	1	0.036	0.00089	<0.023	<0.00014	0.00020	0.00075
England	Paignton	1	0.047	0.0020	<0.023	<0.00010	0.00020	0.00042
England	Pudsey	1	0.040	0.0012	<0.023	<0.00012	0.00070	0.00024
England	Sunderland	1	0.035	0.0017	<0.023	<0.00011	0.00080	<0.00023
Wales	Bangor	1	0.030	0.00089	<0.024	<0.00010	0.00030	<0.00013
Northern Ireland	Newtownards	1	0.036	0.00088	<0.024	<0.00013	0.00030	<0.00010
Mean			0.038	0.0012	<0.023	<0.00014	0.00037	<0.00027

[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. Concentrations of radionuclides in regional diet in Scotland, 2006[a]

Area	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po	^{226}Ra
Anstruther (Fife)	1	<20	34	<1.0	0.061	<0.40	0.39	0.13	0.067
Springburn (Lanarkshire)	1	<20	43	<1.0	<0.050	<0.40	<0.20	0.044	0.058

Area	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
		^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239+}$ ^{240}Pu	^{241}Am
Anstruther (Fife)	1	<0.010	<0.050	<0.050	<0.050	<0.00068	<0.00068	<0.00052
Springburn (Lanarkshire)	1	<0.010	<0.050	<0.050	<0.050	<0.00071	<0.00071	<0.00048

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

Table 8.9. Estimates of radiation exposure from radionuclides in diet, 2006[a]

Region	Mean[b] exposure, mSv per year			Maximum exposure, mSv	
	Man-made radionuclides[c]	Naturally occurring radionuclides[d]	All radionuclides	Location	All radionuclides
England	<0.001	0.036	0.036	Banstead	0.049
Wales	<0.001	0.029	0.030	Bangor	0.030
Northern Ireland	<0.001	0.039	0.040	Newtownards	0.040
Scotland	0.003	0.12	0.13	Anstruther (Fife)	0.17
UK	0.001	0.049	0.050	Anstruther (Fife)	0.17

[a] *Assessments of dose are based on some concentration results at limits of detection.*
Exposures due to potassium-40 content of diet are not included here because they do not vary vary according to the potassium-40 content of diet.
Levels of potassium are homeostatically controlled. The average annual dose from potassium-40 in general diet is 0.17mSv, which is in addition to the above figures
[b] *Average of the doses to the most exposed age group at each location*
[c] *Including tritium*
[d] *Including carbon-14*

Table 8.10. Concentrations of radionuclides in canteen meals, 2006[a]

Region	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	4	26	93	<0.048	<0.03
Northern Ireland	4	29	100	<0.040	<0.08
Scotland	1	<36		<0.079	<0.03
Wales	4	27	98	0.038	<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 8.11. Concentrations of radionuclides in milk remote from nuclear sites, 2006

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	<4.5	15	0.020	0.15
Co. Armagh		1	<5.0	12	0.022	0.080
Cambridgeshire		1	<2.8	12	0.013	0.071
Cheshire		1	<5.0	14	0.018	0.11
Clwyd		1	<4.5	16	0.025	0.082
Cornwall		1	<5.0	12	0.031	0.068
Devon		1	<4.0	16	0.033	0.066
Dorset		1	<5.0	16	0.016	0.088
Co. Down		1	<5.0	13	0.031	0.12
Essex		1	<5.0	16	0.016	0.067
Co. Fermanagh		1	<5.0	19	0.023	0.11
Gloucestershire		2	<4.8	12	0.020	0.058
	max		<5.0	18	0.039	0.087
Guernsey		1	<3.1	12	0.021	0.076
Gwent		1	<2.6	11	0.029	0.077
Gwynedd		1	<4.5	15	0.027	0.063
Hampshire		1	<4.5	14	0.028	0.060
Humberside		1	<5.0	12	0.019	0.068
Kirkcudbrightshire		1	<5.0	<16	<0.10	<0.06[c]
Kent		1	<5.0	16	0.020	0.098
Lanarkshire		1			<0.044	<0.05[c]
Lancashire		2	<5.0	14	0.021	0.073
	max		<5.0	17	0.031	0.12
Leicestershire		1	<5.0	15	0.018	0.085
Lincolnshire		1	<5.0	16	0.016	0.061
Middlesex		1	<4.5	12	0.018	0.068
Midlothian		1	<5.0	<18	<0.10	<0.05[c]
North Yorkshire		2	<4.8	20	0.023	0.083
	max		<5.0	39	0.052	0.16
Nairnshire		1	<5.0	<16	<0.12	<0.05[c]
Norfolk		1	<5.0	15	0.016	0.062
Renfrewshire		1	<5.0	<15	<0.10	<0.05[c]
Suffolk		1	<5.0	13	0.013	0.065
Tyneside		1	<5.0	14	0.025	0.072
Co. Tyrone		2	<3.3	18	0.022	0.13
	max		7.0	23	0.036	0.28
Mean Values						
Channel Islands			<3.1	12	0.021	0.0760
England			<4.7	14	0.020	0.074
Northern Ireland			<4.6	15	0.024	0.12
Wales			<3.9	14	0.027	0.074
Scotland			<5.0	<16	<0.093	<0.05[c]
United Kingdom			<4.5	<15	0.041	0.08

[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 8.12. Concentrations of radionuclides in crops remote from nuclear sites, 2006[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
Anglesey								
Newborough	Cabbage	1	<4.0	4.0	0.10	<0.015	<0.039	0.0043
	Raspberries	1	<5.0	11	0.057	0.016	<0.050	0.020
Barnsley								
Barnsley	Cabbage/Cauliflower	1	<5.0	<3.0	0.066	0.058	<0.038	0.0048
	Raspberries	1	<4.0	16	0.091	0.081	0.10	0.016
Cambridgeshire								
Huntingdon	Beetroot	1	<4.0	5.0	0.060	0.16	<0.033	0.0092
	Cabbage	1	<5.0	5.0	0.37	0.075	0.17	0.044
Channel Islands								
Guernsey	Blackberries	1	<5.0	10	0.061	0.039	0.12	0.047
	Lettuce	1	<5.0	<3.0	0.0090	0.0090	<0.032	0.0060
Jersey	Potatoes-General	1	<5.0	15	0.026	0.043		
	Strawberries	1	<5.0	5.0	0.066	0.034		
Cornwall								
Launceston	Cabbage	1	<5.0	9.0	0.35	0.067	<0.038	0.063
	Carrots	1	<5.0	3.0	0.24	0.054	<0.037	0.018
Cumbria								
Ulverston	Cabbage	1	<5.0	<3.0	0.22	<0.025	<0.037	0.018
	Turnips/Potatoes	1	<5.0	9.0	0.15	0.053	<0.036	0.014
Devon								
Sidmouth	Raspberries	1	<4.0	8.0	0.091	0.036	0.085	0.034
	Swiss Chard	1	<5.0	<3.0	0.18	0.038	0.29	0.19
Dorset								
Verwood	Chard/Lettuce	1	<5.0	<3.0	0.52	0.19	0.35	0.14
	Strawberries	1	<5.0	3.0	0.045	0.050	0.093	0.025
Dumfriesshire								
Dumfries	Lettuce	4			<0.10	<0.05[b]		
Durham								
Bishop Auckland	Blackberries	1	<5.0	10	0.086	0.086	<0.044	0.025
	Cabbage	1	<5.0	<3.0	0.25	0.053	<0.042	0.034
East Lothian								
North Berwick	Lettuce	4			<0.10	<0.05[b]		
East Sussex								
Eastbourne	Potatoes	1	<5.0	20	<0.0080	<0.013	<0.042	0.0038
	Spinach	1	<4.0	<2.0	0.39	0.090	0.091	0.084
Essex								
Chelmsford	Cabbage	1	<5.0	7.0	0.091	0.051	0.12	0.026
	Plums	1	<5.0	11	0.037	0.037	<0.032	0.010
Gloucestershire								
Cirencester	Potatoes	1	<5.0	19	0.038	0.093	<0.047	0.0094
	Spring Greens	1	<5.0	<3.0	0.20	0.12	<0.042	0.028
Isle of Wight								
Newport	Gooseberries	1	<5.0	12	0.044	0.031	<0.036	0.059
	Spring Greens	1	<5.0	<3.0	0.30	0.043	<0.035	0.012
North Yorkshire								
Northallerton	Cabbage	1	<5.0	3.0	0.13	<0.027	<0.037	0.014
	Potatoes	1	<5.0	15	0.029	0.022	<0.045	0.0080
Northumberland								
Alnwick	Cabbage	1	<5.0	5.0	0.25	0.17	<0.037	0.0054
	Raspberries	1	<4.0	15	0.10	0.031	<0.048	0.027
Nottinghamshire								
Sutton in Ashfield	Carrots	1	<5.0	9.0	0.096	0.031	<0.040	<0.0025
	Lettuce	1	<5.0	3.0	0.12	0.044	0.20	0.042
Powys								
Builth Wells	Chard	1	<5.0	<3.0	0.54	0.087	0.40	0.18
	Potatoes	1	<4.0	9.0	0.015	<0.014	<0.036	0.037
Renfrewshire								
Paisley	Lettuce	4			<0.11	<0.05[b]		
Ross-shire								
Dingwall	Lettuce	4			<0.12	<0.05[b]		
Shropshire								
Market Drayton	Raspberries	1	<4.0	18	0.072	0.053	<0.033	0.020
	Spinach	1	<4.0	10	0.62	0.62	0.19	0.075
Staffordshire								
Stoke on Trent	Cabbage	1	<5.0	<3.0	0.12	<0.030	0.048	0.0036
	Potatoes	1	<5.0	21	0.038	0.20	<0.037	0.012
Surrey								
Weybridge	Beef Kidney	1	<9.0	43	0.066	0.71		
	Beef Liver	1	<9.0	<9.0	0.021	1.2		
	Beef Muscle	1	<5.0	19	0.017	0.51		
	Sheep Kidney/Liver	1	<9.0	14	0.032	0.38		
	Sheep Muscle	1	<6.0	35	0.011	0.21		
Wiltshire								
Warminster	Potatoes	1	<6.0	12	0.035	0.052	<0.051	0.0061
	Swiss Chard/Lettuce/ Cabbage	1	<6.0	3.0	0.67	0.078	0.42	0.20
Worcestershire								
Redditch	Lettuce	1	<5.0	<3.0	0.087	0.087	<0.046	0.044
	Raspberries	1	<4.0	11	0.037	<0.014	<0.047	0.022
Mean Values								
Channel Islands			<5.0	<8.3	0.041	0.031	<0.078	0.027
England			<5.2	<10	<0.16	<0.15	<0.086	<0.037
Wales			<4.5	<6.8	0.18	<0.033	<0.13	0.061
Scotland					<0.11	<0.05		
Great Britain			<4.8	<8.5	<0.15	<0.078	<0.11	<0.049

Table 8.12. 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
Anglesey								
Newborough	Cabbage	1	0.023	<0.00080		<0.00010	<0.00020	0.00020
	Raspberries	1	0.014	<0.00080		<0.00010	<0.00010	0.00020
Barnsley								
Barnsley	Cabbage/Cauliflower	1	0.0090	0.00060		<0.00010	<0.00020	<0.00020
	Raspberries	1	0.014	<0.00090		<0.00010	<0.00020	<0.00020
Cambridgeshire								
Huntingdon	Beetroot	1	0.017	0.0017	<0.034	<0.00020	<0.00010	0.00060
	Cabbage	1	0.043	0.0041		0.00010	<0.00010	<0.00020
Channel Islands								
Guernsey	Blackberries	1	0.010	0.0016	<0.030	<0.00010	<0.00020	<0.00020
	Lettuce	1	0.011	0.0016		0.00010	<0.00020	<0.00020
Jersey	Potatoes-General	1				<0.00020	<0.00020	<0.00020
	Strawberries	1				<0.00020	<0.00010	0.00080
Cornwall								
Launceston	Cabbage	1	0.044	<0.0016		<0.00020	<0.00020	<0.00020
	Carrots	1	0.26	0.0021	<0.035	<0.00010	<0.00020	<0.00030
Cumbria								
Ulverston	Cabbage	1	0.036	<0.0010		0.00010	<0.00010	0.00020
	Turnips/Potatoes	1	0.057	0.0073		0.00010	0.00020	<0.00020
Devon								
Sidmouth	Raspberries	1	0.016	<0.0010		0.00010	<0.00020	<0.00020
	Swiss Chard	1	0.18	0.0041		0.00010	<0.00010	0.00050
Dorset								
Verwood	Chard/Lettuce	1	0.23	0.0085		0.00010	0.00020	0.00050
	Strawberries	1	0.057	<0.0012	<0.032	<0.00010	<0.00010	0.00030
Durham								
Bishop Auckland	Blackberries	1	0.023	<0.00070		<0.00010	<0.00010	0.00020
	Cabbage	1	0.042	0.0052		0.00010	0.00020	0.00020
East Sussex								
Eastbourne	Potatoes	1	0.0090	0.0025		<0.00020	<0.00020	0.00020
	Spinach	1	0.37	0.0078		<0.00010	<0.00010	0.0010
Essex								
Chelmsford	Cabbage	1	<0.0070	<0.0011		<0.00020	<0.00010	0.00050
	Plums	1	0.0050	<0.0010		<0.00020	0.00010	<0.00020
Gloucestershire								
Cirencester	Potatoes	1	0.016	0.0036		<0.00020	<0.00040	0.00060
	Spring Greens	1	0.015	<0.0012	<0.035	<0.00010	<0.00010	0.00040
Isle of Wight								
Newport	Gooseberries	1	0.0080	<0.0010	<0.029	<0.00010	<0.00020	0.00040
	Spring Greens	1	0.022	<0.00070		<0.00020	<0.00020	<0.00020
North Yorkshire								
Northallerton	Cabbage	1	0.036	0.0048		0.00010	0.00020	0.00020
	Potatoes	1	0.022	0.0041		<0.00010	<0.00010	0.00030
Northumberland								
Alnwick	Cabbage	1	0.065	<0.0015	0.035	<0.00020	<0.00020	<0.00020
	Raspberries	1	0.041	<0.00080	<0.034	<0.00010	<0.00010	0.00020
Nottinghamshire								
Sutton in Ashfield	Carrots	1	0.056	0.00080		<0.00010	<0.00020	<0.00020
	Lettuce	1	<0.0040	0.0052	0.039	<0.00010	0.00010	0.00040
Powys								
Builth Wells	Chard	1	0.11	0.0038		<0.00010	0.00020	0.00030
	Potatoes	1	0.018	0.017	0.040	<0.00010	0.00020	0.00030
Shropshire								
Market Drayton	Raspberries	1	0.010	<0.0014		<0.00010	<0.00020	<0.00020
	Spinach	1	0.075	0.013	0.045	<0.00030	0.00040	<0.00020
Staffordshire								
Stoke on Trent	Cabbage	1	0.037	<0.0012		<0.00010	<0.00020	<0.00020
	Potatoes	1	0.028	0.010		<0.00010	<0.00010	<0.00020
Surrey								
Weybridge	Beef Kidney	1				<0.00010	<0.00020	0.00040
	Beef Liver	1				<0.00010	<0.00010	0.00050
	Beef Muscle	1				<0.00010	<0.00010	0.00050
	Sheep Kidney/Liver	1				<0.00020	<0.00020	0.00040
	Sheep Muscle	1				<0.00010	<0.00010	0.00050
Wiltshire								
Warminster	Potatoes	1	0.012	0.0026		<0.00020	0.00010	<0.00030
	Swiss Chard/Lettuce/ Cabbage	1	0.086	0.0015		<0.00010	0.00020	0.00050
Worcestershire								
Redditch	Lettuce	1	0.037	0.0057		<0.00010	<0.00020	<0.00030
	Raspberries	1	0.029	0.0092		<0.00010	<0.00020	0.00030
Mean Values								
Channel Islands			0.011	0.0016	<0.030	0.00015	<0.00018	0.00035
England			<0.056	<0.0050	<0.035	<0.00013	<0.00017	0.00033
Wales			0.042	<0.010	0.040	<0.00010	<0.00018	0.00025
Scotland								
Great Britain			<0.049	<0.0077	<0.038	<0.00011	<0.00017	<0.00029

[a] *Results are available for other artificial nuclides detected by gamma spectrometry. All such results are less than the limit of detection*
[b] ^{137}*Cs only*

Table 8.13. Concentrations of caesium-137 in imported foods monitored at ports, 2006

Port	Country of origin	Foodstuff	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1} (fresh)[a] ^{137}Cs
Dover				
	Austria	Blueberry juice concentrate[b]	1	1500
	Germany	Blueberry juice concentrate[c]	1	1000
	Poland	Wild blueberries (whole)	1	90
		Wild blueberries (whole)	1	160
		Wild blueberries (whole, frozen)	1	88
Felixstowe				
	Holland	Blueberry juice concentrate[d]	1	1200
		Gooseberries	1	<2.0
		Cured back bacon	1	<3.0
		Chicken fillets	1	<7.0
		Boneless beef	1	<2.0
		Chicken breast	1	<3.0
		Chicken breast	1	<5.0
		Chicken breast	1	<7.0

[a] Except for Blueberry juice concentrate where the units are Bq l^{-1}
[b] The result of 1100 Bq kg^{-1} was multiplied by the sample density to give Bq l^{-1}
[c] The result of 780 Bq kg^{-1} was multiplied by the sample density to give Bq l^{-1}
[d] The result of 920 Bq kg^{-1} was multiplied by the sample density to give Bq l^{-1}

Table 8.14. Concentrations of radionuclides in grass, soil, rainwater and air, 2006

Location	Sample	No. of sampling obser-vations	Mean radioactivity concentration[a]									
			^{3}H	^{7}Be	^{90}Sr[b]	^{137}Cs	^{210}Pb	^{210}Po	$^{239}Pu+$ ^{240}Pu[c]	^{241}Am[c]	Total alpha[e]	Total beta[e]
Ceredigion												
Aberporth	Rainwater	4	<0.72	<1.6		<0.052			<6.0 10^{-6}	<3.6 10^{-5}		
	Air	4		0.0023		<7.2 10^{-7}			6.5 10^{-10}	<1.5 10^{-9}		
Co. Down												
Conlig	Rainwater	4		1.9		<0.040						
	Air	4		0.0022		<7.9 10^{-7}						
Dumfries and Galloway												
Eskdalemuir	Rainwater	4	<0.56	1.5		<0.024						
	Air	4		0.0018		6.2 10^{-7}						
	Grass	3				<0.51						
	Soil[d]	3				25						
Glasgow												
Glasgow	Air	12				<0.0060						0.0020
North Yorkshire												
Dishforth	Rainwater	4		1.6		<0.045						
	Air	4		0.0016		<8.2 10^{-7}						
Oxfordshire												
Chilton	Rainwater	12		<2.3	<0.0016	<0.064					<0.047	0.12
	Air	4		0.0021		<6.1 10^{-7}						
	Air	12					0.00019	7 10^{-6}				
Shetland												
Lerwick	Rainwater	4		<2.1		<0.042						
	Air	4		0.0016		<9.6 10^{-7}						
Suffolk												
Orfordness	Rainwater	4	<0.66	<2.7		<0.078						
	Air	4		0.0024		<7.8 10^{-7}						

Location	Sample	Mean radioactivity concentration[a]				
		^{40}K	^{54}Mn	^{208}Tl	^{210}Pb	^{228}Ac
Additional radionuclides detected by gamma spectrometry in some quarters						
Ceredigion						
Aberporth	Air	0.00016			0.00011	4.4 10^{-6}
Co. Down						
Conlig	Air	0.00015			0.00011	
Dumfries and Galloway						
Eskdalemuir	Air	0.00012	3.9 10^{-6}		8.7 10^{-5}	
North Yorkshire						
Dishforth	Rainwater	2.9				
	Air				9.7 10^{-5}	
Oxfordshire						
Chilton	Air			9.2 10^{-7}	0.00013	
Shetland						
Lerwick	Rainwater			0.066		
	Air				7.0 10^{-5}	
Suffolk						
Orfordness	Air				0.00018	

[a] *Bq l^{-1} for rainwater, Bq kg^{-1} (fresh) for grass and soil and Bq kg^{-1} for air, 1 kg air occupies 1 m^3 at standard temperature and pressure* [b] *Bulked from 4 quarterly samples*
[c] *Separate annual sample for rain, annual bulked sample for air* [d] *The gamma dose rate in air at 1 m was 0.073 µGy h^{-1}* [e] *Bulked from 12 monthly samples*

Table 8.15. Concentrations of radionuclides in sources of drinking water in Scotland, 2006

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Total alpha	Total beta
Angus	Loch Lee	4	<1.5	<0.0058	<0.01	<0.032	<0.043
Argyll and Bute	Auchengaich	1	<1.1		<0.01	<0.010	0.014
Argyll and Bute	Helensburgh Reservoir	1	<1.3		<0.01	<0.010	0.020
Argyll and Bute	Loch Ascog	1	<1.1		<0.01	<0.010	0.10
Argyll and Bute	Loch Eck	1	<1.1		<0.01	<0.010	0.023
Argyll and Bute	Loch Finlas	1	<1.3		<0.01	<0.010	0.019
Clackmannanshire	Gartmorn	1	1.5		<0.01	<0.010	0.11
Dumfries and Galloway	Black Esk	1	<1.3		<0.01	<0.010	0.025
Dumfries and Galloway	Purdomstone	1	2.3		<0.01	<0.010	0.055
Dumfries and Galloway	Winterhope	1	1.5		<0.01	<0.010	0.051
East Lothian	Hopes Reservoir	1	1.7		<0.01	0.013	0.024
East Lothian	Thorters Reservoir	1	1.7		<0.01	<0.010	0.050
East Lothian	Whiteadder	1	2.7		<0.01	<0.010	0.040
Fife	Holl Reservoir	1	1.2		<0.01	<0.010	0.033
Highland	Loch Glass	4	<1.2	<0.0044	<0.01	<0.032	0.026
North Ayrshire	Camphill	1	2.4		<0.01	<0.010	0.015
North Ayrshire	Knockendon Reservoir	1	<1.3		<0.01	<0.010	0.019
North Ayrshire	Munnoch Reservoir	1	2.3		<0.01	<0.010	0.041
North Ayrshire	Outerwards	1	<1.3		<0.01	<0.010	0.084
Perth and Kinross	Castlehill	1	<1.1		<0.01	<0.010	0.024
Scottish Borders	Knowesdean	4	<1.7	<0.0078	<0.01	<0.032	<0.043
Stirling	Loch Katrine	12	<1.4	<0.0060	<0.001	<0.0075	<0.031
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.1		<0.01	<0.010	0.024
West Lothian	Morton No 2	1	<1.3		<0.01	<0.010	0.056

Table 8.16. Concentrations of radionuclides in sources of drinking water in England and Wales, 2006

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}					
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	^{210}Po
England								
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.050	<0.0010		<0.0010	<0.010
Cambridgeshire	Grafham Water	4	<4.0	0.38	0.0018		<0.0010	<0.010
Cheshire	River Dee, Chester	4	<4.0	0.14	0.0021	<0.0020	0.0015	<0.010
Cornwall	River Fowey	4	<4.0	0.068	0.0017	0.0019	<0.0010	<0.010
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.075	0.0033		<0.0010	<0.010
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	<0.063	0.0037		<0.0011	0.011
County Durham	River Tees, Darlington	4	<4.0	0.053	0.0030	<0.0021	<0.0010	<0.010
Cumbria	Haweswater Reservoir	4	<4.0	<0.025	0.0032		0.00090	<0.010
Cumbria	Ennerdale Lake	4	<4.0	<0.031	0.0029		0.0012	<0.010
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.049	0.0013		0.0011	<0.010
Derbyshire	Matlock, Groundwater	4	<4.0	0.046	<0.0010		<0.0010	0.012
Devon	River Exe, Exeter	4	<4.0	0.10	0.0031	<0.0020	<0.0011	<0.010
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.18	0.0019	<0.0023	<0.0010	<0.010
Greater London	River Lee, Chingford	4	<4.0	0.36	<0.0010	<0.0020	<0.0010	<0.010
Hampshire	River Avon, Christchurch	4	<4.0	0.090	<0.0010	0.0020	<0.0010	<0.010
Humberside	Littlecoates, Groundwater	4	<4.0	0.11	<0.0018		<0.0010	<0.010
Kent	Denge, Shallow Groundwater	4	<4.0	0.15	0.0034		<0.0010	<0.010
Kent	Chatham, Deep Groundwater	4	<4.0	0.064	<0.0015		<0.0010	<0.010
Lancashire	Corn Close, Groundwater	4	<4.0	0.073	<0.0010		<0.0010	<0.010
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.12	<0.0012	<0.0019	<0.0010	<0.010
Northumberland	Kielder Reservoir	4	<4.0	<0.053	0.0020		<0.0010	<0.010
Oxfordshire	River Thames, Oxford	3	<4.0	0.16	0.0041	<0.0020	<0.0012	<0.010
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.083	0.0017		<0.0010	<0.010
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.14	0.0017		<0.0010	<0.010
Surrey	River Thames, Walton	4	<4.0	0.25	0.0016	<0.0024	<0.0010	<0.010
Surrey	River Thames, Chertsey	4	<4.0	0.23	0.0013	<0.0021	<0.0010	<0.010
Yorkshire	Chellow Heights, Bradford	2	<4.0	0.025	0.0038		<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	Total alpha	Total beta[1]	Total beta[2]
England									
Buckinghamshire	Bourne End, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.075	0.056
Cambridgeshire	Grafham Water	4	<0.010	0.0099	<0.010	<0.010	0.026	0.53	0.34
Cheshire	River Dee, Chester	4	<0.010	<0.0099	<0.010	<0.010	0.044	0.27	0.17
Cornwall	River Fowey	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.088	0.058
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.088	0.055
County Durham	Honey Hill Water Treatment Works, Consett	4	<0.010	<0.010	<0.010	<0.010	0.037	0.10	0.064
County Durham	River Tees, Darlington	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.077	0.055
Cumbria	Haweswater Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050
Cumbria	Ennerdale Lake	4	<0.010	<0.010	<0.010	<0.010	<0.021	<0.064	<0.055
Derbyshire	Arnfield Water Treatment Plant	4	<0.010	<0.010	<0.010	<0.010	<0.019	<0.052	<0.050
Derbyshire	Matlock, Groundwater	4	0.011	0.038	<0.010	0.021	0.079	0.10	0.062
Devon	River Exe, Exeter	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.12	0.077
Gloucestershire	River Severn, Tewkesbury	4	<0.010	0.017	<0.010	0.010	0.030	0.26	0.16
Greater London	River Lee, Chingford	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.51	0.32
Hampshire	River Avon, Christchurch	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.13	0.096
Humberside	Littlecoates, Groundwater	4	<0.010	<0.010	<0.010	<0.010	0.023	0.11	0.080
Kent	Denge, Shallow Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.21	0.13
Kent	Chatham, Deep Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.019	0.055	<0.049
Lancashire	Corn Close, Groundwater	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.091	0.060
Norfolk	River Drove, Stoke Ferry	4	<0.010	0.011	<0.010	0.0097	0.026	0.15	0.097
Northumberland	Kielder Reservoir	4	<0.010	<0.010	<0.010	<0.010	0.021	0.067	0.049
Oxfordshire	River Thames, Oxford	3	<0.010	<0.010	<0.010	<0.010	<0.020	0.23	0.16
Somerset	Ashford Reservoir, Bridgwater	4	<0.010	<0.010	<0.010	<0.010	<0.021	0.12	0.082
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.010	0.011	<0.010	0.0097	0.023	0.20	0.13
Surrey	River Thames, Walton	4	<0.010	<0.010	<0.010	<0.010	<0.020	0.31	0.20
Surrey	River Thames, Chertsey	4	<0.010	0.0099	<0.010	<0.010	0.022	0.31	0.20
Yorkshire	Chellow Heights, Bradford	2	<0.010	<0.010	<0.010	<0.010	<0.020	0.062	<0.050

Table 8.16. continued

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
Wales								
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.021	0.0038		0.0019	0.010
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.048	0.0019		0.0012	0.012
Powys	Elan Valley Reservoir	4	<4.0	<0.035	0.0033		<0.0011	0.010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta[1]	Total beta[2]
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	0.051	<0.050
Powys	Elan Valley Reservoir	4	<0.010	<0.010	<0.010	<0.010	<0.020	<0.050	<0.050

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

Table 8.17. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2006

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{90}Sr	^{137}Cs	^{210}Po	^{226}Ra	^{234}U	^{235}U	^{238}U	Total alpha	Total beta
Co. Londonderry	R Faughan	4	<1.3	<0.0027	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.072
Co. Antrim	Lough Neagh	4	<1.3	<0.0036	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.13
Co. Down	Silent Valley	4	<1.5	<0.0034	<0.05	0.020	<0.010	<0.010	<0.010	<0.010	0.030	0.064

Table 8.18. Estimates of radiation exposure from radionuclides in drinking water, 2006[a]

Region	Mean[b] exposure, mSv per year			Maximum exposure, mSv	
	Man-made radionuclides[c]	Naturally occurring radionuclides[d]	All radionuclides	Location	All radionuclides
England	<0.001	0.027	0.027	Derbyshire, Matlock	0.033
Wales	<0.001	0.028	0.028	Mid-Glamorgan, Llwyn-on Reservoir	0.031
Northern Ireland	<0.001	0.039	0.040	Co. Down, Silent Valley	0.046
Scotland [e]	<0.001			Scottish Borders, Knowsdean	0.001[e]
UK[f]	<0.001	0.028	0.028	Co. Down, Silent Valley	0.046

[a] *Assessments of dose are based on some concentration results at limits of detection.*
Exposures due to potassium-40 content of water are not included here because they do not vary vary according to the potassium-40 content of water.
Levels of potassium are homeostatically controlled.
[b] *Average of the doses to the most exposed age group at each location*
[c] *Including tritium*
[d] *Including carbon-14*
[e] *Analysis of naturally occurring radionuclides was not undertaken*
[f] *Not including Scotland*

Table 8.19. Concentrations of radionuclides in seawater, 2006

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	<2.2		<0.10			<0.13	
Dounreay (Brims Ness)	4	<2.5		<0.10			<0.15	
Rosyth	1	<1.1		<0.10			<0.16	
Torness	2	4.9		<0.10			<0.23	
Hartlepool (North Gare)	2			<0.31			<2.3	<0.40
Hartlepool (North Gare)	2[F]	<3.4						
Sizewell	2			<0.18			<1.5	<0.23
Aldeburgh	2[F]	8.0						
Bradwell	2			<0.31			<2.4	<0.44
Dungeness (inlet)	2[F]	3.8						
Dungeness south	2			<0.14			<1.2	<0.18
Winfrith (Lulworth Cove)	2			<0.17			<1.5	<0.25
Alderney	3[F]	5.9						
Jersey	1[F]							
Guernsey	3[F]							
Devonport (Millbrook Lake)	2	<4.0	<4.0	<0.30				
Devonport (Tor Point South)	2	<4.0	<4.0	<0.30				
Hinkley	2			<0.18	<0.030		<1.5	<0.25
Berkeley and Oldbury	2			<0.16			<1.4	<0.24
Cardiff Orchard Ledges)[a]	2	<16	<4.0					
Cardiff (Orchard Ledges East)	2[F]	5.0						
Holyhead	4[F]	3.3						
Wylfa (Cemaes Bay)	2			<0.14			<1.1	<0.18
Wylfa (Cemlyn Bay)	2			<0.30			<2.4	<0.43
Heysham (inlet)	2			<0.18			<1.5	<0.23
Heysham (inlet)	1[F]	20						
Seascale (Particulate)	2			<0.28	<0.015		<2.3	<0.38
Seascale (Filtrate)	2			<0.18	<0.087	<0.63	<1.5	<0.24
St. Bees	12[F]	9.0				0.045		
St. Bees (Particulate)	2			<0.28	<0.030		<2.3	<0.44
St. Bees (Filtrate)	2			<0.30	<0.10	<1.2	<2.3	<0.38
Seafield	4	9.1		<0.10			<0.16	
Southerness[b]	4	6.7		<0.10			<0.18	
Auchencairn	4	6.0		<0.10			<0.19	
Knock Bay	4	<3.1		<0.10			<0.18	
Knock Bay	4[F]	3.6						
Hunterston	2	4.1						
North of Larne	12[N]					0.0086		
Faslane (Carnban)	2	<3.9		<0.10			<0.20	

Table 8.19. continued

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
		^{125}I	^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Total alpha	Total beta
Dounreay (Sandside Bay)	4		<0.10	<0.10	<0.11	<0.10		
Dounreay (Brims Ness)	4		<0.10	<0.10	<0.11	<0.10		
Rosyth	1		<0.10	<0.10	<0.10	<0.10		
Torness	2		<0.10	<0.10	<0.14	<0.10		
Hartlepool (North Gare)	2		<0.29	<0.25	<1.0	<0.38	<2.2	16
Sizewell	2		<0.17	<0.15	<0.79	<0.33	<2.5	21
Bradwell	2		<0.30	<0.29	<1.1	<0.57	<1.7	20
Dungeness south	2		<0.14	<0.11	<0.59	<0.28	<2.8	21
Winfrith (Lulworth Cove)	2		<0.17	<0.15	<0.79	<0.32	<1.3	5.4
Alderney	3[F]		*	0.002				
Jersey	1[F]		*	0.004				
Guernsey	3[F]		*	0.002				
Hinkley	2		<0.18	<0.14	<0.81	<0.46	<2.0	10
Berkeley and Oldbury	2		<0.17	<0.15	<0.72	<0.28	<1.6	11
Cardiff								
(Orchard Ledges)[a]	2	<0.25						
Holyhead	4[F]		*	0.03				
Wylfa (Cemaes Bay)	2		<0.13	<0.11	<0.61	<0.26	<1.9	12
Wylfa (Cemlyn Bay)	2		<0.31	<0.23	<1.1	<0.37	<2.4	17
Llandudno	1[F]		*	0.04				
Prestatyn	1[F]		*	0.06				
New Brighton	1[F]		*	0.06				
Ainsdale	1[F]		0.002	0.10				
Rossall	1[F]		*	0.10				
Heysham (inlet)	2		<0.18	<0.20	<0.81	<0.46	<2.3	18
Half Moon Bay	1[F]		*	0.20				
Silecroft	1[F]		*	0.09				
Seascale (Particulate)	2		<0.27	<0.27	<1.1	<0.34	0.17	0.66
Seascale (Filtrate)	2		<0.18	<0.20	<0.83	<0.47	<1.8	12
St. Bees	12[F]		<0.0004	0.12				
St. Bees (Particulate)	2		<0.27	<0.29	<1.1	<0.30	0.090	0.42
St. Bees (Filtrate)	2		<0.28	<0.32	<1.1	<0.38	<2.1	8.9
Whitehaven	1[F]		*	0.09				
Maryport	1[F]		*	0.18				
Silloth	1[F]		0.002	0.19				
Seafield	4		<0.10	<0.17	<0.12	<0.10		
Southerness[b]	4		<0.10	<0.13	<0.11	<0.00045		
Auchencairn	4		<0.10	<0.10	<0.12	<0.10		
Ross Bay	1[F]		*	0.06				
Isle of Whithorn	1[F]		*	0.03				
Drummore	1[F]		*	0.05				
Knock Bay	4		<0.10	<0.10	<0.12	<0.10		
Knock Bay	4[F]		*	0.03				
North of Larne	12[N]		*	0.02				
Faslane (Carnban)	2		<0.10	<0.10	<0.12	<0.10		

** Not detected by the method used*

[a] The concentration of ^{3}H as tritiated water was 6.0 Bq l^{-1} and the concentration of ^{125}I was <0.25 Bq l^{-1}

[b] The concentrations of ^{238}Pu and $^{239+240}Pu$ were <0.00025 and <0.0011 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 Environment and Heritage Service

9. References

(Includes references from Appendix 1: CD supplement)

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APPENDIX 1. CD Supplement

This Appendix contains information on the methods of sampling, measurement, presentation and assessment. It is provided on the CD accompanying the main report.

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2006

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (BNGSL)				
	Tritium	1600	$5.9\ 10^{-6}$	<1
	Uranium[c]	BPM	$7.20\ 10^{-8}$	NA
Capenhurst (Urenco)	Uranium	$2.5\ 10^{-6}$	$3.24\ 10^{-7}$	13
Sellafield[d]	Alpha	$8.8\ 10^{-4}$	$6.60\ 10^{-5}$	7.5
	Beta	0.042	$9.42\ 10^{-4}$	2.2
	Tritium	1100	185	17
	Carbon-14	3.3	0.71	22
	Krypton-85	$4.4\ 10^{5}$	$2.28\ 10^{4}$	5.2
	Strontium-90	$7.1\ 10^{-4}$	$4.80\ 10^{-5}$	6.8
	Ruthenium-106	0.028	0.00158	5.6
	Antimony-125	0.0023	0.00151	66
	Iodine-129	0.07	0.00665	9.5
	Iodine-131	0.055	$6.61\ 10^{-4}$	1.2
	Caesium-137	0.0058	$5.87\ 10^{-4}$	10
	Plutonium alpha	$1.9\ 10^{-4}$	$2.64\ 10^{-5}$	14
	Plutonium-241	0.003	$2.25\ 10^{-4}$	7.5
	Americium-241 and curium-242	$1.2\ 10^{-4}$	$2.54\ 10^{-5}$	21
Springfields	Uranium	0.0053	$4.40\ 10^{-4}$	8.3
Springfields (Nexia Solutions)	Tritium	10^{-4}	$2.50\ 10^{-7}$	<1
	Carbon-14	10^{-5}	$4.40\ 10^{-7}$	4.4
	Other alpha radionuclides	10^{-6}	Nil	Nil
	Other beta radionuclides	10^{-5}	$1.70\ 10^{-8}$	<1
Research establishments				
Dounreay (Fuel Cycle Area)	Alpha[e]	$9.8\ 10^{-4}$	$9.85\ 10^{-6}$	1.0
	Beta[f,g]	0.045	$2.39\ 10^{-4}$	<1
	Tritium	2	0.265	13
	Krypton-85	3000	1.24	<1
	Strontium-90	0.0042	$7.14\ 10^{-5}$	1.7
	Ruthenium-106	0.0039	$6.72\ 10^{-6}$	<1
	Iodine-129	0.0011	$1.65\ 10^{-4}$	15
	Iodine-131	$1.5\ 10^{-4}$	$7.96\ 10^{-5}$	53
	Caesium-134	$8.4\ 10^{-4}$	$8.42\ 10^{-7}$	<1
	Caesium-137	0.007	$3.99\ 10^{-5}$	<1
	Cerium-144	0.007	$4.70\ 10^{-6}$	<1
	Plutonium-241	0.0033	$8.20\ 10^{-6}$	<1
	Curium-242	$2.7\ 10^{-4}$	$7.05\ 10^{-8}$	<1
	Curium-244[h]	$5.4\ 10^{-5}$	$9.01\ 10^{-8}$	<1
Dounreay (Fast Reactor)	Alpha	10^{-5}	$7.80\ 10^{-9}$	<1
	Beta	0.0015	$2.97\ 10^{-8}$	<1
	Tritium	4.5	$1.33\ 10^{-3}$	<1
	Krypton-85	$4\ 10^{-4}$	Nil	Nil
Dounreay (Prototype Fast Reactor)	Alpha	$6\ 10^{-6}$	$3.71\ 10^{-8}$	<1
	Beta	$5.1\ 10^{-5}$	$1.30\ 10^{-6}$	2.5
	Tritium	10.5	$7.62\ 10^{-2}$	<1
	Krypton-85	4	3.64	91
Dounreay (PFR minor sources)	Alpha[i]	$6\ 10^{-8}$	$3.88\ 10^{-10}$	<1
	Beta[f]	$5\ 10^{-7}$	$1.50\ 10^{-9}$	<1
	Tritium	0.2	$3.85\ 10^{-3}$	1.9

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Dounreay				
(East minor sources)	Alpha[i]	$1.37\ 10^{-5}$	$6.63\ 10^{-8}$	<1
	Beta[f,g]	$3.71\ 10^{-4}$	$3.95\ 10^{-7}$	<1
	Krypton-85[j]	1	Nil	Nil
Dounreay				
(West minor sources)	Alpha[i]	$3\ 10^{-7}$	$1.03\ 10^{-9}$	<1
	Beta[f,g]	$7.5\ 10^{-5}$	$4.27\ 10^{-9}$	<1
	Tritium	0.01	$3.24\ 10^{-4}$	3.2
Harwell				
(AEA Technology)	Alpha	$7\ 10^{-7}$	Nil	Nil
	Beta	$3\ 10^{-5}$	Nil	Nil
	Tritium	$2\ 10^{-4}$	Nil	Nil
Harwell				
(UKAEA)	Alpha	$8\ 10^{-7}$	$5.39\ 10^{-8}$	6.7
	Beta	$2\ 10^{-5}$	$1.10\ 10^{-6}$	5.5
	Tritium	15	0.23	1.6
	Krypton-85	2	0.118	5.9
	Radon-220	100	9.64	9.6
	Radon-222	3	0.29	9.7
	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	$1\ 10^{-7}$	$1.64\ 10^{-9}$	1.6
	Beta/gamma	$3\ 10^{-5}$	$8.18\ 10^{-7}$	2.7
	Radon-222	1	Nil	Nil
	Tritium	2	Nil	Nil
	Krypton-85	0.06	Nil	Nil
Windscale	Alpha	$1.2\ 10^{-5}$	$1.05\ 10^{-7}$	<1
	Beta	$5\ 10^{-4}$	$1.66\ 10^{-6}$	<1
	Tritium	2.3	Nil	Nil
	Krypton-85	14	0.03	<1
	Iodine-131	0.0012	$8.64\ 10^{-7}$	<1
Winfrith[s]				
(AEA Technology to 23/03/06	Alpha	$1\ 10^{-7}$	Nil	Nil
WMT Ltd from 23/03/06)	Beta	$2.5\ 10^{-5}$	$1.03\ 10^{-5}$	4.1
	Tritium	19.5	10.1	52
	Carbon -14	0.03	$3.86\ 10^{-6}$	<1
	Other	$1\ 10^{-7}$	Nil	Nil
Winfrith				
(UKAEA)	Alpha	$2\ 10^{-6}$	$2.06\ 10^{-9}$	<1
	Tritium	4	1.10	22
	Carbon-14	0.006	$8.6\ 10^{-4}$	14
	Other	$5\ 10^{-6}$	$1.47\ 10^{-8}$	<1
Minor sites				
Imperial College Reactor Centre				
Ascot	Tritium	$3\ 10^{-4}$	$4.20\ 10^{-5}$	14
	Argon-41	1.7	$9.49\ 10^{-2}$	5.6
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 2006	
			TBq	% of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	$3\ 10^{-5}$	$4.04\ 10^{-7}$	1.3
	Tritium	0.075	0.00386	5.1
	Carbon-14	0.011	$1.66\ 10^{-4}$	1.5
Bradwell	Beta	$6\ 10^{-4}$	$9.76\ 10^{-6}$	1.6
	Tritium	1.5	0.00843	<1
	Carbon-14	0.6	$5.63\ 10^{-4}$	<1
Chapelcross	Tritium	5000	121	2.4
	Sulphur-35	0.05	$4.20\ 10^{-5}$	<1
	Argon-41	4500	Nil	Nil
Dungeness				
A' Station	Beta[q]	$5.5\ 10^{-4}$	$1.97\ 10^{-4}$	36
	Tritium	2.6	0.181	7.0
	Carbon-14	5	1.93	39
	Sulphur-35	0.15	0.047	31
	Argon-41	1700	1280	75
Dungeness				
B' Station	Beta[q]	0.001	$5.54\ 10^{-6}$	<1
	Tritium	15	2.99	20
	Carbon-14	5	0.601	12
	Sulphur-35	0.45	0.0201	4.5
	Argon-41	150	13.6	9.1
	Iodine-131	0.005	$2.19\ 10^{-6}$	<1
Hartlepool	Beta[q]	0.001	$4.32\ 10^{-6}$	<1
	Tritium	6	1.26	21
	Carbon-14	5	1.47	29
	Sulphur-35	0.16	0.0198	12
	Argon-41	60	4.52	7.5
	Iodine-131	0.005	$2.29\ 10^{-5}$	<1
Heysham				
Station 1	Beta[q]	0.001	$8.57\ 10^{-6}$	<1
	Tritium	6	1.04	17
	Carbon-14	4	1.72	43
	Sulphur-35	0.12	0.0241	20
	Argon-41	60	8.55	14
	Iodine-131	0.005	$1.10\ 10^{-4}$	2.2
Heysham				
Station 2	Beta[q]	0.001	$1.18\ 10^{-5}$	1.2
	Tritium	15	0.994	6.6
	Carbon-14	3	1.27	42
	Sulphur-35	0.3	0.0149	5.0
	Argon-41	85	11.8	14
	Iodine-131	0.005	$5.39\ 10^{-5}$	1.1
Hinkley Point				
A' Station	Beta	$1.5\ 10^{-4}$	$8.39\ 10^{-7}$	<1
	Tritium	1.5	0.121	8.1
	Carbon-14	0.6	$6.87\ 10^{-4}$	<1
Hinkley Point				
B' Station	Beta[q]	0.001	$2.48\ 10^{-5}$	2.5
	Tritium	30	6.52	22
	Carbon-14	8	1.32	17
	Sulphur-35	0.4	0.180	45
	Argon-41	300	8.04	2.7
	Iodine-131	0.005	$4.06\ 10^{-6}$	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Hunterston A' Station	Beta[q]	$6\ 10^{-5}$	$2.83\ 10^{-7}$	<1
	Tritium	0.02	0.00197	9.9
	Carbon-14	0.002	$1.84\ 10^{-4}$	9.2
Hunterston B' Station	Beta[q]	0.002	$3.40\ 10^{-5}$	1.7
	Tritium	20	1.66	8.3
	Carbon-14	3	1.68	56
	Sulphur-35	0.8	0.0222	2.8
	Argon-41	220	20.6	9.4
Oldbury	Beta	10^{-4}	$1.39\ 10^{-5}$	14
	Tritium	9	1.72	19
	Carbon-14	4	0.887	22
	Sulphur-35	0.45	0.0412	9.2
	Argon-41	500	19.6	3.9
Sizewell A' Station	Beta	$8.5\ 10^{-4}$	$2.23\ 10^{-4}$	26
	Tritium	3.5	1.42	41
	Carbon-14	2	1.49	75
	Sulphur-35	0.35	0.143	41
	Argon-41	3000	2130	71
Sizewell B' Station	Noble gases	300	3.05	1.0
	Halogens	0.003	$5.33\ 10^{-4}$	18
	Beta[q]	0.01	$4.52\ 10^{-5}$	<1
	Tritium	8	1.23	15
	Carbon-14	0.6	0.169	28
Torness	Beta[q]	0.002	$4.22\ 10^{-6}$	<1
	Tritium	20	1.91	9.6
	Carbon-14	3	0.688	23
	Sulphur-35	0.8	0.0136	1.7
	Argon-41	220	3.76	1.7
Trawsfynydd	Beta	$5\ 10^{-5}$	$2.69\ 10^{-7}$	<1
	Tritium	0.75	0.11	15
	Carbon-14	0.01	0.00296	30
Wylfa	Beta	$7\ 10^{-4}$	$3.69\ 10^{-5}$	5.3
	Tritium	18	2.65	15
	Carbon-14	2.3	1.28	56
	Sulphur-35	0.45	0.161	36
	Argon-41	100	14.8	15
Defence establishments				
Aldermaston[a,m]	Alpha	$4.5\ 10^{-7}$	$5.85\ 10^{-8}$	13
	Tritium	170	1.16	<1
	Krypton-85	1	0.0217	2.2
	Plutonium-241	$1.68\ 10^{-6}$	$1.82\ 10^{-7}$	11
	Other beta and gamma emitters	$5\ 10^{-6}$	$1.05\ 10^{-7}$	2.1
Barrow[l]	Tritium	$3.2\ 10^{-6}$	Nil	Nil
	Argon-41	0.048	Nil	Nil
Burghfield[a,m]	Tritium	0.05	Nil	Nil
	Uranium	$2\ 10^{-8}$	$4.60\ 10^{-10}$	2.3
Coulport	Tritium	0.05	0.00407	8.1
Derby[n,r]	Uranium	$4\ 10^{-6}$	$6.22\ 10^{-7}$	16
	Alpha[q]	$2.4\ 10^{-8}$	$1.98\ 10^{-10}$	<1
	Beta[q]	$1.8\ 10^{-6}$	$4.56\ 10^{-8}$	2.5

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq	% of annual limit[b]
Devonport[o]	Beta/gamma[q]	$3\ 10^{-7}$	$3.91\ 10^{-8}$	13
	Tritium	0.004	$4.28\ 10^{-4}$	11
	Carbon-14	0.043	$8.84\ 10^{-3}$	21
	Argon-41	0.015	$1.22\ 10^{-4}$	<1
Dounreay (Vulcan)	Alpha[q]	10^{-6}	$4.68\ 10^{-11}$	<1
	Beta[q]	10^{-4}	$1.20\ 10^{-6}$	1.2
	Noble gases	0.027	$3.26\ 10^{-4}$	1.2
	Iodine-131	$3.7\ 10^{-4}$	$2.60\ 10^{-5}$	7.0
Rosyth[p]	Beta	10^{-7}	Nil	Nil
	Argon-41	0.4	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$2.25\ 10^{-6}$	$1.21\ 10^{-7}$	5.4
	Beta>0.4 MeV	0.0202	$5.42\ 10^{-5}$	<1
	Radionuclides T1/2<2hr	0.01	$7.59\ 10^{-4}$	7.6
	Tritium	2	$1.08\ 10^{-6}$	<1
	Sulphur-35	0.035	0.00787	22
	Selenium-75	0.0015	$2.12\ 10^{-4}$	14
	Iodine-125	0.02	0.00118	5.9
	Iodine-131	0.001	$4.55\ 10^{-4}$	46
	Radon-222	10	2.92	29
	Other noble gases	50	17.2	34
	Other	0.016	$5.87\ 10^{-4}$	3.7
Cardiff (GE Healthcare)	Soluble tritium	156	70.69	45
	Insoluble tritium	600	248	41
	Carbon-14	2.38	1.68	71
	Phosphorus-32/33	$5\ 10^{-6}$	$7.80\ 10^{-7}$	16
	Iodine-125	$1.8\ 10^{-4}$	$4.49\ 10^{-5}$	25
	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 Technology Centre*

[l] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*

[m] *Discharges were made by AWE plc*

[n] *Discharges were made by Rolls Royce Marine Power Operations Ltd*

[o] *Discharges were made by Devonport Royal Dockyard Ltd*

[p] *Discharges were made by Rosyth Royal Dockyard Ltd*

[q] *Particulate activity*

[r] *Annual limits on beta and alpha derived from monthly and weekly notification levels*

[s] *New authorisation in force from 23 March 2006. Authorisation held by AEAT revoked at the same time. discharges include those from AEAT up to 23 March 2006. the authorisation from AEAT included a limit for beta which was revoked at the same time.*

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, 2006

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst				
(Rivacre Brook)	Tritium[c]	78	$0.0325\ 10^{-4}$	<1
	Uranium	0.02	$9.50\ 10^{-5}$	<1
	Uranium daughters	0.02	$1.78\ 10^{-4}$	<1
	Non-uranic alpha	0.003	$2.07\ 10^{-5}$	<1
	Technetium-99	0.1	$8.50\ 10^{-5}$	<1
Sellafield[d] (sea pipelines)	Alpha	1	0.205	21
	Beta	220	29	13
	Tritium	$2\ 10^{4}$	1090	5.5
	Carbon-14	21	10.9	52
	Cobalt-60	3.6	0.14	3.9
	Strontium-90	48	4.96	10
	Zirconium-95 + Niobium-95	3.8	0.155	4.1
	Technetium-99[f]	10	5.62	56
	Ruthenium-106	63	3.51	5.6
	Iodine-129	2.0	0.198	9.9
	Caesium-134	1.6	0.154	9.6
	Caesium-137	34	5.93	17
	Cerium-144	4.0	0.553	14
	Neptunium-237	1.0	0.0548	5.5
	Plutonium alpha	0.7	0.147	21
	Plutonium-241	25	3.64	15
	Americium-241	0.3	0.0518	17
	Curium-243+244	0.069	0.00215	3.1
	Uranium[i]	2000	439	22
Sellafield (factory sewer)	Alpha	$3\ 10^{-4}$	$6.38\ 10^{-5}$	21
	Beta	0.0061	$5.78\ 10^{-4}$	9.5
	Tritium	0.068	0.0214	31
Springfields	Alpha	0.55	0.08	15
	Beta	140	20.7	15
	Technetium-99	0.6	0.065	11
	Thorium-230	0.4	0.0119	3.0
	Thorium-232	0.015	$3.10\ 10^{-4}$	2.1
	Neptunium-237	0.04	0.00158	4.0
	Other transuranic radionuclides	0.02	0.00235	12
	Uranium	0.1	0.026	26
Research establishments				
Dounreay	Alpha[4]	0.02	$9.33\ 10^{-6}$	<1
PFR liquid metal disposal plant	Beta[1]	0.11	$3.20\ 10^{-4}$	<1
	Tritium	1.4	0.00126	<1
	Sodium-22	1.8	0.0191	1.1
	Caesium-137	0.066	$1.48\ 10^{-4}$	<1
Dounreay	Alpha	0.09	$4.08\ 10^{-4}$	<1
Other facilities	Beta	0.62	$6.50\ 10^{-4}$	<1
	Tritium	5.5	0.335	6.1
	Strontium-90	0.77	0.0963	13
	Caesium-137	1.0	0.0116	1.2
Harwell (pipeline)	Alpha	5 10-5	$5.61\ 10^{-6}$	11
	Beta	0.0033	$1.93\ 10^{-4}$	5.9
	Tritium	0.3	0.00260	<1
	Cobalt-60	$1.2\ 10^{-4}$	$1.74\ 10^{-6}$	1.5
	Caesium-137	$5.4\ 10^{-4}$	$2.98\ 10^{-5}$	5.5
Harwell (Lydebank Brook)	Alpha	10^{-4}	$9.77\ 10^{-6}$	9.8
	Beta	$6\ 10^{-4}$	$4.81\ 10^{-5}$	8.0
	Tritium	0.08	0.00631	7.9

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Winfrith (inner pipeline)[7]	Alpha	0.02	$1.01\ 10^{-4}$	<1
	Tritium	220	16.0	7.3
	Caesium-137	2	0.033	1.7
	Other radionuclides	1	0.00421	<1
Winfrith (outer pipeline)[7]	Alpha	0.002	$3.11\ 10^{-5}$	1.6
	Tritium	0.15	0.00513	3.4
	Other radionuclides	0.001	$4.93\ 10^{-5}$	4.9
Winfrith (River Frome)[7]	Tritium	0.75	Nil	Nil
Minor sites				
Imperial College Reactor Centre	Tritium	$4\ 10^{-5}$	$1.08\ 10^{-5}$	27
Ascot	Other radioactivity	10-4	$1.00\ 10^{-9}$	<1
Scottish Universities Environmental Research Centre				
East Kilbride	Total activity	0.00169	$6.34\ 10^{-5}$	3.8
Nuclear power stations				
Berkeley	Tritium	2	$2.34\ 10^{-4}$	<1
	Caesium-137	0.2	$7.20\ 10^{-4}$	<1
	Other radionuclides	0.4	$6.36\ 10^{-4}$	<1
Bradwell	Tritium	7	0.255	3.6
	Caesium-137	0.7	0.173	25
	Other radionuclides	0.7	0.263	38
Chapelcross	Alpha	0.1	$1.06\ 10^{-5}$	<1
	Beta[1]	25	0.0036	<1
	Tritium	5.5	0.0113	<1
Dungeness	Tritium	8	2.70	34
A' Station	Caesium-137	1.1	0.0789	7.2
	Other radionuclides	0.8	0.0908	11
Dungeness	Tritium	650	264	41
B' Station	Sulphur-35	2	0.249	12
	Cobalt-60	0.03	0.00356	12
	Other radionuclides	0.25	0.0213	8.5
Hartlepool	Tritium	1200	238	20
	Sulphur-35	3	0.275	9.2
	Cobalt-60	0.03	$2.08\ 10^{-4}$	<1
	Other radionuclides	0.3	0.0100	3.3
Heysham	Tritium	1200	351	29
Station 1	Sulphur-35	2.8	0.284	10
	Cobalt-60	0.03	$3.58\ 10^{-4}$	1.2
	Other radionuclides	0.3	0.0176	5.9
Heysham	Tritium	1200	321	27
Station 2	Sulphur-35	2.3	0.107	4.7
	Cobalt-60	0.03	$7.74\ 10^{-5}$	<1
	Other radionuclides	0.3	0.0124	4.1
Hinkley Point				
A' Station	Tritium	1.8	0.28	16
	Caesium-137	1	0.14	14
	Other radionuclides	0.7	0.13	19
Hinkley Point				
B' Station	Tritium	620	309	50
	Sulphur-35	5	0.381	7.6
	Cobalt-60	0.033	$1.35\ 10^{-4}$	<1
	Other radionuclides	0.235	0.0119	5.1

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Hunterston A' Station	Alpha	0.04	$8.72\ 10^{-5}$	<1
	Beta	0.6	0.0455	7.6
	Tritium	0.7	$5.30\ 10^{-4}$	<1
	Plutonium-241	1.0	$6.30\ 10^{-5}$	<1
Hunterston B' Station	Alpha	0.001	$5.94\ 10^{-5}$	5.9
	Beta	0.45	0.00601	1.3
	Tritium	800	315	39
	Sulphur-35	10	0.582	5.8
	Cobalt-60	0.03	$5.30\ 10^{-4}$	1.8
Oldbury	Tritium	1	0.154	15
	Caesium-137	0.7	0.396	57
	Other radionuclides	0.7	0.115	16
Sizewell A' Station	Tritium	11	0.916	8.3
	Caesium-137	1	0.569	57
	Other radionuclides	0.7	0.398	57
Sizewell B' Station	Tritium	80	55.1	69
	Other radionuclides	0.2	0.0217	11
Torness	Alpha	0.001	$1.44\ 10^{-5}$	1.4
	Beta[2,3,6]	0.45	0.00217	<1
	Tritium	800	273	34
	Sulphur-35	10	0.0141	<1
	Cobalt-60	0.03	$2.46\ 10^{-4}$	<1
Trawsfynydd	Tritium	0.5	0.00332	<1
	Strontium-90	0.05	$3.2\ 10^{-4}$	<1
	Caesium-137	0.03	0.00192	5.3
	Other radionuclides[5]	0.17	0.00181	1.1
Wylfa	Tritium	15	3.27	22
	Other radionuclides	0.11	0.017	15
Defence establishments				
Aldermaston (River Thames)[g]	Alpha	$6\ 10^{-5}$	Nil	Nil
	Tritium	0.05	Nil	Nil
	Plutonium-241	$2.4\ 10^{-4}$	Nil	Nil
	Other radionuclides	$6\ 10^{-5}$	Nil	Nil
Aldermaston (Silchester)	Alpha	$4\ 10^{-5}$	$2.09\ 10^{-6}$	5.2
	Beta/gamma	$1.2\ 10^{-4}$	$1.01\ 10^{-5}$	8.4
	Tritium	0.05	$9.85\ 10^{-4}$	2.0
Aldermaston (to Stream)	Tritium	0.01	0.00110	11
Barrow[l]	Tritium	0.012	$2.80\ 10^{-4}$	2.3
	Other gamma emitting radionuclides	$3.5\ 10^{-6}$	$2.28\ 10^{-6}$	65
Derby[m]	Alpha[n]	0.002	$5.12\ 10^{-5}$	2.6
	Alpha[o]	$3\ 10^{-7}$	Nil	Nil
	Beta[o]	$3\ 10^{-4}$	$3.03\ 10^{-8}$	<1
Devonport[k] (sewer)	Tritium	0.002	$2.87\ 10^{-4}$	14
	Cobalt-60	$3.5\ 10^{-4}$	$1.50\ 10^{-5}$	4.3
	Other radionuclides	$6.5\ 10^{-4}$	$3.43\ 10^{-4}$	53

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2006	
			TBq[a]	% of annual limit[b]
Devonport[k,p] (pipeline)	Tritium	0.7	0.127	18
	Carbon-14	0.0017	$3.25\ 10^{-4}$	19
	Cobalt-60	$8\ 10^{-4}$	$1.90\ 10^{-4}$	24
	Other radionuclides	$3\ 10^{-4}$	$1.54\ 10^{-4}$	51
Faslane	Alpha	$2\ 10^{-4}$	$7.10\ 10^{-7}$	<1
	Beta[3,6]	$5\ 10^{-4}$	$6.20\ 10^{-6}$	1.2
	Tritium	1	0.121	12
	Cobalt-60	$5\ 10^{-4}$	$3.01\ 10^{-6}$	<1
Rosyth[j]	Alpha	$5.00\ 10^{-7}$	$8.50\ 10^{-8}$	17
	Beta[3,6]	$4.80\ 10^{-4}$	$7.49\ 10^{-5}$	16
	Tritium	0.012	0.00112	9.4
	Cobalt-60	0.0025	$9.93\ 10^{-5}$	4.0
Radiochemical production				
Amersham (GE Healthcare)	Alpha	$3\ 10^{-4}$	$1.24\ 10^{-5}$	4.1
	Beta>0.4 MeV	0.06	$3.00\ 10^{-4}$	<1
	Tritium	0.141	$6.89\ 10^{-4}$	<1
	Iodine-125	0.004	$6.13\ 10^{-5}$	1.5
	Caesium-137	0.005	$1.54\ 10^{-5}$	<1
	Other radionuclides	0.215	$6.25\ 10^{-3}$	2.9
Cardiff (GE Healthcare)	Tritium	130	24.8	19
	Carbon-14	0.91	0.285	31
	Phosphorus-32/33	$8.5\ 10^{-5}$	$1.19\ 10^{-6}$	1.4
	Iodine-125	$3\ 10^{-4}$	$1.87\ 10^{-6}$	<1
	Others	$1.2\ 10^{-4}$	$1.85\ 10^{-7}$	<1
Industrial and landfill sites				
Drigg (sea pipeline)[e8]	Alpha	BPM	$7.37\ 10^{-5}$	NA
	Beta	BPM	$9.53\ 10^{-4}$	NA
	Tritium	BPM	0.157	NA
Drigg (stream)[h8]	Alpha	NA	NA	
	Beta	NA	NA	
	Tritium	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 ceased from 15 March 2005
[h] Discharges and limits are expressed in terms of concentrations of activity in Bq m^{-3} (discharges are expressed as the annual mean)
[i] The limit and discharge data are expressed in kg
[j] Discharges were made by Rosyth Royal Dockyard Ltd
[k] Discharges were made by Devonport Royal Dockyard Ltd
[l] Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd
[m] Discharges were made by Rolls Royce Marine Power Operations Ltd
[n] Discharge limit is for Nuclear Fuel Production Plant
[o] Discharge limit is for Neptune Reactor and Radioactive Components Facility
[p] Discharges were also made by the Ministry of Defence. Discharge limits amended to BPM (1 May 2006)
[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
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, 2006

Establishment	Radioactivity	Disposal limit, (annual equivalent) TBq	Disposals during 2006	
			TBq	% of limit[a]
Drigg[b]	Tritium	10	0.470	4.7
	Carbon-14	0.05	0.0100	20
	Cobalt-60	2	0.150	7.5
	Iodine-129	0.05	$1.71\ 10^{-4}$	<1
	Radium-226 plus			
	thorium-232	0.03	0.00661	22
	Uranium	0.3	0.03	10
	Other alpha[d]	0.3	0.184	61
	Others[d,e]	15	3.22	21
Dounreay[c]	Alpha		Nil	Nil
	Beta/gamma		Nil	Nil

[a] *Data quoted to 2 significant figures except where values are less than 1%*
[b] *Discharge authorisations at Drigg were revised with effect from 1 May 2006*
[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*

APPENDIX 3. Abbreviations and glossary

AEA	Atomic Energy Authority
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BNFL	British Nuclear Fuels plc
BNG	British Nuclear Group
BNGSL	British Nuclear Group Sellafield Ltd
CAC	Codex Alimentarius Commission
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DML	Devonport Management Ltd.
DPAG	Dounreay Particles Advisory Group
DRDL	Devonport Royal Dockyard Ltd
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EHS	Environment and Heritage Service
EU	European Union
FEPA 85	Food and Environment Protection Act 1985
FHP	Fuel Handling Plant
FSA	Food Standards Agency
GDL	Generalised Derived Limit
GE	General Electric
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency
HSE	Health & Safety Executive
HSL	Harwell Scientifics Limited
IAEA	International Atomic Energy Agency
IC	Imperial College
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
LLW	Low-Level Waste
LLWR	Low-Level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries & Food
MoD	Ministry of Defence
MRL	Minimum reporting level
ND	Not detected
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval Reactor Test Establishment
NSL	Nexia Solutions Ltd
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Convention
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Ltd.
RRMPOL	Rolls Royce Marine Power Operations Ltd
RNAS	Royal Naval Air Station
RSA 93	Radioactive Substances Act 1993
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Ltd
SIXEP	Site Exchange Effluent Plant
SL	Scientific Ltd
SLC	Site Licence Company
SRP	Society for Radiological Protection
TDS	Total Diet Study
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally-Occurring Radioactive Material
TPP	Tetrophenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority
VLA	Veterinary Laboratories Agency
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WMTL	Waste Management Technology Limited
YP	Ystradyfodwg and 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 toJ 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 foodchain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the 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 tecnologically 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 carried out around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gathers data on people's occupancy close to each site and local food intake rates. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Cardiff, Chapelcross, Devonport, Dounreay, Dungeness, Faslane, Hartlepool, 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 who are responsible for regulating dose from direct radiation to the public (see Table A4.1) (Stephen, 2006 and Bunker, 2007).

Table A4.1. Individual radiation exposures - direct radiation pathway, 2006

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.085
Sellafield	Bgd[a]
Springfields	<0.020
Research establishments	
Dounreay	<0.010
Harwell	0.026
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	0.089[b]
Bradwell	<0.067[b]
Chapelcross	Bgd[a,c]
Dungeness	0.54[b]
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	<0.0021[b]
Hunterston	0.083[b]
Oldbury	<0.0049[b]
Sizewell	<0.026[b]
Torness	<0.020
Trawsfynydd	0.019[b]
Wylfa	0.0086[b]
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Radiochemical production	
Amersham	0.22
Cardiff (Amersham plc)	Bgd[a]
Industrial and landfill sites	
Drigg	<0.090

[a] *Doses not significantly different from natural background*
[b] *2005 data used due to unavailability of 2006 data*
[c] *2004 data used due to unavailability of 2005 and 2006 data*

The methodology may be summarised in four steps;

1) Starting with the first pathway, individuals are selected from the habit data based on the 'cut-off' method whereby all those who have habits within a factor of three of the maximum observed for the pathway are selected as members of the potential critical group for that pathway (Hunt *et al.*, 1982; Preston *et al.*,1974).

2) Habit profiles for a particular pathway (for example fish consumers) are calculated for the selected adults by averaging the habit data chosen by the cut-off method. The profile includes averages of *all the other habits* identified in the integrated habit survey. Habit profiles for children and infants are derived from the adult profiles using scaling factors.

3) Steps 1) and 2) are repeated for each pathway, thereby deriving a profile associated with each pathway and a series of potential critical groups.

4) Once all pathway profiles have been determined, doses are calculated for each profile using the environmental and food data. Doses from direct radiation are included via those profiled groups who spend time near to the nuclear site. The group with the highest dose near each site becomes the critical group.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2006 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 summarised in Table A4.2 for each site. The data are presented in three parts. The group receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in the upper half of the tables, part A; those for liquid discharges in the middle part, part B. Occasionally the group receiving the highest dose from all pathways is different from that in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented.

In all cases, doses estimated for 2006 were less than the limit of 1mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most important groups for liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose was at Dungeness and was mostly due to direct radiation. The next highest dose was at Sellafield and Whitehaven though about half was due to the legacy of discharges of naturally-occurring radionuclides from a phosphate processing works in Whitehaven. These broad results and the numerical values of dose are similar to those found in routine assessments earlier in this report, taking into account the additional effect of direct radiation where it is prominent

A4.5 Trends in *total dose*

Total doses have been calculated in RIFE using the methodology described in this Appendix since 2003. Over this time the number of sites with combined habits survey data has increased from 6 to the current 20. The *total doses* calculated for nuclear sites since 2003 are presented in Table A4.3. There has been a steady decrease in *total dose* at Cardiff due to reductions in discharges of tritium in liquid wastes. *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 A4.2. Individual radiation exposures integrated across pathways, 2006

Site	Critical group	Exposure, mSv	
		Total	Dominant contributions
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)	0.22	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	0.024	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Prenatal children of green vegetable consumers	<0.005	Fruit, green vegetables, root vegetables, ^{3}H
Dounreay	Milk consumers aged 1y	0.029	Milk, ^{90}Sr, ^{106}Ru, ^{129}I, ^{144}Ce, ^{241}Am
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Faslane	-	-	
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	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, plume related pathways
Hunterston	Adult mushroom consumers	0.097	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Milk consumers aged 1y	0.019	Milk, ^{90}Sr, ^{60}Co, ^{137}Cs
Sizewell	Prenatal children of wild fruit and nut consumers	0.091	Direct radiation
Springfields	Adult mushroom consumers	0.020	Direct radiation
Torness	Adult root vegetable consumers	0.024	Direct radiation
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.022	Direct radiation, milk
Winfrith	Adult green vegetable consumers	<0.005	Potatoes, root vegetables, green vegetables, milk, domestic fruit, gamma dose rate over sediment, ^{137}Cs
Wylfa	Adult local inhabitants (0 - 0.25km)	0.009	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, freshwater fish, ^{241}Am
Cardiff	Prenatal children of fish consumers	0.011	Fish, ^{3}H, ^{14}C
Chapelcross	Adult occupants over sediment	0.015	Gamma dose rate over sediment
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	'Other' vegetable consumers aged 1 y	0.012	Potatoes, root vegetables, ^{90}Sr, ^{103}Ru
Dungeness	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Prenatal children of mollusc consumers	<0.005	Direct radiation, molluscs,^{14}C
Heysham	Adult occupants over sediment	0.037	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.048	Gamma dose rate over sediment
Hunterston	Adult occupants over sediment	0.009	Gamma dose rate over sediment
Rosyth	Adult crustacean consumers	<0.005	Fish, crustaceans, ^{241}Am
Sellafield and Whitehaven	Adult mollusc consumers	0.44	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Adult fish consumers	<0.005	Direct radiation, fish, ^{241}Am
Trawsfynydd	Prenatal children of occupants over sediment	0.007	Gamma dose rate over sediment, direct radiation, fish, ^{90}Sr
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
C Combined releases 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)	0.22	Direct radiation
Cardiff	Prenatal children of fish consumers	0.011	Fish, ^{3}H, ^{14}C
Chapelcross	Milk consumers aged 1y	0.024	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Milk consumers aged 1y	0.029	Milk, ^{90}Sr, ^{106}Ru, ^{129}I, ^{144}Ce, ^{241}Am

Table A4.2. continued

Site	Critical group	Exposure, mSv	
		Total	Dominant contribution
Dungeness	Local adult inhabitants (0 - 0.25km)	0.55	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Prenatal children of local inhabitants (0 - 0.25km)	0.021	Direct radiation
Heysham	Adult occupants over sediment	0.037	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.048	Gamma dose rate over sediment
Hunterston	Adult mushroom consumers	0.097	Direct radiation
Rosyth	Adult crustacean consumers	<0.005	Fish, crustaceans, ^{241}Am
Sellafield and Whitehaven	Adult mollusc consumers	0.44	Molluscs, ^{210}Po, ^{241}Am
Sizewell	Prenatal children of wild fruit and nut consumers	0.091	Direct radiation
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Adult root vegetable consumers	0.024	Direct radiation
Trawsfynydd	Local inhabitants aged 1 y (0.25 - 0.5km)	0.022	Direct radiation, milk
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult local inhabitants (0.25 - 0.5km)	0.009	Direct radiation

Table A4.3. Trends in total dose from all sources[a]

Site	2003	2004	2005	2006
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005
Amersham		0.24	0.24	0.22
Cardiff	0.038	0.023	0.023	0.011
Chapelcross			0.023	0.024
Devonport		<0.005	<0.005	<0.005
Dounreay	0.012	0.011	0.043	0.029
Dungeness			0.55	0.55
Faslane				<0.005
Hartlepool	0.021	0.021	0.021	0.021
Heysham				0.037
Hinkley				0.048
Hunterston		0.10	0.090	0.097
Rosyth			<0.005	<0.005
Sellafield and Whitehaven	0.71	0.60	0.41	0.44
Sizewell			0.086	0.091
Springfields				0.13
Torness				0.024
Trawsfynydd			0.021	0.022
Winfrith	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.009

[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 2006 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 Emergency Planning, Radiation and Incidents Division, Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by the Scottish Environment Protection Agency and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.environment-agency.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.

Table A5.1. Extramural projects

Topic	Reference	Further details	Target completion date
Transfer of radionuclides into sewage sludge	SC020150	E	Complete
Soil and herbage survey	UKRSR01 and SC000027	E, S	Jun-07
Total diet studies	R03024	F	Mar-07
Discharges to sewer by non-nuclear industry in Scotland	SEPA	S	Sep-07
Tritium transfer from sewage sludge to plants	R01041	F	Sep-07
Availability of technetium-99 to seafood from contaminated sediments	R01062	F	Mar-08
Transfer from seaweed to terrestrial foods	R04003	F	Dec-08
Measurement of radioactivity in canteen meals for Euratom (2005-2008)	R03025	F	Mar-09

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

Radionuclides in Sewage Systems – P3-109A and P3 -109B

In 2006, two research projects on the behaviour of radionuclides in sewage came to completion.

This first report described a set of laboratory experiments designed to provide robust sludge retention factors for using in predicting the partitioning of radionuclides between sludge and treated effluent during sewage treatment (Punt *et al*, in publication, 2007a).

The second report followed the fate of I-131 after discharge to a Sewage Treatment works in South West London (Punt *et al*, in publication, 2007b).

The first study (P3-109A) carried out partitioning experiments on the solid-solution behaviour of a range of radio-elements (Br; Ca; Co; Cu; Fe; Ga; I; In; La; Mn; Ni; P; Re (as an analogue for Tc); S; Sr; Th; U; V; and, Y. These elements were chosen because radioisotopes of these elements are discharged to sewers from a number of non-nuclear establishments in England and Wales and the radiological impact of the discharges can be relatively high. Experiments were carried out to emulate sewage treatment by specialist laboratories using sewage materials sourced from a domestic housing estate. The experiments were designed to assess the partitioning processes likely to occur during sewage transport through the sewer, the transfer to primary solids during primary settlement (Primary Settlement Retention Factor, PSRF), the transfer of tracer to solids during secondary (activated sludge) treatment (the Activated Sludge Retention Factor, ASRF); and the overall Sludge Retention Factor (SRF), likely to be achieved in a typical sewage works.

The second study (P3-109B) assessed iodine-131 activity concentrations in raw sewage, in sewage effluent and sludge cake and in river water and sediment in and around the Hogsmill sewage treatment works. 15.1 GBq of iodine-131 was discharged over three consecutive days in February 2006, leading to concentrations of up to 50 Bq l^{-1} in raw sewage, 20 Bq l^{-1} in treated effluent, 76 Bq l^{-1} in primary sludge, 130 Bq l^{-1} in activated sludge and 1800 Bq kg^{-1} in dewatered sludge. Gamma dose was also detected in river water, river sediment and Thames estuary sediment. Iodine-131 rates were measured and were found to be slightly enhanced relative to background (up to 10 nGy h^{-1}) near the pressed sludge cake.

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

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

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

Scottish Environment Protection Agency
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ENVIRONMENT AND HERITAGE SERVICE
FOOD STANDARDS AGENCY
SCOTTISH ENVIRONMENT PROTECTION AGENCY

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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 2005 unchanged. The main additions are:

- assessment for Dalgety Bay in Fife
- reference is made to a new programme of operator monitoring for particles using large area detectors on beaches at Sellafield
- analyses of samples of food in consignments being imported through Dover and Felixstowe Ports were undertaken because screening equipment detected unusually high results
- ambient air monitoring trials were undertaken at Aldermaston and Dungeness
- special sampling undertaken at nuclear sites where there were unusual short-term increases in discharges and inadvertent releases
- concerns about the environmental effects of contamination from the Litvinenko incident were addressed by sampling of sediments and water for polonium-210
- the *ad hoc* programme of monitoring naturally-occurring radionuclides at Hartlepool was reduced to reflect the restricted nature of the local enhancement in the marine environment
- additional monitoring was undertaken in the River Clyde to check levels of radioactivity due to discharges from non-nuclear sites
- a further five sites have been assessed using a new *Total Dose* assessment methodology. This brings together information on all sources of exposure at nuclear sites, including direct radiation. Currently 20 sites are assessed in this manner and it should be possible to assess all major sites in this way within the next three years
- new charts are provided of trends in dose rates and sediment concentrations in the Irish Sea
- maps of sites and sampling locations have been revised and updated
- more information on the *total dose* from all sources is recorded in the Technical Summary and the main text and tables
- consumption and occupancy rates for critical groups have been updated with the benefit of recent habit survey results at Sellafield, Heysham, Hinkley Point, Springfields, Faslane and Torness
- an assessment of doses to sewage workers at Amersham and Cardiff is included for the first time

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 carried out in areas remote from nuclear sites to establish the general safety of the food chain, drinking water and the environment. Results from this sampling generate data that are used as background levels to compare with results from around nuclear sites and to show the variation in levels across the UK. Levels in the environment can also be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from both past nuclear weapons testing and the nuclear reactor accident in 1986 at Chernobyl in the Ukraine.

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 carried out 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 impacts of the non-nuclear industry at two main sites were studied in 2006. They were at Dalgety Bay, Fife and 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 several small programmes that considered the effects of discharges from non-nuclear sites such as hospitals.

About fifty landfill sites were monitored in England, Scotland and Wales. 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 currently operated by LLW Repository Ltd. at the LLWR at Drigg, in Cumbria. The previous operators were British Nuclear Group (BNG) and then during 2006 the operators were Sellafield Ltd.

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 2006 to investigate the effects of polonium-210 contamination in the environment in relation to the Litvinenko poisoning incident.

Channel Islands, Isle of Man and Northern Ireland

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

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

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

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

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the whole population, rather than to those in the vicinity of particular sources of contamination such as the nuclear industry. This programme provides background information that is useful in interpreting site-related measurements and also helps ensure that all significant sources of contamination form part of the site-related programme. As part of the Total Diet Study (TDS), representative mixed diet samples are collected from towns throughout the UK (see Section 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).

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 2006, 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 Environment and Heritage Service funds analysis of freshwater used for drinking water. These data are sent to the EC under Article 36 of the Euratom Treaty.

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

Seawater surveys

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

2.2 Methods of measurement

There are two basic types of measurement made: (i) 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 carried out on samples vary according to the nature of the radionuclide under investigation. The types of analysis can be broadly categorised in two groups: (i) gamma-ray spectrometry; and (ii) radiochemical methods. The former is a cost-effective method of detecting a wide range of radionuclides commonly found in radioactive wastes and is used for most samples. The latter comprise a range of analyses involving chemical separation techniques to quantify the alpha and beta emitting radionuclides 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).

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

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

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 Ltd. scarried out 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 differences 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 carried out on that part of the sampled material that is normally eaten, for example, the shells of shellfish and the pods of some of the legumes are discarded before analysis. Foodstuff samples are prepared in such a way so as to minimise losses of activity during the analytical stage. Most shellfish samples are boiled soon after collection to minimise losses from the digestive gland. Although some activity may be lost, these generally reflect the effects of the normal cooking process for shellfish. Most other foodstuffs are analysed raw 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 river banks is undertaken using similar instrumentation to that for measurements of dose rates. In England and Wales, a Mini Instruments series 900 mini monitor with a beach monitoring probe is used. The aim is to cover a large area including strand-lines where radioactive debris may become deposited. Any item found with activity levels in excess of the action levels is removed for analysis. An action level of 100 counts per second (equivalent to 0.01 mSv h^{-1}) is used in England and Wales. 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 2006 as well as the mean value. The maximum is labelled 'max' in the tables and forms the basis for the assessment of dose.

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

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

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

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

2.4 Detection limits

There are two main types of results presented in the tables (i) positive values and (ii) values preceded by a 'less than' symbol ("<"). Where the results are 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 2006. 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 carried out 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 is currently revising its recommendations and has undertaken a consultation process on its proposals. The final draft has now been approved for publication. The documents, which provide the foundation for the system of protection, can be viewed at www.icrp.org. The implications concerning EU and UK radiation protection standards will be taken into account in future issues of this report.

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

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

As discussed in last year's RIFE report, the Codex Alimentarius Commission (CAC) has been producing revised guideline levels for radionuclides in foods following accidental 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. The Environment Agencies have completed initial assessments using the methods and data in Copplestone *et al*. (2001). Further research is being undertaken to provide methods and data to enable more complete and systematic assessments to be made in the UK (Commission of the European Communities, 2004). The initial assessments have shown that, for important habitats in England and Wales such as Special Areas of Conservation SAC and Special Protection Areas SPA, for all but one of these sites there are no adverse effects on the integrity of the sites from authorised discharges of radioactive substances. The one exception is the Ribble estuary where the assessed dose is 690 μGy h^{-1} in excess of the assessment threshold of 40 μGy h^{-1}. The Environment Agency is considering what action, if any, is required. SEPA undertook a Pressures and Impacts Assessment on Scotland's Water Environment from radioactive substances. The report concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data from some locations to support this conclusion. The report is available from http://www.sepa.org.uk/pdf/publications/technical/ wfd_Assessment_pressures_impacts.pdf

3.2 Assessment methods

Calculations of exposures of members of the public from waste disposals are primarily based on the environmental monitoring data for 2006 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 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 Heysham, Hinkley Point, Springfields, Sellafield, Faslane and Torness in 2006. 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 is introduced routinely for the first time this year following the publication of recommendations by the National Radiological Protection Board in 2005 (National Radiological Protection Board, 2005). We have assumed that a member or members of the adult critical group is/are pregnant in order for the dose assessment of the embryo and 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 (Stephen, 2006; Bunker, 2007).

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} (wet)),
F_m is the fraction of the animal's daily intake by ingestion transferred to milk (d 1^{-1})
F_f is the fraction of the animal's daily intake by ingestion transferred to meat or offal (d kg^{-1} (wet)),
Ca is the concentration in fodder (Bq kg^{-1} (dry)),
Q_f is the amount of fodder eaten per day (kg (dry) d^{-1})

No direct account is taken of radionuclide decay or the intake by the animal of soil associated activity. The concentration in fodder is assumed to be the same as the maximum observed concentration in grass, or in the absence of such data, in leafy green vegetables. The food chain data for the calculations are given in Table A1.1 (Simmonds *et al.,* 1995; Brenk *et al.,* unpublished) and the estimated concentrations in milk, meat and offal are presented in Table A1.2.

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.

An assessment of doses from non-food pathways arising from discharges to air has been made around the operating Magnox power stations Dungeness A, Oldbury, Sizewell A and Wylfa, from Sellafield and GE Healthcare at Amersham and at Cardiff. For the power stations, discharges of argon-41 to air are significant whilst the reactors are operating. Argon-41 is a noble gas with a short radioactive half-life of about 1.8 h. It does not become incorporated into food produce, but people working or living within the plume may be exposed to external radiation from argon-41 as it disperses downwind of the discharge point. Inhalation of other radionuclides downwind of the discharge point has also been assessed.

Average annual concentrations of radionuclides in the air at nearest habitations were calculated using a Gaussian plume model, PC CREAM (Mayall et al., 1997), and the reported discharges of radionuclides to air. Site-specific meteorological data were used in the assessments. The key modelling assumptions (i.e. discharge height, habitations) are shown in Table A1.3.

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. Adults and infants are assumed to have year-round occupancy at the nearest habitation, whilst children are assumed to spend time away at school. The inhalation and occupancy rates assumed in this assessment are shown in Table A1.4. The dose to the fetal age group was taken to be the same as that for an adult. The predicted concentrations of radioactivity in air are given in Tables A1.5 and A1.6.

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 (2006q). 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% of a working year in proximity to the raw sewage, and the other 25% 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 A1.7, and the amounts of radioactivity discharged from each site can be found in Appendix 2 of the main report.

Predicted concentrations of radioactivity in raw sewage and sludge at Amersham (Maple Lodge STW) and Cardiff (WWTW), based on 2006 liquid discharges, have been calculated and are given in Table A1.8.

Table A1.1. 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 A1.2. Predicted concentrations of radionuclides from food chain model used in assessments of exposures

Foodstuff	Location	Radioactivity concentration (wet weight), Bq kg^{-1}			
		^{99}Tc	^{106}Ru	^{144}Ce	^{241}Pu
Milk	Sellafield	[a]	$2.06\ 10^{-4}$	[b]	$7.26\ 10^{-6}$
	Ravenglass	[a]	$3.06\ 10^{-4}$	$3.67\ 10^{-3}$	$1.21\ 10^{-5}$
	Drigg	[a]	$3.47\ 10^{-4}$	$4.77\ 10^{-3}$	$8.88\ 10^{-6}$
	Isle of Man	[a]	$2.25\ 10^{-4}$	$2.43\ 10^{-3}$	$5.72\ 10^{-6}$
Beef	Sellafield	[a]	$2.06\ 10^{-1}$	[b]	$7.26\ 10^{-4}$
	Ravenglass	[a]	$3.06\ 10^{-1}$	$1.84\ 10^{-1}$	$1.21\ 10^{-3}$
	Drigg	$1.97\ 10^{-1}$	$3.47\ 10^{-1}$	$2.38\ 10^{-1}$	$8.88\ 10^{-4}$
	Isle of Man	$5.72\ 10^{-2}$	$2.25\ 10^{-1}$	$1.21\ 10^{-1}$	$5.72\ 10^{-4}$
Lamb	Sellafield	[a]	$2.38\ 10^{-1}$	[b]	$3.35\ 10^{-4}$
	Ravenglass	[a]	$3.53\ 10^{-1}$	$2.12\ 10^{-1}$	$5.58\ 10^{-4}$
	Drigg	[a]	$4.00\ 10^{-1}$	$2.75\ 10^{-1}$	$4.10\ 10^{-4}$
	Isle of Man	$6.60\ 10^{-2}$	$2.60\ 10^{-1}$	$1.40\ 10^{-1}$	$2.64\ 10^{-4}$
Beef offal	Sellafield	[a]	$2.06\ 10^{-1}$	[b]	$1.45\ 10^{-1}$
	Ravenglass	[a]	$3.06\ 10^{-1}$	[a]	[a]
	Drigg	$7.89\ 10^{-2}$	$3.47\ 10^{-1}$	$4.77\ 10^{1}$	$1.78\ 10^{-1}$
	Isle of Man	$2.29\ 10^{-1}$	$2.25\ 10^{-1}$	$2.43\ 10^{1}$	$1.14\ 10^{-1}$
Lamb offal	Sellafield	[a]	$2.38\ 10^{-1}$	[b]	$2.51\ 10^{-2}$
	Ravenglass	[a]	$3.53\ 10^{-1}$	[a]	[a]
	Drigg	[a]	$4.00\ 10^{-1}$	[a]	[a]
	Isle of Man	$2.64\ 10^{-1}$	$2.60\ 10^{-1}$	$2.80\ 10^{1}$	$1.98\ 10^{-2}$

[a] *Positive result used, or LoD result used because modelling result greater than LoD*
[b] *No grass or LGV or data available*

Table A1.3. Air concentration modelling assumptions

Nuclear site	Stack height, m	Exposure location	Distance to exposure location, m	Bearing to exposure location
Amersham	20	Dwelling	250	
Cardiff	20	Dwelling	400	270°
Dungeness	17	Dwelling	300	70°
Oldbury	20	Farm	700	90°
Sizewell	18	Dwelling	300	180°
Sellafield	93	Farm	1200	900°
Wylfa	17	Farm	500	110°

Table A1.4. Inhalation and occupancy data for dose assessment of discharges to air

Age group, y	Inhalation rates, $m^3 h^{-1}$	Occupancy at exposure location, $h y^{-1}$	Fraction of time indoors
Amersham, Cardiff, Dungeness and Sizewell (dwellings)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.7
Oldbury, Sellafield and Wylfa (farm locations)			
1	0.22	8760	0.9
10	0.64	7500	0.8
Adult	0.92	8760	0.5

Table A1.5. Predicted concentrations of radionuclides in air at highest exposure locations in the vicinity of Magnox power stations and Cardiff

Site	Radioactivity concentration in air, $Bq m^{-3}$								
	Tritium	^{14}C	^{32}P	^{35}S	^{41}Ar	^{60}Co	^{85}Kr	^{125}I	^{131}I
Cardiff	9.0	0.16	$7.3\ 10^{-8}$					$4.2\ 10^{-6}$	
Dungeness	0.6	0.48		$1.3\ 10^{-2}$	$2.4\ 10^{2}$	$3.9\ 10^{-5}$			$2.5\ 10^{-7}$
Oldbury	0.1	$5.2\ 10^{-2}$		$2.4\ 10^{-3}$	1.1	$8.2\ 10^{-7}$			
Sizewell	0.18	0.11		$9.2\ 10^{-3}$	$1.4\ 10^{2}$	$1.7\ 10^{-5}$	0.20		$2.5\ 10^{-5}$
Wylfa	$9.7\ 10^{-2}$	$4.7\ 10^{-2}$		$5.9\ 10^{-3}$	0.53	$1.3\ 10^{-6}$			

Table A1.6. Predicted concentrations of radionuclides in air at most exposed location in vicinity of Amersham and Sellafield

Radionuclide	Radioactivity concentration in air, $Bq m^{-3}$	
	Amersham	Sellafield
Tritium	$7.1\ 10^{-8}$	0.38
Carbon-14		$1.4\ 10^{-3}$
Sulphur-35	$5.2\ 10^{-4}$	
Cobalt-60		
Selenium-75	$1.4\ 10^{-5}$	
Krypton-85		$4.6\ 10^{1}$
Strontium-90	$3.6\ 10^{-6}$	$9.7\ 10^{-8}$
Ruthenium-106		$3.2\ 10^{-6}$
Antimony-125		$3.1\ 10^{-7}$
Iodine-125	$7.7\ 10^{-5}$	
Iodine-129		$1.3\ 10^{-5}$
Iodine-131	$3.0\ 10^{-5}$	$1.3\ 10^{-6}$
Xenon-133	1.1	
Caesium-137	$3.9\ 10^{-5}$	$1.2\ 10^{-6}$
Radon-222	0.19	
Plutonium-239		$5.3\ 10^{-8}$
Plutonium-241		$4.6\ 10^{-7}$
Americium-241	$8.0\ 10^{-9}$	$5.1\ 10^{-8}$

Table A1.7. 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]
Inadvertent ingestion rate, $kg\ h^{-1}$		$5\ 10^{-6}$ [d]
Inhalation rate, $m^3\ h^{-1}$		1.2 [d]
Airborne concentration of sewage or sludge, $kg\ m^{-3}$		$1\ 10^{-7}$ [d]
Density of raw sewage and treated sludge, $kg\ l^{-1}$		1 [d]

[a] *Based on average flow rate of 1.8 $m^3\ s^{-1}$ (Jobling et al., 2006)*
[b] *Based on an average flow rate of 0.3 $m^3\ s^{-1}$; this has been derived as 5% of the maximum flow rate at the works (McTaggart, 2003)*
[c] *A working year is assumed to be 40 hours per week and 48 weeks per year*
[d] *Parameter values used in Environment Agency (2006r) methodology*

Table A1.8. Predicted concentrations of radionuclides in raw sewage and sludge at Amersham and Cardiff

Radioactivity	Composition[a]	Radioactivity concentrations, $Bq\ l^{-1}$	
		Sewage	Sludge
Amersham			
Tritium (OBT)		$1.3\ 10^{-2}$	0.19
Iodine-125		$1.1\ 10^{-3}$	$1.9\ 10^{-2}$
Caesium-137		$2.8\ 10^{-4}$	$8.4\ 10^{-3}$
Alpha	Americium-241	$2.3\ 10^{-4}$	$2.0\ 10^{-2}$
Beta >0.4 MeV	50% Phosphorus-32	$2.7\ 10^{-3}$	0.12
	50% Strontium-89	$2.7\ 10^{-3}$	$2.3\ 10^{-2}$
Other radionuclides	50% Thallium-201	$5.3\ 10^{-2}$	0.46
	35% Sulphur-35	$4.0\ 10^{-2}$	0.36
	10% Zinc-65	$1.1\ 10^{-2}$	0.55
	5% Cobalt-57	$5.7\ 10^{-3}$	0.44
Cardiff			
Tritium (OBT)		$2.6\ 10^3$	$3.9\ 10^4$
Carbon-14		30	$4.5\ 10^2$
Phosphorus-32		$1.2\ 10^{-4}$	$5.6\ 10^{-3}$
Iodine-125		$2.0\ 10^{-4}$	$3.4\ 10^{-3}$
Other radionuclides	Sulphur-35	$1.9\ 10^{-5}$	$1.8\ 10^{-4}$

[a] *Based on GE Healthcare impact assessment composition (Shackleton, 2007)*

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 A2.1. 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 A2.2. 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 A2.1. Consumption rates for terrestrial foods

Food Group	Consumption rates (kg y^{-1})					
	Average			Above average consumption rate*		
	Adult	10 year old	Infant	Adult	10 year old	Infant
Beef	15	15	3	45	30	10
Cereals	50	45	15	100	75	30
Eggs	8.5	6.5	5	25	20	15
Fruit	20	15	9	75	50	35
Game	6	4	0.8	15	7.5	2.1
Green Vegetables	15	6	3.5	45	20	10
Honey	2.5	2	2	9.5	7.5	7.5
Sheep	8	4	0.8	25	10	3
Legumes	20	8	3	50	25	10
Milk	95	110	130	240	240	320
Mushrooms	3	1.5	0.6	10	4.5	1.5
Nuts	3	1.5	1	10	7	2
Offal	5.5	3	1	20	10	5.5
Pig	15	8.5	1.5	40	25	5.5
Potatoes	50	45	10	120	85	35
Poultry	10	5.5	2	30	15	5.5
Root crops	10	6	5	40	20	15
Wild fruit	7	3	1	25	10	2

* *These rates are the 97.5th percentile of the distribution across all consumers*

Table A2.2. Consumption, inhalation, handling and occupancy rates for aquatic pathways

Site (Year of last survey)	Group[a]	Rates
Aldermaston (2002)	A	1 kg y^{-1} pike
		320 h y^{-1} over riverbank
	B	1.2 kg y^{-1} crayfish
Amersham (2004)		1 kg y^{-1} pike
		630 h y^{-1} over riverbank
Berkeley and Oldbury (2001)		18 kg y^{-1} salmonids and other fish
		2.3 kg y^{-1} shrimps
		520 h y^{-1} over mud
Bradwell	A (1999)	44 kg y^{-1} fish
		3.1 kg y^{-1} crabs and lobsters
		6.5 kg y^{-1} Pacific oysters and winkles
		2900 h y^{-1} over mud
	B (NA)	300 h y^{-1} over sediment
Capenhurst (NA)	10 year old children	500 h y^{-1} over sediment
		5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		20 l y^{-1} water by inadvertent ingestion
Cardiff	A (2003)	24 kg y^{-1} fish
		3.8 kg y^{-1} prawns and lobster
		500 h y^{-1} over mud
	B (NA)	500 h y^{-1} over bank of the River Taff
		2.5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		34 l y^{-1} water by inadvertent ingestion
	C (2003)	5.6 kg y^{-1} wildfowl
Channel Islands (1997)		62 kg y^{-1} fish
		30 kg y^{-1} crabs, spider crabs and lobsters
		30 kg y^{-1} scallops and whelks
		1400 h y^{-1} over mud and sand
Chapelcross (2005)	A	31 kg y^{-1} salmonids
		950 h y^{-1} over mud
	B	450 h y^{-1} over salt marsh
		19 kg y^{-1} wildfowl
	C	390 h y^{-1} handling nets
		610 h y^{-1} handling sediment
Culham (NA)		600 l y^{-1} water
Derby (NA)		600 l y^{-1} water
Devonport (2004)	A	32 kg y^{-1} fish
		3.5 kg y^{-1} crabs, prawns and shrimps
		1.7 kg y^{-1} scallops
		980 h y^{-1} over sediment and shale
	B	2000 h y^{-1} over mud
Dounreay (2003)	A	1500 h y^{-1} handling fishing gear
	B	30 kg y^{-1} fish
		8.9 kg y^{-1} crab and lobster
		0.5 kg y^{-1} mussels and winkles
	C	410 h y^{-1} over rock and sand
	D	8 h y^{-1} in a Geo
Drigg (NA)		35 l y^{-1} water
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (2005)	A	51 kg y^{-1} fish
		9.3 kg y^{-1} crabs and shrimps
		17 kg y^{-1} king scallops
		1500 h y^{-1} over mud and sand
	B (Rye Harbour houseboats)	2000 h y^{-1} over mud

Table A2.2. continued

Site	Group[a]	Rates
Faslane (2006)		0.17 kg y^{-1} mussels
		19 kg y^{-1} fish
		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 (1991)		1 kg y^{-1} pike
		650 h y^{-1} over river bank
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 (2001)	A	29 kg y^{-1} fish
		22 kg y^{-1} Nephrops and squat lobsters
		2 kg y^{-1} queen scallops
	B	1200 h y^{-1} over mud and sand
Landfill		1.5 l y^{-1} water
Rosyth (2005)	A	31 kg y^{-1} fish
		28 kg y^{-1} crabs and lobsters
	B	14 kg y^{-1} winkles and mussels
		730 h y^{-1} over sediments
Sellafield	A (Sellafield fishing community) (2006)	41 kg y^{-1} cod (60%) and other fish (40%)
		20 kg y^{-1} crab (60%), lobster (20%) and *Nephrops* (20%)
		40 kg y^{-1} winkles (50%) and other molluscs (50%)
		580 h y^{-1} over mud and sand
	B (Fishermen's nets and pots) (2003)	730 h y^{-1} handling nets and pots
	C (Bait digging and mollusc collecting) (2003)	1000 h y^{-1} handling sediment
	D (Whitehaven commercial) (1998)	40 kg y^{-1} plaice and cod
		9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	E (Morecambe Bay)	See Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	G (Dumfries and Galloway) (2002)	43 kg y^{-1} fish
		20 kg y^{-1} Nephrops, crab and lobster
		11 kg y^{-1} whelks and king scallop
		700 h y^{-1} over mud and sand
	H (Laverbread) (1972)	47 kg y^{-1} laverbread
	I (Trout) (NA)	6.8 kg y^{-1} rainbow trout
	J (Typical fish consumer) (NA)	15 kg y^{-1} cod and plaice
	K (Isle of Man) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	L (Northern Ireland) (2000)	99 kg y^{-1} haddock and other fish
		34 kg y^{-1} Nephrops and crabs
		7.7 kg y^{-1} mussels and other molluscs
		1100 h y^{-1} over mud and sand
	M (North Wales) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
		300 h y^{-1} over mud and sand

Table A2.2. continued

Site	Group[a]	Rates
Sellafield	N (Sellafield fishing community 2002-2006) (NA)	43 kg y^{-1} fish 13 kg y^{-1} crabs 5.1 kg y^{-1} lobsters 3.7 kg y^{-1} Nephrops 18 kg y^{-1} winkles 16 kg y^{-1} other molluscs 890 h y^{-1} over mud and sand
	O (Ravenglass recreational use) (NA)	300 h y^{-1} over mud and sand 1.5 10^{-3} kg y^{-1} mud and sand by inadvertent ingestion 2.76 10^{-5} kg y^{-1} mud and sand by resuspension and inhalation
	P (Typical beach user) (NA) Q (Ravenglass nature warden) (2003)	30 h y^{-1} over sand 400 h y^{-1} over salt marsh 2.0 10^{-3} kg y^{-1} mud by inadvertent ingestion 3.7 10^{-5} kg y^{-1} mud by resuspension and inhalation
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)	390 h y^{-1} handling nets
	C (Ribble Estuary houseboats) (2002-2006) (NA)	2200 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 inadvertent 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 A3.1 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 and cockles suggested a factor in the range 0.30 to 0.61 and 0.15 to 0.57 respectively, close to the ICRP value of 0.5 (Hunt and Rumney, 2004 and 2005). Further experiments are planned and until the outcome of these is assessed, estimates of the exposures due to polonium intake have been calculated using the conservative assumption that a factor of 0.8 applies to all seafood except molluscs where specific data suggests 0.5 is more appropriate. We have retained a factor of 0.5 for other food.

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 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 higher than the standard ICRP value for OBT ingestion. After publication of the work the HPA advised that the revised dose coefficients were not significantly different to the ICRP values. Therefore the assessments made using ICRP values were reasonable estimates of dose for fish consumption in the Cardiff area. However, the availability of dose coefficients specific to fish from the area around Cardiff it is appropriate that the specific values should be used in assessments of dose. HPA also recommended that the specific dose coefficients are used for all ingestion intakes that might arise from the same source of exposure.

Table A3.1. 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 A3.1. 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 A4.1 gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis carried out by Cefas (Young *et al.,* 2002 and unpublished studies). Data for lead-210 and polonium-210 are from a detailed study and are quoted as medians with minimum and maximum values given in brackets. Dose assessments for aquatic foodstuffs are based on activity concentrations of these radionuclides net of natural background.

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 A4.2 (MAFF, 1995).

Table A4.1. Concentrations of radionuclides in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (fresh))									
	Fish	Crustaceans	Crabs	Lobsters	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	23	27			23					
Lead-210	0.042 (0.0030-0.55)	0.02 (0.013-2.4)	0.24 (0.043-0.76)	0.080 (0.02-0.79)	1.2 (0.18-6.8)	1.5 (0.69-2.6)	1.6 (0.68-6.8)	0.94 (0.59-1.3)	0.39 (0.18-0.61)	1.5 (0.68-4.9)
Polonium-210	0.82 (0.18-4.4)	9.1 (1.1-35)	19 (4.1-35)	5.3 (1.9-10)	17 (1.2-69)	13 (6.1-25)	42 (19-69)	18 (11-36)	6.5 (1.2-11)	8.4 (5.9-15)
Radium-226	0.04	0.03	0.03	0.06	0.08	0.08				
Thorium-228	0.0054	0.0096	0.04	0.0096	0.37	0.46		0.37		
Thorium-230	0.00081	0.0026	0.008	0.0026	0.19	0.26		0.19		
Thorium-232	0.00097	0.0014	0.01	0.0014	0.28	0.33		0.28		
Uranium-234	0.0045	0.040	0.055	0.040	0.99	0.99				
Uranium-238	0.0039	0.035	0.046	0.035	0.89	0.89				

Table A4.2. 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