

Radioactivity in Food and the Environment, 2009



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

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Preface

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

This report gives a detailed assessment of radioactivity in food and the environment in the UK and the public's exposure to radiation during 2009. Radioactivity in the environment comes from several sources, including radioactive discharges from both nuclear and non-nuclear sites, residues from the Chernobyl accident and atmospheric weapons testing, plus natural radioactivity. The report focuses on key information that shows that radioactivity within food is well within safe levels and that the public's exposure to authorised discharges and direct radiation around the 39 nuclear sites around the UK is within legal limits.

Radionuclide concentrations in food and the environment at many sites were low, and in some cases so low that they could not be detected with the methods used. These low concentrations continue to decrease at many sites as a result of reductions in discharges to the environment. For example, the trend of tritium measured in seafood around Cardiff continued to fall in 2009, from the highest concentrations seen in 2001, due to reductions in liquid discharges of organically-bound tritium which concentrates in the environment. Having previously met the target set in the UK National Discharges Strategy for 2006, discharges of technetium-99 from Sellafield have remained at the low levels achieved. Indeed, the 2009 results show that the discharges from the nuclear sector in the UK continue to be lower than in the past, and that the UK is contributing to the progress towards the OSPAR objective of reducing discharges to the NE Atlantic.

Building on the information derived from the last five RIFE reports (RIFE 10-14), the environment agencies and Food Standards Agency have published a RIFE review report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010). This report "Summary of Radioactivity in Food and the Environment 2004-2008" provides an overview of recent trends in data over this five year period. The report primarily focuses on time trends associated with radiation exposure (doses) to people living around nuclear sites, disposals of radioactive waste (discharges)

to air and water, and radionuclide activity (concentrations) in samples collected around nuclear sites.

During 2009, the Environment Agency, SEPA and Food Standards Agency continued the development of their Environmental Monitoring Guidance document for radioactivity. Guidance is given on planning and implementing routine environmental radiological monitoring programmes, and on objectives and principles for monitoring programmes. It is aimed at operators and regulators, and will provide clarity for these organisations on the monitoring roles. The document also describes the process for defining monitoring programmes, including stakeholder engagement. Technical review with stakeholders on the guidance document will take place during 2010.

In 2009, the UK Government and the Devolved Administrations published their revised UK Strategy for Radioactive Discharges. The scope of the Strategy is now wider and includes gaseous as well as liquid discharges from both decommissioning and operational activities and from the non-nuclear as well as the nuclear industry sectors. It also provides a framework for discharge reductions across sectors and describes how the UK will implement its agreed commitments in the OSPAR Radioactive Substances Strategy. The revised UK Strategy shows the progress that has been made in reducing discharges since the original Strategy was published in 2002 and describes sectoral outcomes which are expected to be achieved by 2020 and 2030. Regulators, together with the nuclear and non-nuclear industries, will consider the revised UK Strategy for Radioactive Discharges when they take operational decisions.

As older power stations have closed down and new treatment plants have opened, this has reduced radionuclide discharges and subsequent concentrations in the environment. Before 2009, nine of the eleven Magnox power stations (the first generation of nuclear power stations in the UK) had been permanently closed. This left the Oldbury and Wylfa Magnox reactors and the eight British Energy nuclear power stations operating at the start of 2009.

During 2009, the Health & Safety Executive and the Environment Agency continued to assess the designs of potential new nuclear power stations. The assessment process, called "Generic Design Assessment" (GDA), allows the safety, security and environmental implications of new power station designs to be assessed and is carried out before an application is made to build that design at any particular site. The designs being assessed are the AP1000 (Westinghouse) and UK-EPR (EDF and AREVA) nuclear plant designs. In June 2010, the Environment Agency began public consultation on the outcome of its assessments. The radiological monitoring results reported

in the RIFE report series will provide a baseline against which future discharges from any new nuclear power stations can be judged.

At certain sites the environment agencies and the Food Standards Agency undertook or required the site operators to undertake detailed investigations. For instance, the monitoring and removal of particles containing radioactivity has continued on beaches around Dounreay, Chapelcross and Dalgety Bay in Scotland. Recovery of particles has also taken place from the seabed around Dounreay. The Food Standards Agency has recently published a review of the Food and Environment Protection Act (FEPA) Order at Dounreay, which has been in place since 1997. This concluded that the Order should remain in place to facilitate the remediation of the area. The Environment Agency has required Sellafield Limited to use up-to-date monitoring equipment to check for particles containing enhanced concentrations of radioactivity

on beaches near the site. The programme has continued since 2007. Particles have been found and removed, and further investigated. Sellafield Limited is also preparing to investigate particle distributions offshore. The Health Protection Agency has offered initial advice that, based on the particles recovered near Sellafield so far, no special precautionary measures or interventions is necessary. The Health Protection Agency has continued to monitor the situation, and will report in 2010 on a detailed assessment of the health risks from particles on the beaches in the vicinity of the Sellafield site.

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 authorised discharges from nuclear licensed sites do not pose a significant risk to public health and that all public radiation doses remain within legal limits.

Technical summary

We have divided the technical summary into sections to highlight the main topics within the report. These are:

- Radiation exposures (doses) to people living around nuclear sites
- Radioactivity concentrations in samples collected around nuclear sites
- External dose rates as a result of exposure to radiation from sediments, etc.
- Site incidents and non-routine surveys
- Radiation exposures and radioactivity concentrations at other UK locations not associated with nuclear sites

Radiation exposure around nuclear sites

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

Figure S.1 and Table S.1 show the assessed doses due to the effects of authorised waste discharges for those groups most exposed to radiation near all major nuclear licensed sites in the UK. In 2009, radiation doses to adults and children living around nuclear sites remained well below the national and European limit, which is 1 millisievert (mSv, a measure of dose) per year (see Appendix 3 for explanation of reference to dose).

A small number of people in Cumbria who consumed a large amount of fish and shellfish received the highest dose of radiation due to discharges. Their dose was estimated to be 0.38 mSv in 2009, which was well within the EU and UK limit for members of the public of 1 mSv per year. This dose was due to the effects of current and past liquid discharges from Sellafield and from past liquid discharges from a phosphate processing plant at Whitehaven. Sellafield discharges were estimated to have contributed 0.20 mSv to this dose in 2009, a reduction of 0.03 mSv from the 0.23 mSv reported in 2008 (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. The reduction in dose was largely due to the reduction in mollusc consumption rates. Doses from technetium-99 have been falling for several years as a result of decreasing discharges

from Sellafield. In 2009, technetium-99 in seafood contributed 0.002 mSv (about 1 per cent) to the 0.20 mSv dose, a reduction from 0.003 mSv in 2008.

Most liquid radioactive discharges from Sellafield have fallen in recent years. Concentrations of some radionuclides in fish and shellfish have also reduced or are unchanged. Some people in the area have consumed more fish and shellfish since 2000, which has led to an increase in doses, but this trend was not seen in 2009.

As well as the radiation exposure from Sellafield discharges, the people who consumed seafood also received a dose of 0.18 mSv in 2009 from the legacy of past discharges from a phosphate processing works at Whitehaven (which was decommissioned in 2002). This was a man-made practice that generated what is sometimes known as 'technologically enhanced naturally-occurring radioactive material' (TNORM). Where discharges of TNORM occur, this can lead to an increase in the concentrations of naturally-occurring radionuclides in the environment. Near Whitehaven, concentrations of TNORM have fallen in recent years, and so it is now difficult to distinguish between the total naturally-occurring radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. However, using an approach based on average concentrations, small increases of some naturally-occurring radionuclides (in particular polonium-210) are observed above expected concentrations from naturally sourced radioactivity. The dose from naturally-occurring radionuclides in 2009 was 0.18 mSv, and this was lower than the dose of 0.39 mSv in 2008. The reduction was due to decreases in polonium-210 concentrations in seafood in 2009. Doses to people who had consumed crops grown on land fertilised by seaweed from around Sellafield were also assessed. Their estimated dose for 2009 was 0.009 mSv, the same as in 2008. Doses to people using the local beaches and other intertidal areas were less than 0.048 mSv. Doses due to gaseous discharges from Sellafield were much lower than those from liquid discharges, at 0.028 mSv in 2009, and similar to the dose of 0.027 mSv in 2008. The majority of this dose was from consumption of milk. This assessment of dose from gaseous discharges was supplemented by modelling air concentrations.

In terms of radiation exposure from waste discharges, the second highest dose was received by people living on houseboats in the Ribble Estuary. In 2009, their dose was 0.13 mSv. Most of this exposure was due to external dose from radionuclides from Sellafield deposited in intertidal sediments. Their dose in 2008 was the same.

The people most affected in terms of exposure to radiation from waste discharges in Scotland were those on the Dumfries



Figure S1. Radiation exposures in the UK due to radioactive waste discharges, 2009 (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, 2009

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 Terrestrial foods ⁱ	L G	0.012 <0.005	Ext ²³⁸ U
Springfields	External (skin) to fishermen Fish and shellfish consumption Terrestrial foods, external and inhalation near site External in intertidal areas (children playing) ^{g,a} Occupancy of houseboats External in intertidal areas (farmers and wildfowlers)	L L G L L L	0.062 ^f 0.022 <0.005 ^h <0.005 0.13 0.036	Beta Ext ²⁴¹ Am ²³⁴ U Ext ²⁴¹ Am Ext Ext
Sellafield ^e	Fish and shellfish consumption and external in intertidal areas (2005-2009 surveys) (excluding naturally occurring radionuclides) ^k Fish and shellfish consumption and external in intertidal areas (2005-2009 surveys) (including naturally occurring radionuclides) ^l Fish and shellfish consumption and external in intertidal areas (2009 surveys) (excluding naturally occurring radionuclides) ^k Terrestrial foods, external and inhalation near Sellafield Terrestrial foods at Ravenglass ^l External in intertidal areas (Ravenglass) ^a Occupancy of houseboats (Ribble estuary) External (skin) to bait diggers Handling of fishing gear Porphyra/laverbread consumption in South Wales Seaweed/crops at Sellafield	L L L G G/L L L L L L L	0.20 0.38 0.19 0.028 0.012 0.048 0.13 0.043 ^f 0.061 ^f <0.005 0.009	^{239/240} Pu ²⁴¹ Am ²¹⁰ Po ²⁴¹ Am ^{239/240} Pu ²⁴¹ Am ⁹⁰ Sr ¹³⁷ Cs ⁹⁰ Sr Ext ²⁴¹ Am Ext Beta Beta ²⁴¹ Am
Research establishments				
Culham	Water consumption ⁿ	L	<0.005	
Dounreay	Fish and shellfish consumption and external in intertidal areas Terrestrial foods ⁱ	L G	0.011 0.029	Ext ²⁴¹ Am
Harwell	Fish consumption and external to anglers Terrestrial foods, external and inhalation near site ⁱ	L G	0.006 <0.005	Ext ²²² Rn
Winfrith	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ^o	L G	<0.005 <0.005	Ext ²⁴¹ Am ¹⁴ C ¹³⁷ Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	0.025 <0.005	Ext ²⁴¹ Am ¹⁴ C ³⁵ S
Bradwell	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ^o	L G	<0.005 <0.005	Ext ²⁴¹ Am ¹⁴ C
Chapelcross	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	0.024 0.009	Ext ¹⁴ C ⁹⁰ Sr
Dungeness	Fish and shellfish consumption and external in intertidal areas Occupancy of houseboats Terrestrial foods, external and inhalation near site ⁱ	L L G	0.012 0.014 0.005	Ext ²⁴¹ Am Ext ¹⁴ C
Hartlepool	External in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	0.014 <0.005	Ext ³⁵ S
Heysham	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	0.041 0.005	Ext ¹³⁷ Cs ¹⁴ C
Hinkley Point	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	0.046 <0.005	Ext ²⁴¹ Am ³⁵ S
Hunterston	Fish and shellfish consumption Terrestrial foods, external and inhalation near site ⁱ	L G	0.006 0.007	Ext ²⁴¹ Am ³⁵ S ⁹⁰ Sr
Sizewell	Fish and shellfish consumption and external in intertidal areas Terrestrial foods, external and inhalation near site ⁱ	L G	<0.005 <0.005	Ext ²⁴¹ Am ¹⁴ C ³⁵ Cs

Summary Table S1. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source ^d	Exposure, mSv ^b per year	Contributors ^c
Nuclear power production <i>continued</i>				
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	¹³⁷ Cs ²⁴¹ Am ⁹⁰ Sr
	Terrestrial foods, external and inhalation near site ⁱ	G	0.005	
Trawsfynydd	Fish consumption and external to anglers	L	0.011	¹³⁷ Cs ²⁴¹ Am ¹⁴ C ⁹⁰ Sr
	Terrestrial foods, external and inhalation near site ⁱ	G	<0.005	
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ²⁴¹ Am ¹⁴ C ³⁵ S
	Terrestrial foods, external and inhalation near site ⁱ	G	<0.005	
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005 ^h	Ext ¹³⁷ Cs
	Terrestrial foods, external and inhalation near site ⁱ	G	<0.005 ^h	
Derby	Water consumption, fish consumption and external to anglers ⁿ	L	<0.005	Ext U
	External and inhalation near site	G	<0.005	
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ¹⁴ C
	Terrestrial foods, external and inhalation near site ^o	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ¹³⁷ Cs
Rosyth	Fish and shellfish consumption	L	<0.005	Ext ¹³⁷ Cs
	Shellfish consumption and external in intertidal areas	L	<0.005	
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext ¹³⁷ Cs ²²² Rn
	Terrestrial foods, external and inhalation near site ⁱ	G	0.016	
Cardiff	Fish and shellfish consumption and external in intertidal areas ^o	L	0.009	Ext ³ H ¹⁴ C ³² p Ext
	Terrestrial foods, external and inhalation near site ⁱ	G	0.008	
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	
Industrial and landfill				
LLWR near Drigg	Terrestrial foods ⁱ	G	0.013	⁹⁰ Sr
	Water consumption ⁿ	L	<0.005	
Whitehaven	Fish and shellfish consumption ^j	L	0.18	²¹⁰ Po ²¹⁰ Pb ²¹⁰ Po ²⁴¹ Am
	Fish and shellfish consumption ^m	L	0.38	

^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 LLWR. The contribution due to LLWR 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

and Galloway coast who consumed large quantities of seafood. It was estimated that they received 0.047 mSv in 2009, the same as in 2008. Most of this dose was due to americium-241 and plutonium in shellfish, originating from Sellafield.

Relatively high concentrations of tritium have previously been found in food and the environment near GE Healthcare's Maynard Centre, at Cardiff, where radiochemicals for life science research are produced. In 2009, the most exposed people were represented by unborn children of women who had eaten seafood, with an estimated dose of 0.009 mSv. Their dose in 2008 was 0.012 mSv. The dose was due to eating fish from the Severn Estuary that contained tritium and carbon-14. There was also a contribution to this dose from external radiation (0.006 mSv) that was not derived from operations at the Maynard Centre. The dose to adults was similar to that of unborn children at 0.008 mSv. Doses at this site have been steadily falling since 2000 in line with lower discharges.

The gaseous discharge limit for antimony-125 at Sellafield was exceeded in 2009 and this has been associated with receipt of high burn-up fuel at Sellafield. The radiation exposure due to the discharges of antimony-125 was less than 0.005 mSv. The Environment Agency reviewed a proposal to increase the limit and considered a supporting case which demonstrated that Sellafield Limited was using the Best Practicable Means to reduce discharges. The increase in the limit was accepted by the Environment Agency after a favourable Euratom Article 37 opinion from the European Commission. A new permit with a higher limit became operative on 1st April 2010.

The dose estimates above apply to discharges from nuclear and other sites. The public is also exposed to another source of radiation near some of these facilities. This is radiation that comes directly from operations on the sites and is known as 'direct radiation' or 'direct shine'. This source of exposure has been significant around some of the Magnox power stations when they were operating. The Health and Safety Executive (which is the regulatory authority for these exposures) 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 2009, *total doses* to the public were assessed at 25 nuclear site locations. The results are shown in Figure S.2 and Table S.2. In 2009, the *total doses* at these sites were all less than the annual EU and UK limit of 1 mSv, with direct radiation doses at Dungeness A and Sizewell A much lower than before closure of the sites at the end of 2006.

Habits surveys near nuclear sites

In 2009, the regular programmes of habits surveys around nuclear sites continued. These give site-specific information on diets and occupancy habits of people near nuclear sites. In 2009, surveys were carried out at Amersham, Derby and Sellafield in England, and at Wylfa in Wales. The findings were used to strengthen and update monitoring programmes and

to improve the assessment of doses to members of the public near nuclear sites. Habit surveys to obtain data on activities undertaken on beaches relating to potential public exposure to radioactive particles, in the vicinity of the Sellafield nuclear site and at Dunnet Bay in Caithness, were also undertaken in 2009.

Radioactivity concentrations in samples collected around nuclear sites

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

A revised UK Radioactive Discharge Strategy was published in 2009, extending and strengthening the scope of the earlier Strategy published in 2002. Both describe how the UK will implement the commitments in the OSPAR Radioactive Substances Strategy on radioactive discharges to the marine environment of the North-East Atlantic. One of the aims of the UK Strategy is to progressively and substantially reduce liquid radioactive discharges and the associated regulatory discharge limits. This means that nuclear sites need action plans to achieve these goals, which will have a real impact on the amount of radioactive materials in the environment in the future. In 2009, the Environment Agency issued new permits, or varied existing ones, at nine sites (Capenhurst, Cardiff, Devonport, Dungeness, Hartlepool, Harwell, Heysham (1 & 2), Springfields and Winfrith), resulting in strengthened conditions, reduced limits or new routes for disposing of radioactive waste.

Reductions in discharges can reduce concentrations in food and environmental samples near the site. During the past decade, discharges from GE Healthcare at Cardiff have continued to fall. This has led to a downward trend in concentrations of tritium in fish and molluscs. Similarly, lower discharges of technetium-99 from Sellafield have led to a fall in technetium-99 in local food and the environment since the peaks seen in 1997. There were no major variations in concentrations of radioactivity in 2009 compared to those in 2008.

In 2009, the highest concentration of tritium measured in seafood from near Cardiff was 2,200 Bq kg⁻¹ in flounder, compared with a value of 1,400 Bq kg⁻¹ in 2008. However, the overall concentrations in seafoods decreased compared to 2008 levels. The 2009 concentrations were less than 10 per cent of the levels seen in 2000, when tritium concentrations in flounder were 54,000 Bq kg⁻¹. Tritium concentrations in seafood at some other coastal locations around the UK were in excess of 100 Bq kg⁻¹, which is well above the expected background tritium concentration of 1 Bq kg⁻¹. The increase was due to discharges of tritium. The degree of this bioaccumulation was of little significance and much lower than the concentrations found near Cardiff.

During 2009, discharges of technetium-99 from Sellafield continued at the lower level seen since new abatement technology was successfully introduced. Discharges are

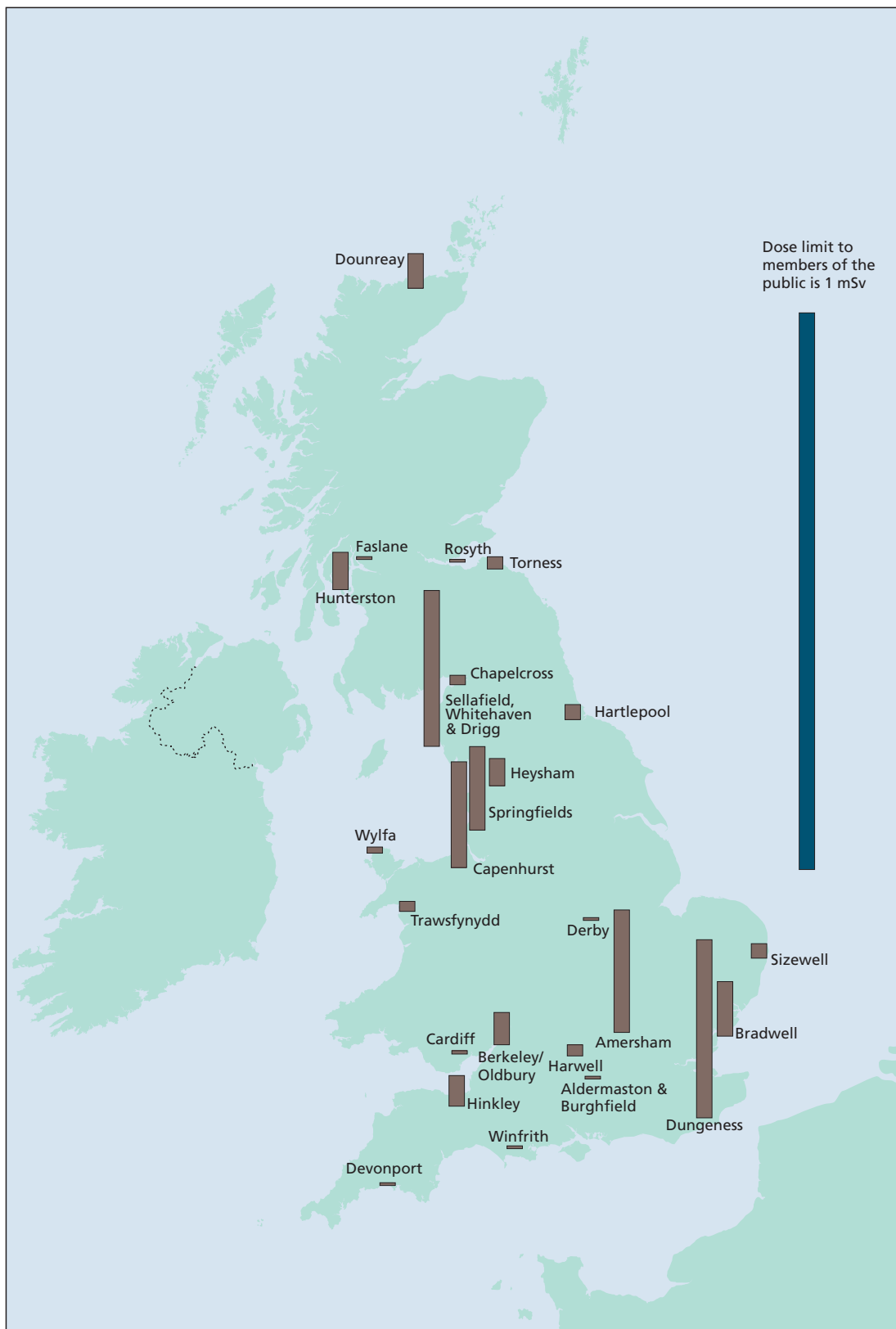


Figure S2. Total radiation exposures* in the UK due to radioactive waste discharges and direct radiation, 2009 (Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

* Total radiation exposure (total dose) is an assessment that uses a defined method that takes account of all exposure pathways in combination (e.g. radionuclides in food, the environment and direct radiation). Further information describing this type of assessment is given in Appendix 4 of this report, and in Section 3.8 of the CD supplement.

Summary Table S2. Radiation doses due to all sources at major UK sites, 2009^a

Establishment	Exposure, mSv ^b per year	Contributors ^c
Nuclear fuel production and processing		
Capenhurst	0.19	Direct radiation
Springfields	0.15	Gamma dose rate over sediment
Sellafield ^d	0.28	Crustaceans, molluscs, ²¹⁰ Po, ^{239/240} Pu, ²⁴¹ Am
Research establishments		
Dounreay	0.063	Game meat, ¹³⁷ Cs
Harwell	0.023	Direct radiation
Winfrith	<0.005	Potatoes, ¹⁴ C
Nuclear power stations		
Berkeley and Oldbury	0.058	Direct radiation
Bradwell	0.098	Direct radiation
Chapelcross	0.017	Gamma dose rate over sediment
Dungeness	0.32	Direct radiation
Hartlepool	0.027	Direct radiation, gamma dose rate over sediment
Heysham	0.049	Gamma dose rate over sediment
Hinkley Point	0.055	Gamma dose rate over sediment
Hunterston	0.067	Direct radiation
Sizewell	0.026	Direct radiation
Torness	0.022	Direct radiation
Trawsfynydd	0.018	Direct radiation, milk
Wylfa	0.011	Direct radiation, milk
Defence establishment		
Aldermaston and Burghfield	<0.005	Gamma dose rate over riverbank
Derby	<0.005	Water, ⁶⁰ Co
Devonport	<0.005	Gamma dose rate over sediment
Faslane	<0.005	Gamma dose rate over mud, fish, ²⁴¹ Am
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.006	Gamma dose rate over sediment, fish, ³ H
Industrial and landfill		
LLWR near Drigg ^d	0.28	Crustaceans, molluscs, ²¹⁰ Po, ^{239/240} Pu, ²⁴¹ Am
Whitehaven ^d	0.28	Crustaceans, molluscs, ²¹⁰ Po, ^{239/240} Pu, 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 0.15 and 0.14 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR site into the same area

expected to remain low in the future. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and in the North Sea. Concentrations of technetium-99 have shown a continued reduction from their most recent peak in 2003, with a further decrease in 2009 compared with 2008. Technetium-99 has been found in seaweed, and our monitoring has shown a small-scale transfer of technetium-99 from sea to land where seaweed has been used as a soil conditioner. In 2009, SEPA and the Foods Standards Agency published a detailed assessment of the impact of applying seaweed as a soil conditioner, or use as an animal feed, in remote communities. The research, conducted by the Health Protection Agency, concluded that the highest dose was in the range of a few microsieverts per year.

Marine sediment samples are a useful indicator of trends in the environment. People who spend time on beaches can be exposed to radiation through the radionuclide content of the sediments. Near Sellafield, the environmental concentrations of most radionuclides have declined substantially over the last 20 years. In some recent years, concentrations of caesium-137, plutonium isotopes and americium-241 in mud samples from the Ravenglass estuary near Sellafield have increased, and this was the case in 2009. These trends are unlikely to be associated with changes in discharges. Concentrations of americium-241 will have increased due to radioactive 'in-growth' from the decay of the parent radionuclide plutonium-241 in the environment. Higher activity concentrations can occur in sediments as a result of their containing radioactivity from discharges in earlier decades and then being remobilised, or due to the differences in their particle size. The changes are small and are not seen in fish and shellfish samples from Cumbria.

Dose rates from around nuclear sites

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

There were no major changes in external dose rates in intertidal areas in 2009 compared with 2008. At most locations, the external dose rates were close to background levels. Levels were higher in some estuaries near Sellafield (up to twice the background rate) and in the Ribble Estuary

Nuclear site incidents and non-routine surveys

During 2009, as a result of an ongoing programme of monitoring radioactive items were detected on beaches on the Cumbrian coastline, where 178 particles* and contaminated pebbles/stones from Sellafield were removed.

An update on further progress of the enhanced beach monitoring was provided by the Environment Agency in March 2010 (Environment Agency, 2010b). The Health Protection Agency has offered initial advice, from the particles recovered so far, that no special precautionary measures or interventions are necessary. The Health Protection Agency has continued to monitor the situation, and will report in 2010 on a detailed assessment of the health risks from particles on the beaches in the vicinity of the Sellafield site. Monitoring, removal and research into the origins, fate and effects of the particles by Sellafield Limited will continue.

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

'Special' (or *ad hoc*) sampling related to nuclear operation was needed at four sites (Chapelcross, Dounreay, Torness and Sizewell) in 2009. This was because of concerns about site operations or because of higher than normal discharges that triggered reporting procedures.

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 artificial radionuclides only contributed a small proportion of the total public radiation dose in people's general diet.

Monitoring artificial radioactivity on the Isle of Man and in Northern Ireland showed that consumer doses were all less than 2 per cent of the annual limit of 1 mSv for members of the public. A survey on the Channel Islands confirmed that doses due to discharges from the French reprocessing plant at Cap de la Hague and other local sources were less than 1 per cent of the limit.

In the past, liquid slurry containing thorium and uranium was discharged into the Irish Sea from a phosphate plant near Whitehaven. This site stopped operating at the end of 2001 and the plant has subsequently been demolished. Concentrations of naturally-occurring radionuclides in fish and shellfish near Whitehaven have been found to be higher than the maximum expected ranges due to natural sources. Concentrations of natural radionuclides have declined in the last 10 years so that by 2009 the concentrations were very close to natural background, making any increase due to the past discharges difficult to distinguish. Estimates of the concentrations of naturally-occurring radionuclides in seafood caused by past discharges from the site have been made by subtracting the expected natural concentration of these radionuclides in UK seafood from the measured levels.

* The term particle is used in RIFE to describe a large range of radioactive items from particles of scale to fragments of irradiated nuclear fuel and larger objects. Particles are not comparable at each of the sites mentioned.

Polonium-210, which is naturally-occurring, is present in some seafood samples at slightly above background levels. People in the Sellafield area who consume large amounts of seafood were estimated to receive a dose of 0.18 mSv, mostly from polonium-210.

In 2008, SEPA carried out monitoring at Dalgety Bay in Fife to assess the impact of radium contamination in the intertidal area. The objective of this monitoring was to characterise the contamination and obtain data to enable a dose determination, in accordance with the Scottish Government's Statutory Guidance on the Radioactive Contaminated Land (Scotland) Regulations 2007. A copy of SEPA's assessment is available from the website: http://www.sepa.org.uk/radioactive_substances/publications/dalgety_bay_reports.aspx

At the end of May 2009, regulations were issued and laid before the Scottish Parliament to amend the Radioactive Contaminated Land (Scotland) Regulations 2007. Radioactive Contaminated Land Guidance was also published in 2009. The changes removed the exclusion of radon and its daughters from the legislation. However, the provisions of the guidance allow for management arrangements to be taken into account, and since 2009 the Defence Estates (an executive agency of the Ministry of Defence) has been undertaking a series of investigations including a programme of monitoring and recovery on the Dalgety Bay Foreshore including a programme of monitoring and recovery of radioactive items. SEPA has welcomed the work undertaken by Defence Estates and will review the findings of the work once this is available.

Food imported into the UK may contain radioactive contamination. A monitoring system is in place to detect radioactivity in consignments. In 2009, the Food Standards Agency analysed samples of fruit products that had been imported into Dover and Felixstowe. The maximum concentration found was 520 Bq kg⁻¹ of caesium-137 in concentrated blueberry juice. By law the concentration in the final food product has to be compared with the maximum level permissible under EC Regulations, which is 600 Bq kg⁻¹ (fresh weight). In all cases, the fruit products were below the maximum and the UK authorities did not need to take any further action.

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

The environmental effects of the Chernobyl accident continued to be monitored in 2009. There are still restrictions on moving, selling and slaughtering sheep in some upland areas of the UK. These were limited to 343 farms in 2009, compared with 9,700 farms following the accident in 1986. In Scotland, restrictions for all of the five remaining farms were lifted during 2010.

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 contribute to the data collected by the OSPAR Commission. They also help to measure progress towards the UK Government's targets for improving the state of the marine environment.

Disposal of dredge spoil from harbours and other areas is licensed under the Food and Environment Protection Act, 1985. In 2009, the Department for Environment, Food and Rural Affairs (Defra) considered a proposal for the disposal of sediment from Oldbury in South Gloucestershire. Samples of the dredge spoil were analysed for radioactivity and an assessment of potential radiation doses was made. Doses to members of the public were all less than the International Atomic Energy Agency (IAEA) *de minimis* criterion of 0.010 mSv per year, and a licence was issued.

The monitoring programmes and further research

The monitoring programmes in this report involved six specialist laboratories working together, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised by the Environment Agency, the Food Standards Agency, NIEA and SEPA and they are independent of the industries discharging radioactive effluents. The programmes include monitoring on behalf of the Scottish Government, Channel Island States, the Department of Energy and Climate Change, the Department for Environment, Food and Rural Affairs, the Manx Government and the Welsh Assembly Government. Overall, around 16,000 analyses and dose rate measurements were completed in 2009.

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

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

1. Introduction

1.1 Background

1.1.1 Purpose and scope of the monitoring programmes

This report gives the results of programmes that monitored food and environmental materials for radioactivity in the UK during 2009. In England and Wales, the Food Standards Agency conducts food monitoring, whilst the Environment Agency carries out environmental and dose rate monitoring. In Scotland, the Scottish Environment Protection Agency (SEPA) carries out food and environmental monitoring, working closely with the Food Standards Agency on its programme, and in Northern Ireland this is carried out by the Northern Ireland Environment Agency (NIEA). The Food Standards Agency continues to monitor some upland areas in England, Wales and Scotland for caesium-137, arising from the 1986 Chernobyl accident. Drinking water, air and rain are monitored on behalf of the Department of Energy and Climate Change (DECC), NIEA and the Scottish Government. The Food Standards Agency and SEPA also carry out nationwide monitoring of whole diet, milk and crops that are not near nuclear sites. The marine environment of the whole of the British Isles away from nuclear sites is monitored for the Department for Environment, Food and Rural Affairs (Defra).

The Food Standards Agency is responsible for food safety throughout the UK (under the Food Standards Act 1999). The Environment Agency, NIEA and SEPA, referred to together as the environment agencies in this report, are responsible for environmental protection in England and Wales, Northern Ireland and Scotland, respectively. The Environment Agency regulates radioactive waste disposal under the Environmental Permitting (England and Wales) Regulations (EPR 10), (United Kingdom – Parliament, 2010a). Whilst in Scotland and Northern Ireland, SEPA and NIEA control radioactive substances under the Radioactive Substances Act 1993 (RSA 1993) (United Kingdom – Parliament, 1993). The Environment Agency and SEPA also have broader responsibilities (under the Environment Act 1995 (United Kingdom – Parliament, 1995a)) for protecting (and determining general concentrations of pollution in) the environment.

The monitoring programmes have several purposes. Ongoing monitoring helps to establish the long-term trends in concentrations of radioactivity over time and at distance from nuclear licensed sites. The results are also used to confirm the safety of the food chain. Monitoring the environment provides indicators of radionuclide dispersion around each site. Environmental and food results are used to assess dose to the public which can then be compared with the UK statutory dose limits. Most of the monitoring carried out and presented in this report concerns the local effects of discharges from

Key points

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

nuclear licensed sites in the UK. Other work includes the Chernobyl monitoring, which provides the authorities with information on caesium-137 concentrations in affected areas and helps them decide if restrictions are still needed. Monitoring of food and the environment remote from nuclear licensed sites is also carried out. This gives information on background concentrations of radionuclides.

The European Commission is reviewing how Article 35 of the Euratom Treaty is implemented by signature states, which includes the UK, and requires Member States to facilitate monitoring for radioactivity. The Commission is required to verify the operation and efficiency of these facilities. The first stage of the review has begun (Hunt *et al.*, 2007), and 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 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. A summary of recent trends in monitoring data and doses for 2004 – 2008 has been published (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010).

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

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

- Winfrith Environmental Level Laboratory (Amec NNC Ltd)

1.1.2 Dose assessments

The majority of the monitoring was carried out to check the effects of discharges from nuclear and non-nuclear operators on people's food and their environment. The results are used to assess doses to the public that can then be compared with the relevant dose limits. The dose assessments are retrospective in that they apply to 2009, using monitoring results for that year. The radioactivity concentrations and dose rates reported include the consequences of all discharges made up to the time of sampling.

In this report, two main types of retrospective dose assessment are made. The first type considers people near nuclear sites who may be affected by radioactivity in food and the environment from discharges of radioactive waste.

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

Both types of assessment consider the people in the population who are most exposed to radiation.

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

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

Collective doses are beyond the scope of this report. They are derived using modelling techniques. The European Commission

has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for the gaseous and liquid waste disposals in the years 1997 to 2004 (Harvey *et al.*, 2008).

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

1.2 Disposals of radioactive waste

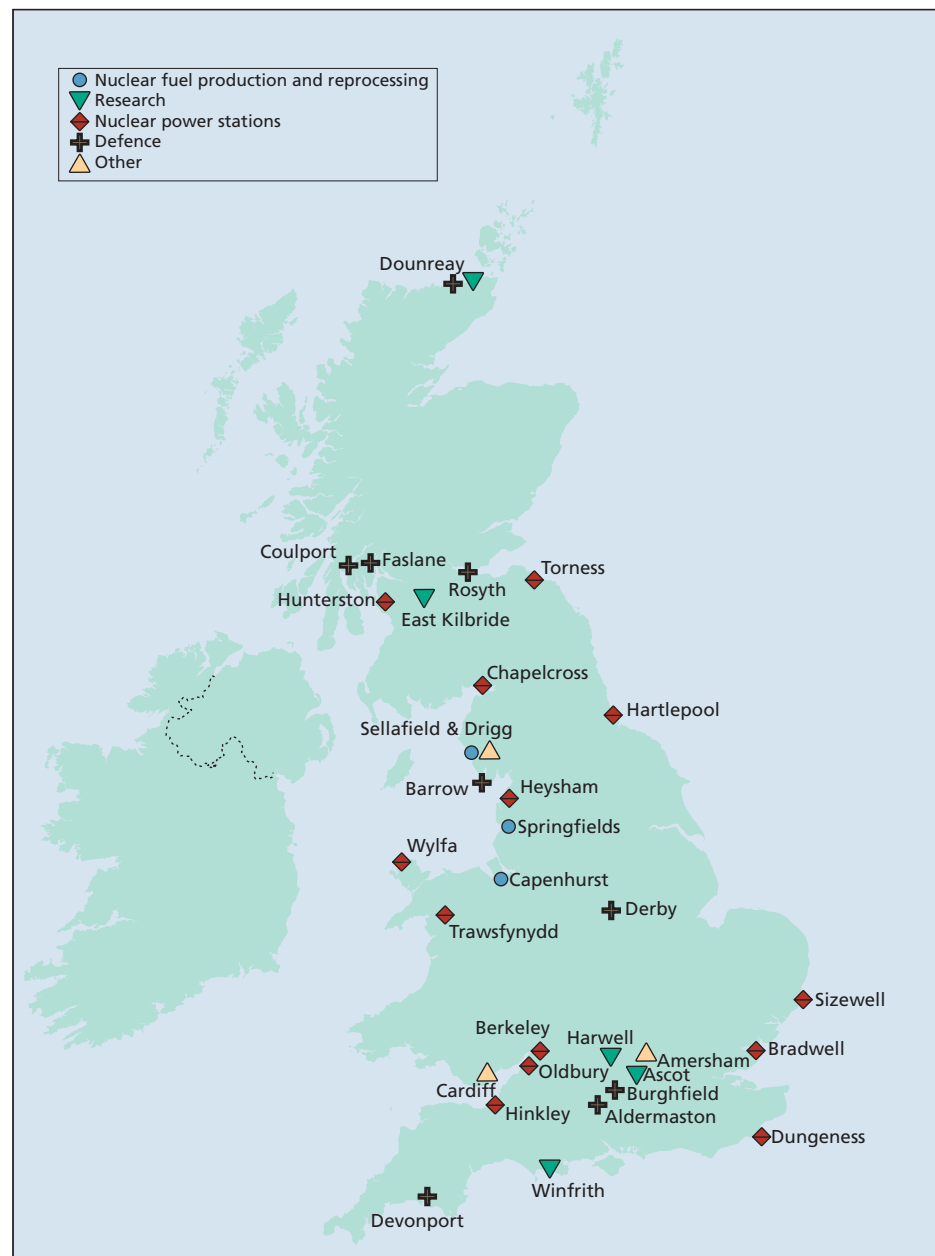
1.2.1 Radioactive waste disposal from nuclear sites

Nuclear sites in the UK discharge radioactive waste as liquid and/or gas as part of their operations. In addition, solid low level waste (LLW) from nuclear sites can be transferred to the Low Level Waste Repository (LLWR) near Drigg for disposal. There is also a solid LLW facility at Dounreay. These discharges and disposals are regulated by the environment agencies under RSA 93 or EPR 10*.

Figure 1.1 shows the nuclear sites that produce waste containing artificial radionuclides. Nuclear licensed sites are authorised to dispose of radioactive waste (United Kingdom – Parliament, 1993). They are also subject to the Nuclear Installations Act (United Kingdom – Parliament, 1965). The programmes reported here include monitoring at each of these sites. Discharges of radioactive waste from other sites such as hospitals, industrial sites and research establishments are also regulated under RSA 93 or EPR 10 but are not subject to the Nuclear Installations Act. Occasionally, these programmes detect radioactivity in the environment as a result of these discharges. For example, iodine-131 from hospitals is occasionally detected in some marine samples. Small amounts of very low level solid radioactive waste are disposed of from some non-nuclear sites. There is also a significant radiological impact due to the legacy of past discharges of radionuclides from non-nuclear industrial activity that also occur naturally in the environment. This includes radionuclides discharged from the former phosphate processing plant at Whitehaven, and so monitoring is carried out near this site. Discharges from other non-nuclear sites are generally considered insignificant and so monitoring to protect public health is not usually carried out by all the environment agencies, although some routine monitoring programmes are undertaken. For example, SEPA undertake routine sampling in the Firth of Clyde and at landfill sites across Scotland to assess the impact of the non-nuclear industry on the environment. Additionally, SEPA

* In England and Wales, the term 'authorisation' has been replaced by 'permit' with EPR 10 taking effect from 6th April 2010. In this report 'permit' has been used to apply to all sites in England and Wales irrespective of whether the period considered includes activities prior to 6th April 2010.

Figure 1.1. Principal sources of radioactive waste disposal in the UK, 2009 (Showing main initial operation. Some operations are undergoing decommissioning)



periodically undertake intensive sampling at major sewage treatment plants to monitor the combined discharges from the non-nuclear industry. However, the non-nuclear situation is reviewed from time to time and, where appropriate, surveys are included in the programme.

Appendix 2 gives a summary of the discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2009. The tables also list the discharge and disposal limits that are specified or, in the case of the Ministry of Defence (MoD), administratively agreed. In 2009, in all cases except one, discharges and disposals were below the limits. The tables show the percentage of the limit actually discharged in 2009. The gaseous discharge limit for antimony-125 at Sellafield was exceeded in 2009. Further details are given in Section 2. Section 7 gives information on discharges from non-nuclear sites.

The discharge limits are set through an assessment process, which either the operator or the relevant environment agency can initiate. In support of the process, prospective assessments of doses to the public are made assuming discharges at the specified limits. Regulations are set so that doses to the public from the site will be below the dose constraint of 0.3 or 0.5 mSv per year if discharges occurred at the limits. The implications of the regulations for the food chain are also considered. During the determination of the limits, the effect of the planned discharges on the environment and wildlife is also considered. In addition, the regulations require Best Practicable Means to be used to further minimise discharges.

The discharges and disposals made by sites are generally regular throughout the year. However, from time to time there may be unplanned events that cause unintended leakages, spillages or other emissions that are different to the normal or expected pattern of discharges. These events must

be reported to the environment agencies and may lead to follow up action, including reactive monitoring by the site, the environment agencies or the Food Standards Agency. In cases where there has been a breach of limits, or if appropriate actions have not been undertaken to ensure discharges are as low as possible, regulatory action may be taken. Where monitoring took place because of these events, the results are presented and discussed in the relevant site text later in this report. Appendix table A2.4 summarises the types of events that took place in 2009.

The UK Government and Devolved Administrations began a consultation process on standardised approaches to reporting radioactive discharges in 2005. The results of the consultation were published (Department for Environment, Food and Rural Affairs, 2008). The aim of the proposed changes was to standardise reporting across EU Member States, so that accurate and meaningful comparisons of discharges across the Community can be made. The UK's proposed approach is intended to establish reporting requirements on a secure statistical basis, to minimise over- and under-reporting of radioactive discharges and to ensure a consistent regulatory approach across the UK and industry. There was general agreement that there is benefit in standardising reporting, though it was not clear that a regulatory route was the most cost-effective way to achieve the desired aim. As a result the environment agencies will instead provide guidance in 2010 on what they will expect from industry in terms of reporting of discharges as part of granting future authorisations/permits.

1.2.2 International agreements, the UK Discharge Strategy and building new nuclear power stations

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

In July 1998, the Ministers of the UK Government agreed a long-term Radioactive Discharge Strategy and signed the Sintra Statement which included the following commitment (OSPAR, 1998):

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

In July 2002, a UK Strategy for Radioactive Discharges was published (Department for Environment, Food and Rural Affairs, 2002). This described how the UK would implement the agreements reached at the 1998 and subsequent meetings

of OSPAR. The aims of the Strategy related to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes.

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

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

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

The expected outcomes of the UK Strategy are:

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

To support implementation of Government policy, the Scottish Government has issued Statutory Guidance to SEPA (Scottish Government, 2008). Similarly DECC and the Welsh Assembly Government issued guidance to the Environment Agency (Department of Energy and Climate Change and Welsh Assembly Government, 2009). The Environment Agency has developed Radioactive Substances Regulation (RSR) Environmental Principles (RSR Environmental Principles, or REPs) to form a consistent and standardised framework for the technical assessments that will be made when regulating radioactive substances (Environment Agency, 2008a). It has also issued guidance for assessment of Best Available Techniques (BAT) (Environment Agency, 2008b).

Information on work in progress within the OSPAR Convention can be found on the OSPAR website www.ospar.org. The basis for OSPAR's approach is the Radioactive Substances Strategy

whose primary objective is to prevent marine pollution (OSPAR, 2003). This strategy is now under review. 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, 2009a). It also considers the relationship between OSPAR and its work on radioactivity and the separate initiative to develop a European Marine Strategy. Progress towards reducing man-made inputs of radioactivity into the north-east Atlantic by Contracting Parties has been published (OSPAR, 2007). An agreement has been reached on the basis for monitoring of relevance to OSPAR by Contracting Parties (OSPAR, 2006). The programme includes sampling in fifteen divisions of the OSPAR maritime area and is supported by procedures for ensuring quality control. Inputs in the north-east Atlantic have been summarised for both nuclear and non-nuclear sectors (OSPAR, 2009 b, c). The UK submission concerning the implementation of the principle of using Best Available Technology (BAT) has also been published (OSPAR, 2009d). Progress by Contracting Parties towards meeting the objectives in the Radioactive Substances Strategy has been reviewed (OSPAR, 2009e). The overall conclusions of the review were that there is evidence of:

- A reduction in total beta discharges from the nuclear sector, including technetium-99 discharges
- Reductions in marine concentrations of radioactive substances in most cases
- Estimated doses to humans were well within international and EU limits and
- An indication that the calculated dose rate to marine biota from selected radionuclides from the nuclear sector are low and are below the lowest levels at which any effects are likely to occur

The European Commission (EC) has considered various options for a new policy instrument concerning the protection and conservation of the marine environment and has now issued a Marine Strategy Directive (Commission of the European Communities, 2008). The Directive has been transposed into UK law (United Kingdom – Parliament, 2010b) and is supported by measures to improve management of the marine environment covering the UK, Scotland and Northern Ireland (United Kingdom – Parliament, 2009; Scotland – Parliament, 2010; Department of the Environment Northern Ireland, 2010). It requires Member States to achieve Good Environmental Status in waters under their jurisdiction by 2020, and this includes consideration of radionuclides.

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

for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005) and has completed a new assessment in 2010 (Department for Environment, Food and Rural Affairs, 2010).

The UK Government is of the view that companies should have the option of building new nuclear power stations (Department for Business, Enterprise and Regulatory Reform, 2008) and a draft policy statement for nuclear power generation has been issued for consultation (Department of Energy and Climate Change, 2009b). The statement includes information on:

- The needs for new nuclear power stations
- Policy and regulatory framework
- Assessment of arrangements for the management and disposal of waste from new nuclear power stations
- The impacts of new nuclear power stations and potential ways to mitigate them
- Suitable sites

In November 2009, DECC published a National Policy Statement (NPS), for Nuclear Power Generation. This stated that to meet the objectives in the Low Carbon Transition Plan it is likely that the UK will have to reduce emissions from the power sector to almost zero. Accordingly, there is a significant need for new major energy infrastructure including net additional electricity generating infrastructure. Up to 25 GW of electricity will be required from conventional (non-renewable) generation capacity, with new nuclear power contributing as much as possible towards this. The UK Government and Welsh Assembly Government believe that it is in the public interest for sites that can have new nuclear power stations constructed on them significantly earlier than 2025, to make a contribution in displacing CO₂ as soon as possible. The Scottish Government is opposed to the development of new nuclear power stations in Scotland. It is committed to enhancing Scotland's generation advantage based on renewables and fossil fuel with carbon capture and storage, as well as energy efficiency as the best long term solution to Scotland's energy security.

During 2009, the Health & Safety Executive and the Environment Agency continued to assess the design of potential new nuclear power stations. The assessment process, called "Generic Design Assessment" (GDA), allows the safety, security and environmental implications of new power station designs to be assessed, and is carried out before an application is made to build that design at a particular site in England and Wales. The designs being assessed are AP1000 (Westinghouse) and UK-EPR (EDF and AREVA) nuclear plants. The Environment Agency's assessment of the two new nuclear power station designs is to make sure that, if they were built here, their environmental impact, including the radioactive wastes they create and the discharges they make, should be acceptable. The Environment Agency has worked with potential developers and new operators to make sure that they understand what we expect of them so that any proposals they bring forward should provide suitable protection of people and the environment.

In June 2010, the Environment Agency began public consultation on the outcome of its assessment (Environment Agency, 2010c). The radiological monitoring results reported in the RIFE report series will provide a baseline against which future discharges from any new nuclear power stations can be judged.

More details can be found at <http://www.hse.gov.uk/newreactors/index.htm>

1.2.3 Managing radioactive liabilities in the UK

The UK Government and Devolved Administrations have ratified the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (International Atomic Energy Agency, 1997). This agreement aims to ensure that individuals, society and the environment are protected from the harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. The UK's first national report, demonstrating compliance with the Convention, was provided to the International Atomic Energy Agency (IAEA) in May 2003 (Department for Environment, Food and Rural Affairs, 2004a). An updated UK national report was submitted to the IAEA in October 2005 (Department for Environment, Food and Rural Affairs, 2005c). A third Joint Convention report was published by the UK in May 2008.

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up. The Energy Act 2004, which became law in 2004, led to the establishment of the Nuclear Decommissioning Authority (NDA) in April 2005. The NDA is responsible for nuclear sites formerly owned by British Nuclear Fuels Ltd (BNFL), including ownership of its assets and liabilities, and United Kingdom Atomic Energy Authority (UKAEA). It is responsible for developing and implementing an overall strategy for cleaning up the civil public sector nuclear legacy safely, securely, and in ways that protect the environment. The current strategy was published in 2006 (Nuclear Decommissioning Authority, 2006) and the plan for 2010/13 is available (Nuclear Decommissioning Authority, 2010).

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

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

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

The Scottish Government has decided not to progress geological disposal as it does not accept that this is the right way forward for Scotland. For higher activity waste, the Scottish Government's policy is to support long-term near surface, near site storage or disposal facilities so that waste can be monitored and retrievable, and the need for transporting it over long distances is minimal. Details of Scottish policy are outlined on the Scottish Government website (Scottish Government, 2010). The policy is set to be formally adopted by the end of 2010.

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

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

1.2.4 Protecting the environment

The main focus of this report is on the protection of people, but the protection of wildlife and the environment is also relevant. ICRP in its 2007 recommendations concluded that there is a need for systematic approach for the radiological assessment of non-human species to support the management of radiation effects in the environment (International Commission on Radiological Protection, 2007). In pursuit of this aim, ICRP has considered the use of a set of Reference Animals and Plants (RAPs) (International Commission on Radiological Protection, 2008). Further work is planned and whilst this is being undertaken, no dose limits are recommended to apply.

In the UK, legislative measures relevant to the protection of wildlife from radiation are the Water Framework Directive (WFD) and the Habitats Directive (Commission of the European Communities, 1992 and 2000b). Defra, the Scottish Government, Welsh Assembly Government and the Department of the Environment Northern Ireland have policy responsibility for implementing the WFD in the UK. As competent authorities, the environment agencies are largely responsible for implementing the WFD.

The aim of the WFD is to improve the quality of the aquatic environment of the European Community. It provides a framework for Member States to work within and establishes a planning process with key stages for development towards reaching 'good status' by 2015 for inland and coastal waters. The UK has carried out the first stage, which involved characterising the quality of freshwater, estuarine and coastal environments of the UK, paying particular attention to describing ecosystems and to reviewing the presence of hazardous substances (Department for Environment, Food and Rural Affairs, 2005d). In relation to radioactivity, the environment agencies have characterised the aquatic environment using a screening tool, which forecasts the environmental impact of radioactive waste sources. The outcome of the assessment has been published and provided to the European Commission (Environment Agency, 2005). Subsequent stages within this framework involve designing and implementing monitoring programmes to reflect the results of the initial characterisation, reviewing environmental quality using the results from the monitoring programmes, developing standards and producing management plans to improve the environmental status of the UK aquatic environment.

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

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

Stage 3 assessments are carried out by calculating dose rates to reference organisms and feature species for authorised discharges under the Radioactive Substances Act 1993 and, since April 2010, the Environmental Permitting Regulations 2010. When a new permit to discharge or dispose of radioactive waste is issued, or a permit is varied, the applicant is required to make an assessment of the potential impact of the permitted discharges on reference organisms that represent species which may be adversely affected. Environmental concentrations are predicted using appropriate dispersion models and the data are used to assess dose rates. Several methodologies are available to make the assessment of dose rates, including the ERICA Tool (Brown *et al.*, 2008). The assessment of dose rate is compared with the agreed threshold of $40 \mu\text{Gy h}^{-1}$.

The Environment Agency also assesses the impact of discharges at the permit limit using agreed data (Coppelstone *et al.*, 2001). When the predicted dose rate from an individual permit is greater than $1 \mu\text{Gy h}^{-1}$ then the total impact of each individual permit (including the one being considered) is considered on sensitive or protected sections of the environment. The total impact is then compared with the dose criteria of $40 \mu\text{Gy h}^{-1}$. To date, no locations and combinations of discharges have been found where the total impact of discharges made under current permits gives rise to dose rates in excess of $40 \mu\text{Gy h}^{-1}$.

SEPA carried out a Pressures and Impacts Assessment from radioactive substances on Scotland's water environment. The report concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data to support this conclusion. The report is available from SEPA.

1.2.5 Solid radioactive waste disposal at sea

In the past, packaged solid waste of low specific activity was disposed of deep in the North Atlantic Ocean. The last disposal of this type was in 1982. The UK Government announced at the OSPAR Ministerial meeting in 1998 that it was stopping disposal of this material at sea. At that meeting, Contracting Parties agreed that there would no longer be any exception to prohibiting the dumping of radioactive substances, including waste (OSPAR, 1998). The environmental impact of the deep ocean disposals was predicted by detailed mathematical modelling and has been shown to be negligible (Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985). Disposals of small amounts of waste also took place from 1950 to 1963 in a part of the English Channel known as the Hurd Deep. The results of environmental monitoring of this area in 2009 are presented in Section 8. They confirm that the radiological impact of these disposals was insignificant.

In the UK, Defra, the Department of the Environment, Northern Ireland, Scottish Government and Welsh Assembly Government issue licences under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom – Parliament, 1985) to operators disposing of dredge material. The protection of the marine

environment is considered before a licence is issued. Since dredge materials will contain varying concentrations of radioactivity from natural and artificial sources, assessments are carried out, when appropriate, to provide reassurance that there is no significant risk to the food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the IAEA (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003) and which has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2009, a specific assessment was carried out for the disposal of dredged material near Oldbury, South Gloucestershire. Consistent with results for previous operations at other locations, the impact of the radioactivity associated with the disposal operation was very low. Individual doses to members of the crew and the public were both less than 0.005 mSv per year and within *de minimis* criteria of 0.010 mSv per year. Further details are provided in Appendix 6.

1.2.6 Other sources of radioactivity

There are several other man-made sources of radioactivity that may affect the food chain and the environment. These could include disposals of material from offshore installations, transport incidents, satellite re-entry, releases from overseas nuclear installations and the operation of nuclear powered submarines. The Health Protection Agency (HPA) has assessed incidents involving the transport of radioactive materials in the UK (Hughes *et al.*, 2006). They have also considered the effects of discharges from the oil and gas industry into the marine environment (Harvey *et al.*, 2010). Using modelling, the highest individual (per head of population) annual doses for discharges from 2005-2008 were estimated to be less than 0.001 mSv. Submarine berths in the UK are monitored by the MoD (DSTL Radiological Protection Services, 2009). General monitoring of the British Isles is carried out as part of the programmes described in this report, to detect any gross effects from the sources above. No such effects were found in 2008. Low concentrations of radionuclides were detected in the marine environment around the Channel Islands (Section 8) and these may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague in France.

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

al., 2006). A report giving an overview of the progress made by local authorities and the Environment Agency in identifying and remediating contaminated land was published in 2009 (Environment Agency, 2009a). To date, no site has been determined as 'contaminated land' due to radioactivity in England and Wales.

Equivalent legislation for identifying and remediating contaminated land comprising The Radioactive Contaminated Land Regulations (Northern Ireland) 2006 and subsequent amending legislation, issued in 2007 and 2010, exists as Statutory Instruments in Northern Ireland (Statutory Instruments, 2007; 2010).

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

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

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

procedures, such as x-rays. The overall average annual dose was 2.7 mSv. Exposures from non-medical man-made sources were very low and discharges of radioactive wastes contributed less than 0.1 per cent of the total. These figures represent the exposure of the average person. Much of the information in this RIFE report is directed at establishing the exposure of people who might receive the highest doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is the exposure of these people which form the basis for comparisons with dose limits in EU and UK law.

1.2.7 Food irradiation

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

Irradiation may be used to eliminate or reduce food-borne pathogenic organisms, extend shelf life by delaying food

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

Food irradiation has been permitted in the UK since 1990, and UK legislation was amended in 2000 to implement two European Directives on food irradiation (Commission of the European Communities, 1999a, b). These amendments were consolidated into a single Statutory Instrument in 2009 as part of the Food Standards Agency programme of regulatory simplification to reduce administrative burden.

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

http://www.food.gov.uk/foodindustry/imports/imports_advice/irradiated

2. Nuclear fuel production and reprocessing

Key points

- There were minor revisions of radioactive waste permits at the three major sites
- Discharges, environmental concentrations, dose rates and doses in 2009 were broadly similar to those in 2008

Capenhurst, Cheshire

- Liquid discharges of uranium decreased
- Gamma dose rate measurements increased (but were still very low) in Rivacre Brook sediments in 2009
- Radiation doses from all sources were 19 per cent (or less) of the dose limit

Springfields, Lancashire

- Liquid discharges of technetium-99 decreased
- Gamma dose rates were generally higher over marsh but lower in the vicinity of the houseboats in 2009
- Doses to wildfowling/anglers and fishermen increased
- Radiation doses from all sources were 15 per cent (or less) of the dose limit

Sellafield, Cumbria

- The project to strip asbestos cladding from Calder Hall was completed in 2010

- Gaseous discharges were similar to 2008, except antimony-125 which increased
- Liquid discharges of carbon-14, iodine-129, ruthenium-106, strontium-90, technetium-99, plutonium radionuclides and americium-241 were higher in 2009
- Concentrations and dose rates were generally similar to those in 2008. Antimony-125 in milk samples remained below limit of detection (LoD); total caesium in deer muscle increased; technetium-99 continued to decline in fish and shellfish
- Radiation dose to seafood consumers from natural radionuclides (0.18 mSv) was much lower than in 2008, mostly due to a decrease in polonium-210 in shellfish. This was not due to operations at Sellafield. The dose from Sellafield radionuclides (0.20 mSv) also reduced mostly due to the revised mussel consumption rate
- The radiation dose relevant to the Ravenglass nature warden (0.048 mSv) was higher than in 2008, due to updated habits information
- Radiation doses, including the *total dose* and the legacy of phosphate processing, were less than 38 per cent of the public dose limit (Table 2.18)

There are four sites in the UK associated with civil nuclear fuel production and reprocessing. The sites are at:

- Capenhurst, where there are two licensed nuclear sites (one carrying out uranium enrichment and owned by Urenco UK Limited (UUK), the other undergoing decommissioning and owned by the NDA);
- Springfields, a site where fuel for nuclear power stations is fabricated;
- Sellafield, a site where irradiated fuel from nuclear power stations is reprocessed.

Both the Springfields and Sellafield sites are owned by the NDA. In November 2008, the NDA confirmed that the programme to secure a new Parent Body Organisation (PBO) for the Sellafield Site Licence Company (SLC), Sellafield Limited, had been completed, by the site management contract being transferred to the consortium, Nuclear Management Partners Ltd (NMP). The NDA's Capenhurst site was also included in the contract. The Windscale nuclear site, also owned by the NDA, is located on the Sellafield site and (until April 2008)

both were licensed separately to Sellafield Limited; thereafter the two authorisations were combined into one. Windscale is discussed in Section 2.4. The Low Level Waste Repository LLWR near Drigg is discussed in Section 7.1.

Gaseous and liquid discharges from each of the sites are regulated by the Environment Agency. In 2009, gaseous and liquid discharges were below permit limits for each of the sites (see Appendix 2). However, a new permit, with a higher limit for gaseous antimony-125, was effective from 1 April 2010 to reflect the trend of increasing releases in 2009 at Sellafield. Independent monitoring of food and the environment around each of the sites is conducted by the Food Standards Agency and the Environment Agency.

2.1 Capenhurst, Cheshire



There are two adjacent nuclear licensed sites at Capenhurst, near Ellesmere Port, one owned by the NDA and one by Urenco UK Limited (UUK). The NDA site, operated by Sellafield Limited, comprises of uranic material storage facilities and

activities associated with decommissioning redundant plant. Current plans are for final closure of the site to be completed by 2120. The UUK site operates three plants producing enriched uranium for nuclear power stations, and in 2009, the company obtained approval to construct a “tails management facility” for converting its stored depleted uranium hexafluoride tails to uranium oxide for safer long-term storage.

UUK’s new multi-media permit (covering radioactive waste disposals to land, sea and air) took effect from 1 January 2009. The permit increased the annual gaseous discharge limit for uranium but decreased the equivalent liquid discharge limit. It also set limits for other radionuclides, including technetium-99 (see Appendix 2). The most recent habits survey was conducted in 2008 (Tipple *et al.*, 2009). The potentially critical pathway for public exposure in the aquatic environment was identified as children playing around the Rivacre Brook.

Both Capenhurst sites made relicensing applications to NII in 2009, with a view to the issue of new site licences to both Sellafield Limited and UUK in 2010. The primary purpose of the two new site licences will be to reconfigure the boundary between the sites so that UUK’s new plant can be built.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges from Capenhurst, with small amounts of other radionuclides present in discharges by Sellafield Limited. In 2009, discharges from the site incinerator were nil. The main focus for terrestrial sampling was on the content of technetium-99 and uranium in milk, fruit, vegetables, silage, grass and soil. Results for 2009 are given in Table 2.2(a). Concentrations of radionuclides in samples of milk and food 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 2000. The trend reflects the reductions in discharges of technetium-99 from recycled uranium. In future UUK is expecting to increase the enrichment of reprocessed uranium, which may lead to increases in discharges of technetium-99 and neptunium-237. However, no increase in the discharge limits is expected.

Liquid waste discharges and aquatic monitoring

The permit held by Sellafield Limited allows liquid waste discharges (including liquid discharges from UUK) to the Rivacre Brook for tritium, uranium and daughters, technetium-99 and non uranium alpha (mainly neptunium-237). In 2009, discharges of uranium were lower than in 2008.

Monitoring included the collection of samples of freshwater and sediments for analysis of tritium, technetium-99, gamma emitting radionuclides, uranium, neptunium-237, and gross alpha and beta. Fish and shellfish from the local marine environment were sampled and measured for a range of radionuclides. Dose rate measurements were taken on the banks of the Rivacre Brook. Results for 2009 are given in Table 2.2(a) and (b). Concentrations of radionuclides were very low and similar to those in 2008. Dose rates taken 1.5 km

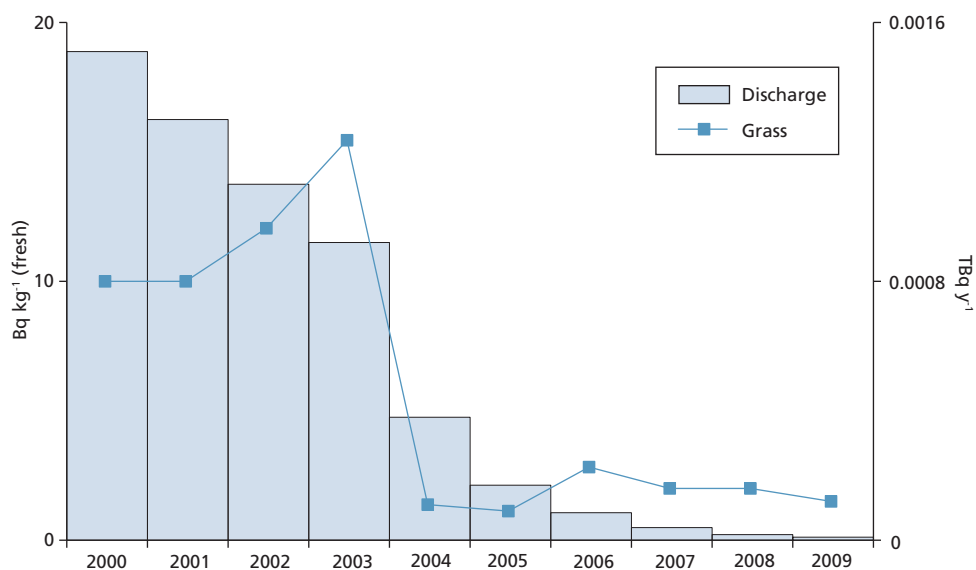


Figure 2.1. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2000-2009

downstream of Rivacre Brook in 2009 were higher than those measured in 2008. Sediment samples from the Rivacre Brook contained very low but measurable concentrations of uranium (enhanced above natural levels) and technetium-99. Some enhancement of these radionuclides was measured close to the discharge point. Variations in concentrations in sediment from the Brook are to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in freshwaters were also very low, although concentrations of uranium-234 were not as significantly reduced further downstream, as in previous years. In 2009, measured dose rates were higher, relative to natural background near to the discharge point, and higher than corresponding downstream values in 2008 and 2007. 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 the doses to people from the operations at the Capenhurst sites. Doses were estimated for children playing in and around Rivacre Brook and for consumers of local milk and vegetables. The highest dose was 0.012 mSv for children who play near the Brook and 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 gamma dose rates. The dose was less in 2008 and 2007 (0.010 mSv and 0.007 mSv, respectively). The increases in dose from 2007 were due to small increases (in each year) in dose rates at 1.5 km downstream of Rivacre Brook. The dose to people who consume terrestrial food at high-rates was much less than 0.005 mSv. After making an allowance for non-food pathways arising from discharges to air (see Appendix 1), the dose was still much less than 0.005 mSv, which was less than 0.5 per cent of the dose limit.

The *total dose* from all sources was assessed (using methods in Appendix 4) to have been 0.19 mSv (Table 2.1) in 2009, or 19 per cent of the dose limit. The increase from 0.17 mSv in 2008 is due to an increase in the estimate of direct radiation from the site (Table A4.1).

2.2 Springfields, Lancashire



The Springfields site at Salwick, near Preston, is owned by the NDA and operated by Springfields Fuels Limited (SFL), under the management of Westinghouse Electric UK Limited. On 1 April 2010 Westinghouse entered into an

agreement with the NDA for a long-term lease of the Springfields site, which transferred responsibility for the commercial fuel manufacturing business and SFL to Westinghouse. The main function conducted is the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Other important activities include recovery of uranium from residues and decommissioning redundant plant. Monitoring around the site is carried out to check wider than just for uranium concentrations, but for other radionuclides such as daughter products from past discharges of uranium ore concentrate and for radionuclides detected from Sellafield.

The most recent habits survey was undertaken in 2006 (Tipple *et al.*, 2007). In 2009, habits information, based on a five-year rolling average (2005 – 2009) was revised, resulting in an increase in the occupancy rate for high-rate houseboat dwellers (see Appendix 1). A study has been commissioned by the Environment Agency to consider the exposures of houseboat owners and wildfowling in the Ribble Estuary area in relation to variables such as tidal inundation of channels and shielding from boat hulls and other materials (Punt *et al.*, *in preparation*). Additional summary information is given in Appendix 5. The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.2.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges, with small amounts of other radionuclides present in discharges from the National Nuclear Laboratory's research and development facilities. Discharges from the site in 2009 were similar to those in 2008.

The main focus of the terrestrial sampling was for the content of tritium, carbon-14, strontium-90, iodine-129, and isotopes of uranium, thorium, plutonium and americium in milk, fruit and vegetables. Gamma-ray spectrometry results are reported for cobalt-60 and caesium-137. Grass and soil samples were collected and analysed for isotopes of uranium. The concentrations of radionuclides found in 2009 are shown in Table 2.3(a). As in previous years, elevated concentrations of uranium isotopes, compared with those at a greater distance, were found in soils around the site, but the isotopic ratio showed they are most likely to be from 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

Regulated discharges of liquid waste (including gross alpha and beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides) are made from the Springfields site to the Ribble Estuary by two pipelines. Discharges in 2009 were generally similar to

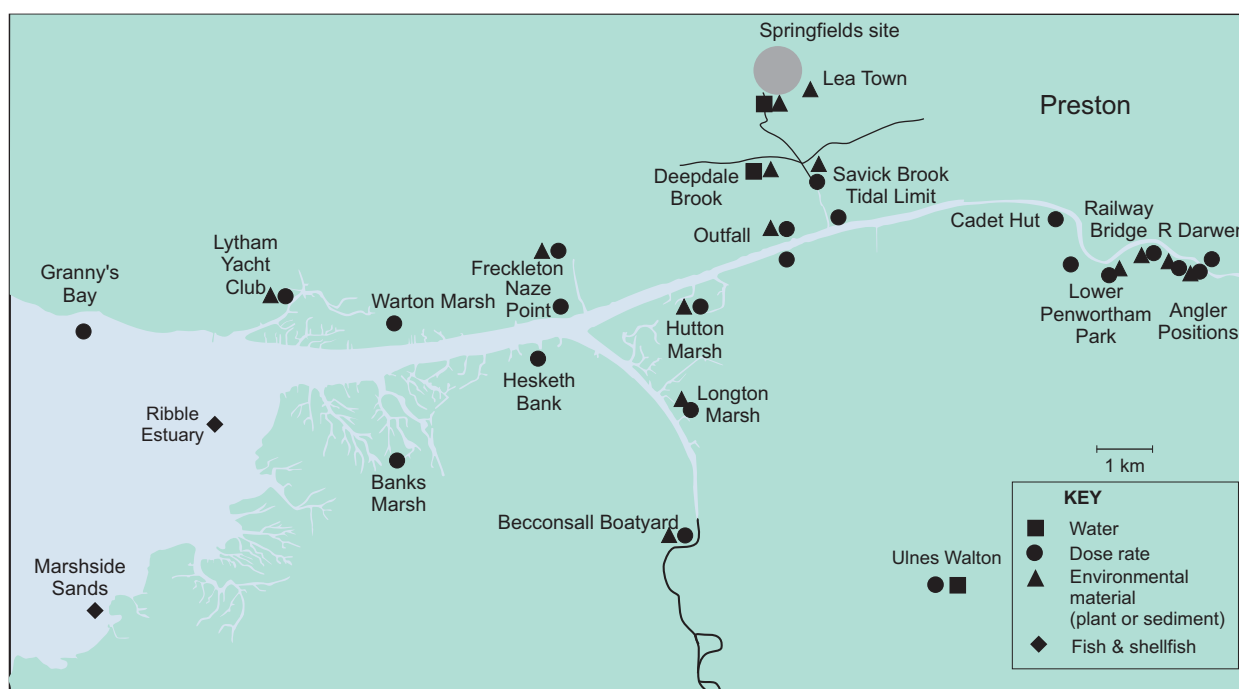


Figure 2.2. Monitoring locations at Springfields, 2009 (not including farms)

those in 2008, including the short half-life beta-emitting radionuclides (mostly thorium-234) that have decreased following the end of the Uranium Ore Concentrate purification process in 2006. Discharges of technetium-99 significantly reduced in 2009. This reduction was due to the phased processing (for operational reasons) of certain uranic residues. The Ribble Estuary monitoring programme consisted of dose rates measurements, and the analysis of sediments for uranium and thorium isotopes, and gamma emitting radionuclides. Locally obtained fish, shellfish and samphire were analysed by gamma-ray spectrometry and for uranium, thorium and plutonium isotopes.

Results for 2009 are shown in Tables 2.3(a) and (b). As in previous years, radionuclides due to discharges from both Springfields and Sellafield were found in the Ribble Estuary sediment and biota. Radionuclides found in the Ribble Estuary originating from Sellafield were technetium-99, caesium-137 and americium-241. Isotopes of uranium and the short half-life radionuclides thorium-234 and protactinium-234, from Springfields, were also found. Concentrations of the latter are closely linked to recent discharges from the Springfields site. In 2009, thorium-234 concentrations in sediments over the range of sampling sites were generally similar compared to 2008. Over a much longer timescale, these concentrations have declined due to reductions in discharges as shown by the trend of sediment concentrations at Lower Penwortham (Figure 2.3).

Caesium-137, americium-241 and plutonium radionuclides were found in biota and sediments from the Ribble Estuary. The presence of these radionuclides is due to past liquid discharges from Sellafield, carried from west Cumbria into the Ribble Estuary by sea currents and adsorbed on fine-grained muds. The concentrations observed were similar to those in recent years. Carbon-14 concentrations in shrimp samples were

elevated in 2009, in comparison to the values in 2008 and 2007.

Gamma dose rates in the estuary were generally higher than expected natural background levels (see Appendix 1, Section 3.7), and this is due to Sellafield-derived gamma-emitting radionuclides (caesium-137 and americium-241). Gamma dose rates in the estuary, excluding rates taken for houseboat assessments, were generally higher in 2009 than those in 2008. Gamma dose rates measured at Beconsall (vicinity of the houseboats) were reduced in 2009. 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. Where comparisons can be made from similar ground types and locations, beta dose rates from sediments in 2009 were generally similar to those in 2008.

Solid waste disposals and related monitoring

The Springfields and Capenhurst permits allow disposal of solid LLW by controlled burial at Clifton Marsh landfill site, Lancashire. Until 1983, BNFL had also disposed of LLW to the Ulnes Walton landfill site. Variations in operator permits were effective during 2009 to allow additional flexibility in solid waste disposal routes, to other sites such as LLWR, near Drigg. The results of Environment Agency monitoring of waters, with respect to these landfill sites are given in Section 7, Table 7.4 (Landfill Sites).

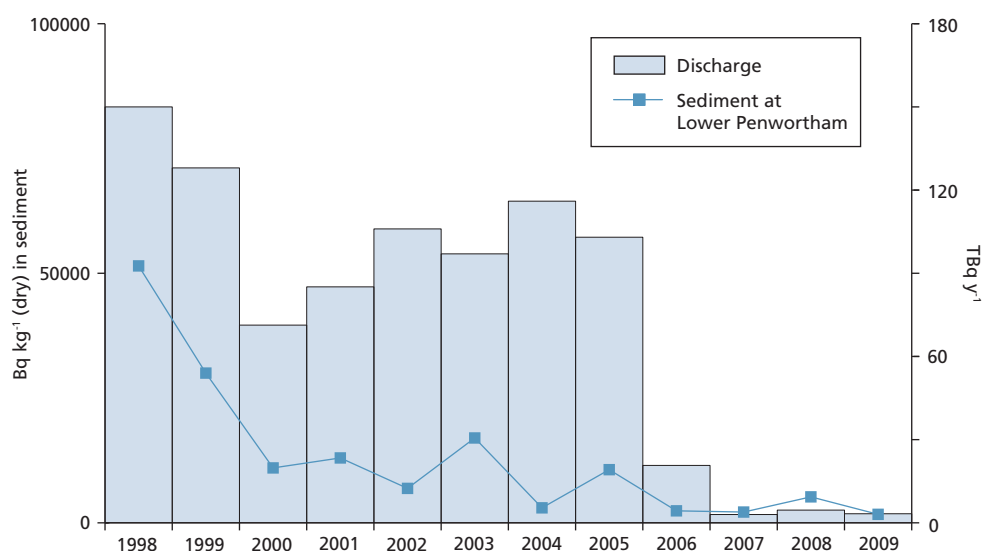


Figure 2.3. Total beta in liquid discharges from Springfields and concentrations in sediment at Lower Penwortham, 1998-2009

Doses to the public

Radiation exposures representative of terrestrial and aquatic pathways were calculated to the following people (Table 2.1): houseboat dwellers in the Ribble estuary, consumers of foods such as fruit and vegetables grown around the site, fish and shellfish consumers, children playing on the banks of the estuary, fishermen handling their gear, and farmers and wildfowlers spending time on the banks of the estuary.

In 2009, the dose to high-occupancy houseboat dwellers in the Ribble Estuary was 0.13 mSv, which was 13 per cent of the 1 mSv dose limit for members of the public, and the same

as in 2008. Gamma dose rate measurements were not taken aboard a houseboat in 2009. Dose rates were derived by using measurements outside the houseboat, and adjusting these by the ratio of onboard and outside dose rates from results reported in earlier years. This information was directly applicable to the locations where high-rate occupancy was taking place. Although the dose in 2009 was identical to that estimated in 2008, the dose contributions changed in 2009; lower gamma dose rates measured at Becconsall reduced the dose (by ~0.015 mSv), but this was offset by an increase in dose from the revision of the occupancy rate. The trend in doses over the period 2001 – 2009 is shown in Figure 2.4. A study conducted by Rollo *et al.* (1994) showed that assessed

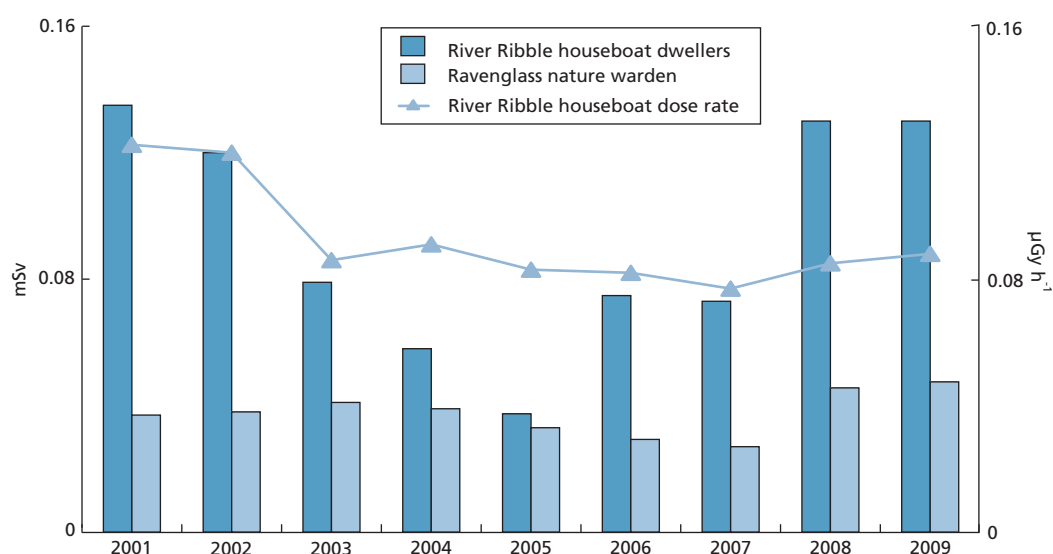


Figure 2.4. Individual radiation exposures to people affected by external gamma dose, 2001-2009

doses to the public from inhaling Ribble Estuarine sediment resuspended in the air were much less than 0.001 mSv, negligible in comparison with other exposure routes.

In 2009, the dose to people who consume terrestrial food at high-rates was less than 0.005 mSv. After making an allowance for non-food pathways arising from discharges to air (see Appendix 1), the dose was still less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.1).

In 2009, the dose to people who consume seafood at high-rates, including a contribution from external exposure, was 0.022 mSv, which was approximately 2 per cent of the dose limit for members of the public of 1 mSv. Of this dose, 0.015 mSv was from external exposure and the remainder was from the consumption of fish and shellfish. The dose in 2008 was 0.017 mSv. The difference between doses was mostly due to inclusion of a higher LoD for americium-241 in fish (flounder, which was not sampled in 2008), resulting in a slightly larger calculated dose in 2009. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site. The dose to children who may play on the riverbanks was much less than 0.005 mSv. The skin dose for fishermen handling nets was estimated to be 0.062 mSv, much less than the skin dose limit of 50 mSv. The dose to wildfowling and farmers from exposure over salt marsh was 0.036 mSv, which was less than 4 per cent of the dose limit for members of the public of 1 mSv. The small increase in dose from 0.033 mSv (in 2008) was due to small increases in gamma dose rates over marsh in 2009.

The *total dose* from all sources (using methods in Appendix 4) was assessed to have been 0.15 mSv, or 15 per cent of the dose limit. The people most affected were houseboat dwellers in the Beconsall boatyard, who were exposed to external radiation from activity in muddy sediments.

2.3 Sellafield, Cumbria



This site is operated by Sellafield Limited (formerly called British Nuclear Group Sellafield Limited), but is owned by the NDA. The main operations on the Sellafield site are: fuel reprocessing at the Magnox Reprocessing Plant and the Thermal

Oxide Reprocessing Plant (THORP); decommissioning and clean-up of redundant nuclear facilities; the manufacture of mixed oxide fuel and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in 2003. This station is undergoing decommissioning, and current plans are for the site to be cleared and available for potential re-use by 2117. The

Windscale site is located on the Sellafield site, and is discussed in Section 2.4.

Sellafield Limited has begun to decommission the Calder Hall site. The first stage involves preparations for care and maintenance. These preparations have included, but have not been limited to, the cooling towers demolition and the progressive asbestos strip of 16 reactor heat exchangers. The project to strip asbestos cladding from the heat exchangers, turbine halls and associated plants was completed on 23 March 2010. In all, 2,300 tonnes of asbestos cladding was removed in a five year project. Up to 1,000 tonnes of the asbestos from the heat exchangers may contain sufficiently low levels of radioactivity to be considered exempt; allowing disposal of the hazardous wastes to landfill offsite. In 2006, Sellafield Limited initiated a process to characterise the asbestos to support a decision about the quantity of asbestos that could be considered exempt. The process involved establishing provenance; sampling (including use of bag monitors where appropriate) and radiochemical analysis. In 2008, the Environment Agency began independent check monitoring of the asbestos by random sampling of asbestos (*in situ* and *ex situ*). Asbestos was analysed for tritium and by gamma-ray spectrometry. This approach supported the decision that the majority of the asbestos could be considered to be exempt from radioactive controls and disposed offsite.

In November 2008, the Environment Agency commissioned HPA to carry out a monitoring study of levels of radioactivity in rubble and other material emplaced in the cooling tower basins at Calder Hall on the Sellafield site. This was to check that the material was exempt waste under the Radioactive Substances (Substances of Low Activity (SoLA)) Exemption Order. Two sampling campaigns were undertaken in December 2008 and February 2009. The purpose of these campaigns was to characterise the emplaced material, identify any areas of higher activity ('hotspots') and collect samples for further analysis. A total of 28 samples were collected, 18 from the north area cooling tower basins (Cooling Towers 3 and 4) and 10 from the south area cooling tower basis, (Towers 1 and 2). Samples were analysed by gamma-ray spectrometry and gross alpha and beta activity concentrations were measured.

The measurement results were assessed following procedures from the Nuclear Industry Code of Practice (NiCOP) on Clearance and Exemption. Statistical tests were carried out to decide if the material had levels of anthropogenic contamination below 400 Bq kg^{-1} (i.e. the material was exempt under the SoLA Exemption Order). The mean total anthropogenic activity in the north area was 166 Bq kg^{-1} with a standard deviation of 119 Bq kg^{-1} . The result for the south area was 43 Bq kg^{-1} with a standard deviation of 13 Bq kg^{-1} . In both cases it could be concluded that the samples were drawn from material whose activity was below 400 Bq kg^{-1} (at the 95% confidence level) and therefore the material can be considered exempt under the SoLA Exemption Order.

In January 2007, the HSE announced that it had granted consent for the re-start of the THORP facility (Health and

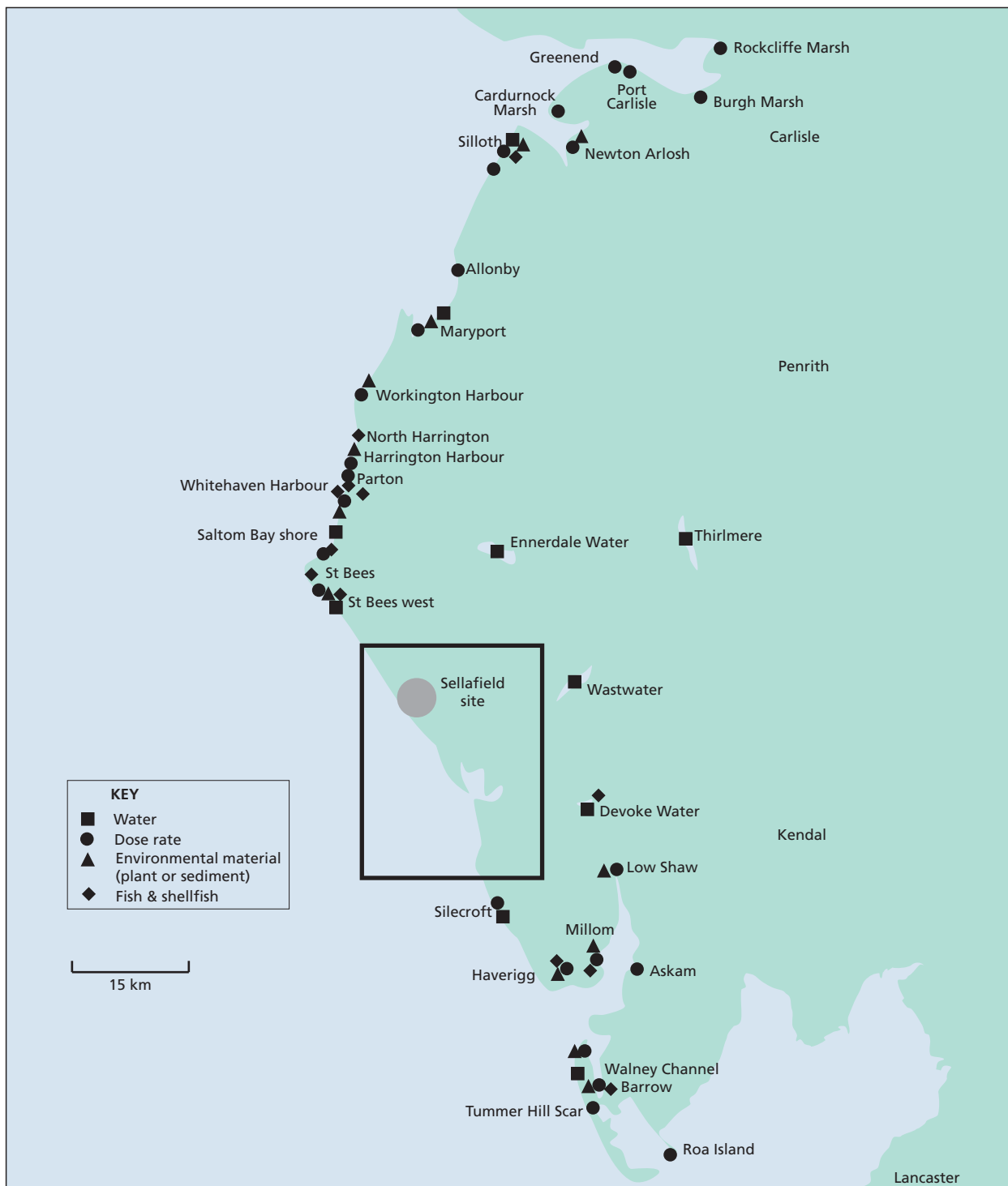


Figure 2.5. Monitoring locations in Cumbria, 2009 (not including farms)

Safety Executive, 2007a), and published a report on its investigation into the leak in 2005 (Health and Safety Executive, 2007b). In 2009, the operation of THORP remained limited due to constraints in downstream plants. Therefore, a limited campaign (196 tonnes) of spent oxide fuel was reprocessed from THORP, which represented the total amount for the year. The reprocessing of spent Magnox fuel continued during 2009 with a total of 547 tonnes of fuel reprocessed, compared to 429.6 tonnes reprocessed in 2008.

Every five years, a habit survey is conducted in the vicinity of the Sellafield site which investigates the exposure pathways relating to liquid and gaseous discharges, and direct radiation. Between these, annual habits surveys (which investigate the pathways relating to liquid discharges) review high-rate fish and shellfish consumption by local people (known as the Sellafield Fishing Community) and their intertidal occupancy rates. The most recent five-year habits survey was conducted in 2008 (Clyne *et al.*, 2009). Habit surveys to obtain data on

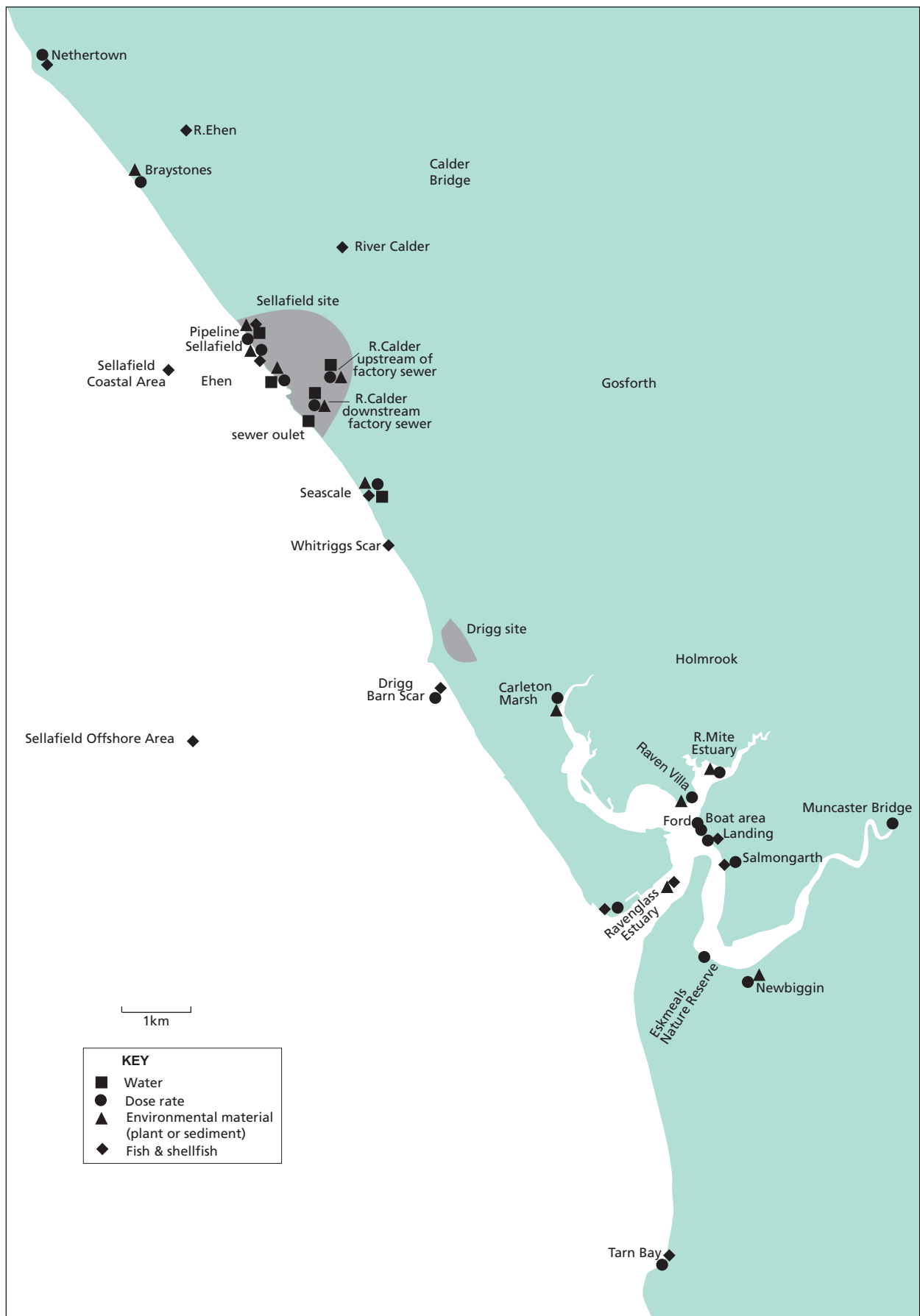


Figure 2.6. Monitoring locations at Sellafield, 2009 (not including farms)

activities undertaken on beaches relating to potential public exposure to radioactive particles in the vicinity of the Sellafield nuclear site were undertaken in 2007 and 2009 (Clyne *et al.*, 2008; Clyne *et al.*, 2010).

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

Regulated discharges to atmosphere are made from a wide range of facilities at the site including the fuel storage ponds, the reprocessing plants and waste treatment plants, and from Calder Hall. Discharges from Calder Hall are now much reduced since the power station ceased generating electricity in 2003. The permit limits discharges to atmosphere for gross alpha and beta activities, and 12 specified radionuclides. In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site.

A new permit, with a higher limit for antimony-125, was effective from 1 April 2010 to reflect the trend of increasing releases of this radionuclide from the Sellafield Fuel Handling Plant. The trend was seen throughout 2009 and was associated with increasingly high burn-up spent Magnox fuels being received at Sellafield from the remaining operational power stations at Wylfa and Oldbury. When it became clear that the permit limit for antimony-125 discharges to air was likely to be exceeded, Sellafield Limited submitted a request to the Environment Agency for the limit to be increased to 0.03 TBq per year. The Environment Agency reviewed the proposal to increase the limit and considered a supporting case which demonstrated that Sellafield Limited was using the Best Practicable Means to reduce discharges. The increase in the limit was accepted and permitted by the Environment Agency after a favourable Euratom Article 37 opinion was received from the European Commission.

Discharges of gaseous wastes from Sellafield in 2009, with the exception of those of antimony-125, (summarised in Appendix 2, with combined Windscale discharges) were much less than the permit limits and were generally similar to 2008.

Monitoring around the site related to gaseous discharges

There is a substantial programme of monitoring of terrestrial foods in the vicinity of Sellafield conducted by the Food Standards Agency, which includes samples collected in Scotland by SEPA. This programme is the most extensive of those for the nuclear sites in the UK, reflecting the scale of the discharges from the site. A wide range of foodstuffs was sampled in 2009 including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials such as grass and soil. Samples

were obtained from different locations around the site to allow for variations due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses conducted included gamma-ray spectrometry and specific measurements for tritium, carbon-14, strontium-90, technetium-99, iodine-129, uranium and transuranic radionuclides.

The results of monitoring in 2009 are given in Table 2.4. The concentrations of all radionuclides around the site were low. Concentrations in terrestrial foodstuffs were generally similar to those in 2008. Concentrations of radionuclides in meat and offal from cattle and sheep were low, with only limited evidence of the effects of Sellafield's atmospheric discharges detected in data for carbon-14 and strontium-90 (tritium and iodine-129 values were below the limit of detection). The total caesium activity concentration in game (deer muscle) increased from 0.44 Bq kg⁻¹ (in 2008) to 86 Bq kg⁻¹ (in 2009). In recent years these concentrations have fluctuated widely. The cause of the fluctuations is not known, but is not linked to variations in discharges. Plutonium concentrations when detectable were low and much lower than those found in seafood. A wide range of fruit and vegetables was sampled in 2009 and the activity concentrations were similar to those found in previous years. In common with meat and offal samples, only limited evidence of the atmospheric discharges from Sellafield was found in some of these foods. Small increases in concentrations of carbon-14 were found in some food samples (including meat and offal), in comparison to 2008. Concentrations of transuranic radionuclides, when detectable in these foods, were very low. Concentrations of antimony-125 were below limits of detection (or very close to, as in barley and grass) in terrestrial samples in 2009, despite the reported increased discharges in 2009. Trends in maximum concentrations of radionuclides, and corresponding discharge levels, in milk near Sellafield over the last decade are shown in Figure 2.7. Over the whole period, concentrations of caesium-137 and carbon-14 are relatively constant, with a suggestion that strontium-90 concentrations are declining overall.

2.3.2 Liquid discharges

Regulated liquid discharges are made from a variety of sources at the site including the fuel storage ponds, the reprocessing plants, from the retrieval and treatment of legacy wastes, the laundry and from general site drainage. Wastes from these sources are treated and then discharged to the Irish Sea via the sea pipelines that terminate 2.1 km beyond low water mark. Liquid wastes are also discharged from the factory sewer to the Ehen Estuary. Discharges from the Sellafield pipelines during 2009 are summarised in Appendix 2. The current permit sets limits on gross alpha and beta, and 16 individual nuclides. In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site (Segregated Effluent Treatment Plant, Site Ion Exchange Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP). All of the discharges in 2009 were well below the limits in the permit. Small increases in discharges of tritium, carbon-14, iodine-129, ruthenium-106, strontium-90, technetium-99, plutonium radionuclides and

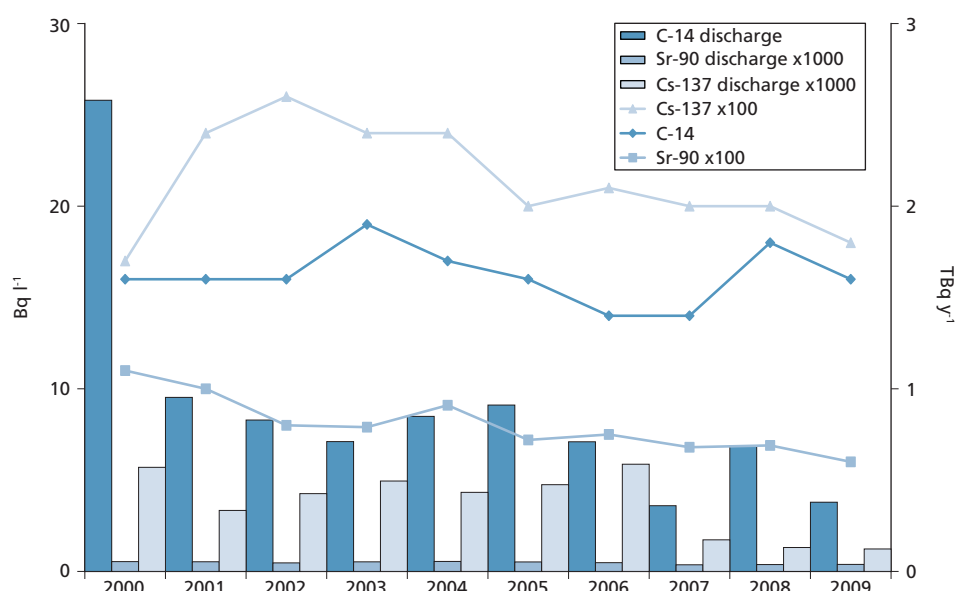


Figure 2.7. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2000-2009

americium-241 were released in 2009 compared with those in 2008. Overall, this reflects the increased amounts of fuel reprocessed in the THORP and Magnox reprocessing plant shutdowns compared to previous years.

Although discharges of technetium-99 were higher in 2009 than in 2008, discharges have remained low and their long-term downward trend, from their peak of 192 TBq in 1995, has continued (Figure 2.20). Technetium-99 discharges from Sellafield are now substantially reduced and met the target set for 2006 in the UK National Discharges Strategy (Department for Environment, Food and Rural Affairs, 2002). The reduction of technetium-99 discharges was due to the diversion, since 2003, of the Medium Active Concentrate (MAC) waste stream from Magnox reprocessing to vitrification and, since 2004, use of a new chemical precipitant (Tetraphenylphosphonium Bromide) in the Enhanced Actinide Removal Plant to remove technetium-99 from the historic stock of MAC.

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2009. The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 2.5 and 2.6. The medium-term trends in discharges, environmental concentrations and dose were considered in a recent RIFE summary report, and overall show a decrease in concentrations over time reflecting reduced discharges at Sellafield (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010).

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 given 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 eaten by local people, and who are high-rate consumers, are taken from this area. Specific surveys are conducted in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The concentrations of most radionuclides have decreased over the previous decades in response to decreases in discharges. Concentrations generally continue to reflect changes in discharges, over time periods, characteristic of radionuclide mobility and organism uptake. Trends in concentrations of radionuclides, and corresponding discharge levels, in seafood near Sellafield (over the last decade) are shown in Figures 2.8 – 2.13. There is variability from year to year, particularly for the more mobile radionuclides. Despite no further reduction in liquid discharges of technetium-99 in 2009, these concentrations in fish and shellfish have continued to show a reduction from their most recent peak in 2003, with a further decrease in 2009 compared with 2008 (Figure 2.10). For the transuranic elements (Figures 2.12 – 2.13), the long-term trends in reductions of concentrations from earlier decades appear to be slowing. In recent years, elevated concentrations of americium-241 in winkles in 2008, and plutonium-239/240 in lobsters in 2007, were observed. Overall, concentrations of plutonium radionuclides and americium-241 were lower in 2009 compared to 2008, despite small increases in discharge values in 2009.

Beta/gamma-emitting radionuclides detected in fish included: tritium, carbon-14, strontium-90 and caesium-137 (Table 2.5). Concentrations of caesium-137 in fish were generally similar in 2009 to those in recent years. However, a relatively

high concentration of caesium-137 (300 Bq kg^{-1}) was detected in brown trout from the River Calder (which has not been collected since 2002 due to difficulties in obtaining a sample), which flows through the Sellafield site. Activity concentrations in fish (and shellfish) generally reflect progressive dilution with increasing distance from Sellafield. However, the rate of decline of caesium-137 concentrations with distance is not as marked as was the case when significant reductions in discharges were achieved some years ago. There is therefore a greater contribution from historical sources.

Caesium-137 in fish from the Baltic Sea originates from the Chernobyl accident. Concentrations of caesium-137 in fish (known to have been caught in Icelandic waters) remained typical of those from weapons test fallout, at $\sim 0.1 - 0.2 \text{ Bq kg}^{-1}$ for caesium-137 in cod. Data for the Barents Sea are similar.

Other artificial beta/gamma-emitting radionuclides detected in fish included carbon-14 and tritium. With an expected carbon-14 concentration from natural sources $\sim 25 \text{ Bq kg}^{-1}$, the data suggest a local enhancement of carbon-14 due to discharges from Sellafield. Tritium (total) gives the highest concentrations of radioactivity in marine fish of approximately 100 Bq kg^{-1} , with similar concentrations of organically bound tritium (OBT). These limited results suggest that virtually all of the total tritium in marine samples was associated with organic matter, although due to the low toxicity of this element and the low concentrations observed, the dose implication was very small. At St Bees, tritium concentrations in local seawater were less than 10 Bq l^{-1} (Table 8.19). This indicates that some bioaccumulation of tritium is taking place, but the resulting concentrations of organically bound tritium (OBT) in environmental samples are much lower than observed in the Severn Estuary near Cardiff (see Section 6).

For shellfish, a wide range of radionuclides are detectable, owing to generally greater uptake of radioactivity by these organisms from sediments. Generally, molluscs tend to contain higher concentrations than crustaceans and both contain higher concentrations than fish. Concentrations of beta/gamma-emitting radionuclides are shown in Table 2.6 (Table 2.7 for plutonium-241). Consumers who collect seafood in the Sellafield coastal area provided some of the winkles, mussels and limpets sampled. There can be substantial variations between species; for example, lobsters tend to concentrate more technetium-99 than crabs (see also Knowles *et al.* 1998, Swift and Nicholson, 2001). The highest concentrations from Sellafield discharges are of tritium, carbon-14, and technetium-99. Comparing 2009 and 2008 data across a wide range of sampling locations and shellfish species, concentrations of radionuclides were reduced for technetium-99 due to progressive reductions in discharges of this radionuclide. In 2009, small increases in ruthenium-106 concentrations, along the Cumbrian coast, were detected in some shellfish (and to a lesser extent in some aquatic plants, Table 2.12) in comparison with those in 2008, presumably due to the small increase in the liquid discharges. Concentrations of other radionuclides were broadly similar to 2008.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2009 are given in Table 2.7. Transuranics are less mobile than other radionuclides in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish. Comparing 2009 and 2008 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish in 2009 were generally similar to those in 2008. Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In comparison to 2008 data, lower concentrations were measured for plutonium radionuclides and americium-241 in 2009 at some north-eastern Irish Sea locations. At the Sellafield coastal area, reduced concentrations were observed in a range of molluscs and crustaceans samples in 2009. A similar reduction was also observed in winkles from Tarn Bay. These observations are likely to have resulted from a combination of mechanisms including natural environmental variability and redistribution of sediments due to natural processes.

Monitoring of sediments

Radionuclides in Sellafield liquid discharges are taken up into sediments along the Cumbrian Coast in particular in more muddy (fine grained) areas such as estuaries. Some of these areas are used by the public. Levels of radionuclides are regularly monitored, both because of their relevance to exposure and in order to keep distributions of radioactivity under review. The results for 2009 are shown in Table 2.8. Radionuclides detected included cobalt-60, strontium-90, 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 2009 were generally similar to those in 2008.

The trends over time (1985 – 2009) for concentrations in mud from Ravenglass with discharges from Sellafield are shown in Figures 2.14 – 2.17. The concentrations of most radionuclides have decreased over the past 25 years in response to decreases in discharges, with sustained reductions in discharges of caesium-137 and transuranic elements. Discharges of cobalt-60 have been variable over the last decade but reducing in recent years, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 2.16). Over the last decade, caesium-137 and transuranic levels in sediments have generally remained constant with the lowest levels reported in 2008 (Figures 2.14 – 2.15, 2.17). Since the mid 1990s, discharges of caesium-137, plutonium isotopes and americium-241 have remained at low levels, but there has been some variability and even a suggestion of progressive increases in the concentrations in sediments (peaking over the

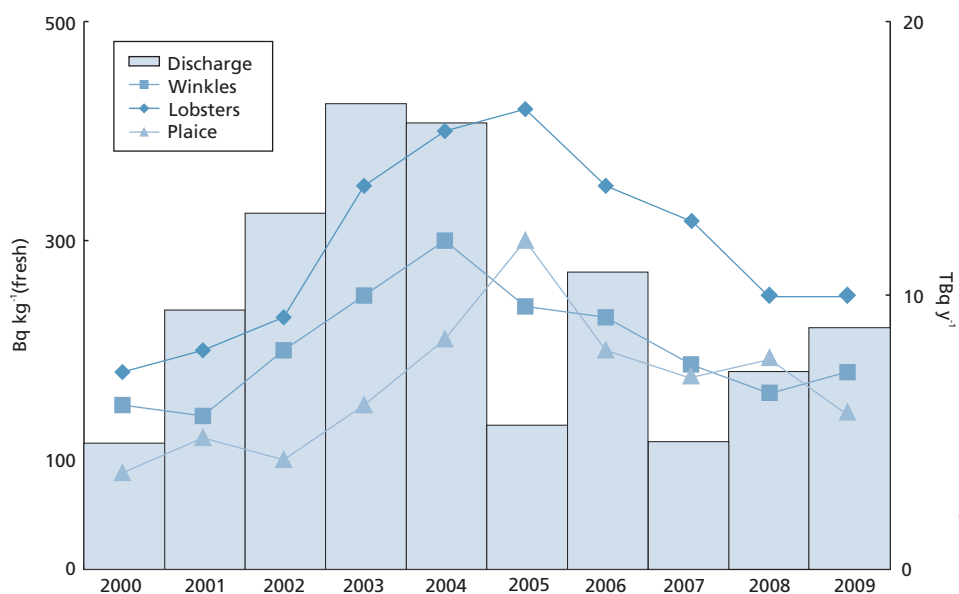


Figure 2.8. Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

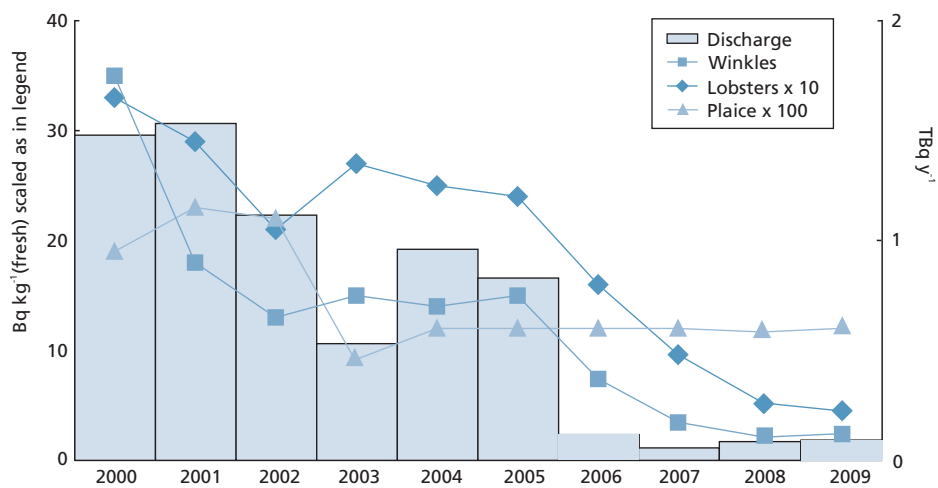


Figure 2.9. Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

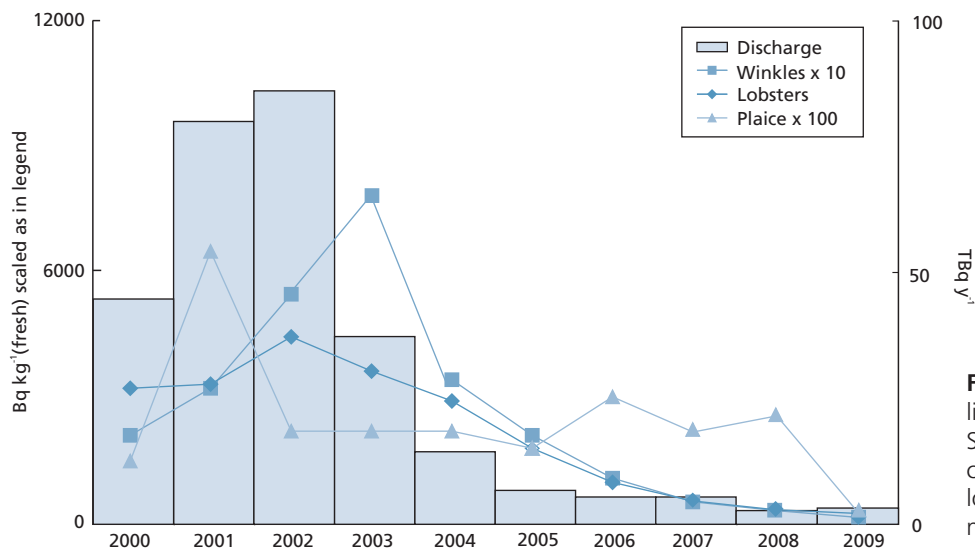


Figure 2.10. Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

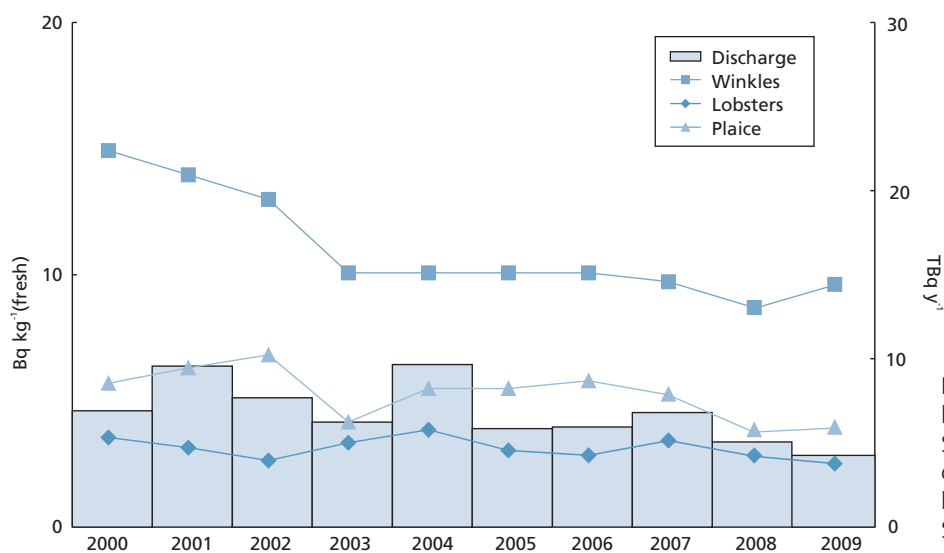


Figure 2.11. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

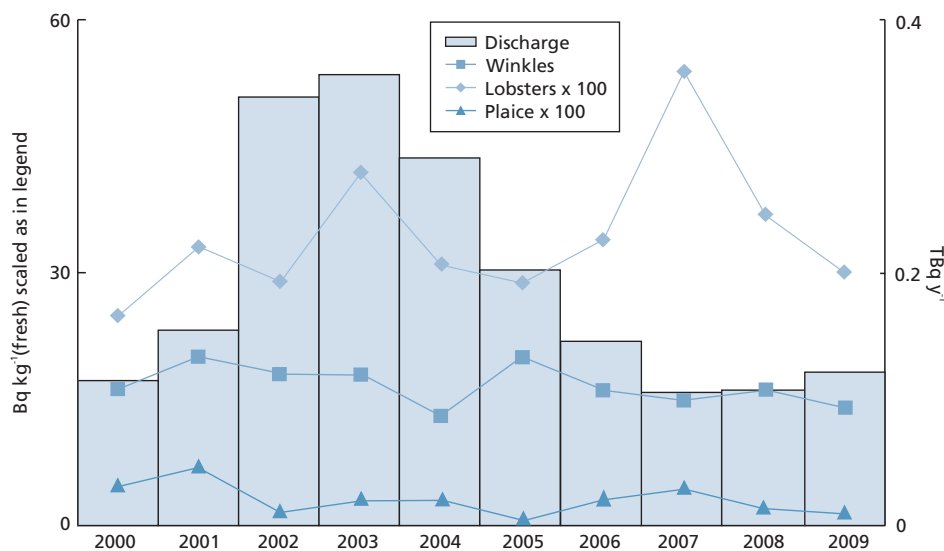


Figure 2.12. Plutonium-239/240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

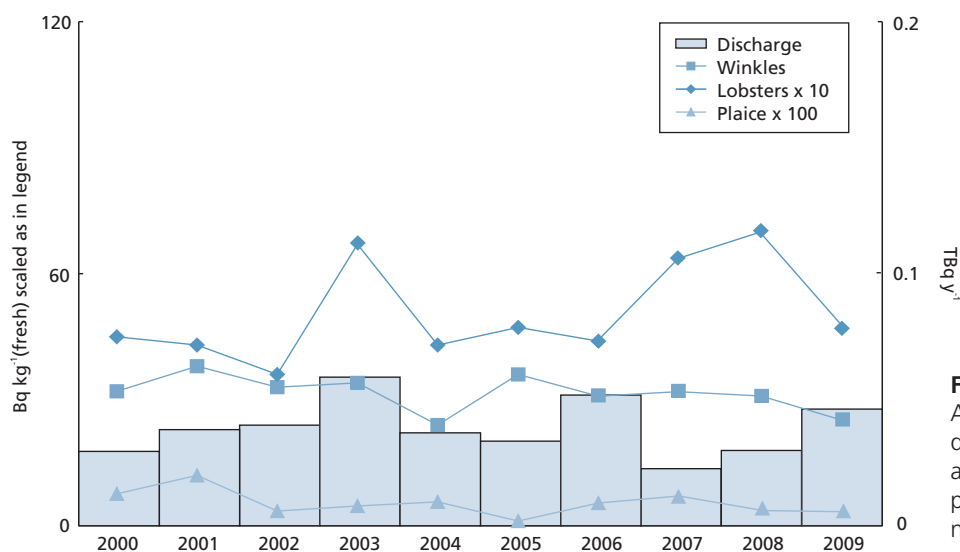


Figure 2.13. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2000-2009

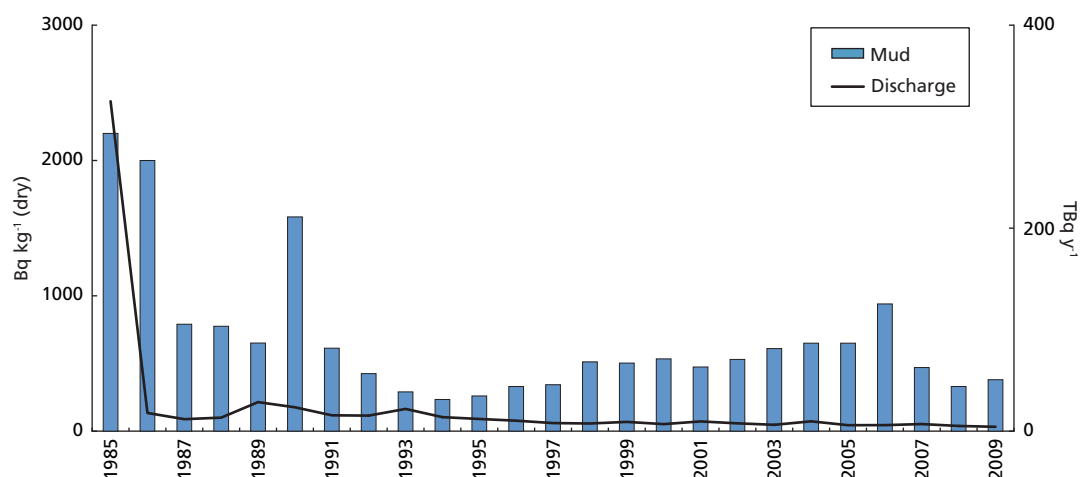


Figure 2.14. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1985-2009 (data prior to 1988 are from BNFL surveys)

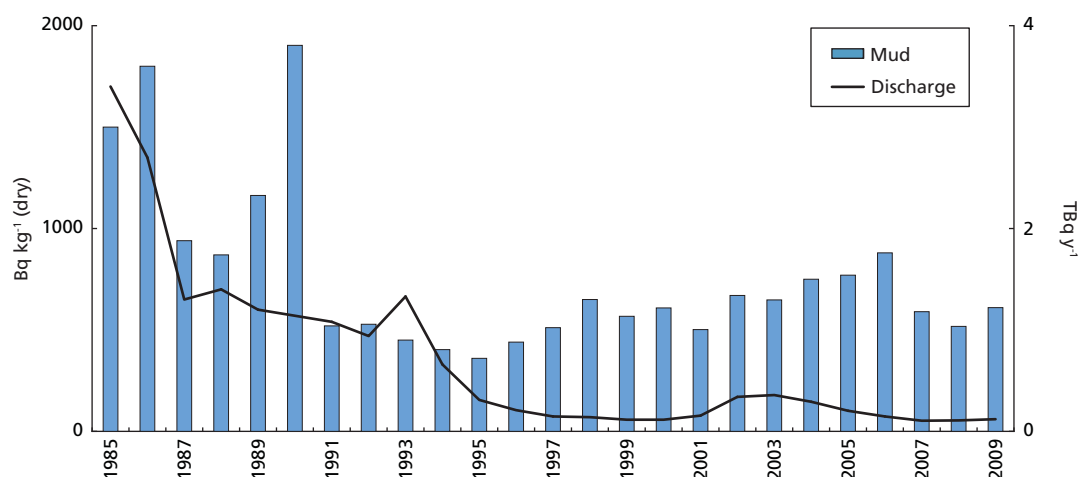


Figure 2.15. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass, 1985-2009 (data prior to 1988 are from BNFL surveys)

period, ~2003 – 2006). Although there has been a slight increase in concentrations in 2009, the earlier increasing trend has not been substantiated in the last three years. The likely explanation is that changes in these concentrations are due to remobilisation and subsequent accretion of fine-grained sediments containing higher activity concentrations. For americium-241, there is also an additional contribution due to radioactive in-growth from the parent plutonium-241 already present in the environment. The effect is less apparent in fish and shellfish (Figures 2.11 – 2.13) 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 2.18. 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. In 2009, caesium-137 and americium-241 concentrations in sediments at Newton Arlosh were elevated in comparison to values in the previous two years. 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 dosimeters. Table 2.9 lists the locations monitored by the environment agencies and the gamma dose rates in air at 1 m above ground. Where comparisons can be made from similar ground types and locations, dose rates over intertidal areas throughout the Irish Sea in 2009 were generally similar to those data in 2008. Small decreases in gamma dose rates from Greenend and the Ravenglass estuary were measured in 2009, compared with 2008. This is likely to have been due to normal variability in the environment. Gamma dose rates measured on the banks of the River Calder, which flows through the Sellafield site, continued to show significant excess above natural background downstream of the site (of approximately $0.04 \mu\text{Gy h}^{-1}$). Although the dose rates are locally

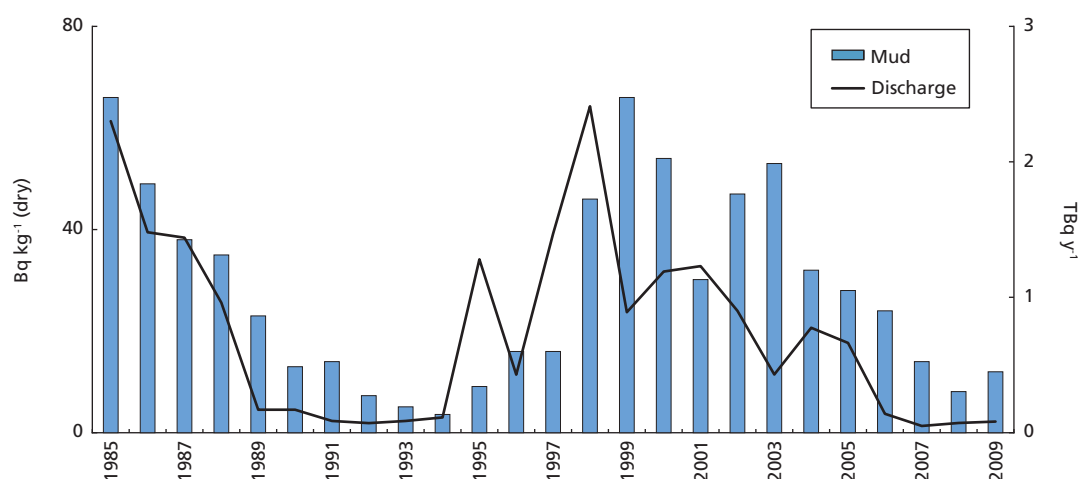


Figure 2.16. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1985-2009 (data prior to 1988 are from BNFL surveys)

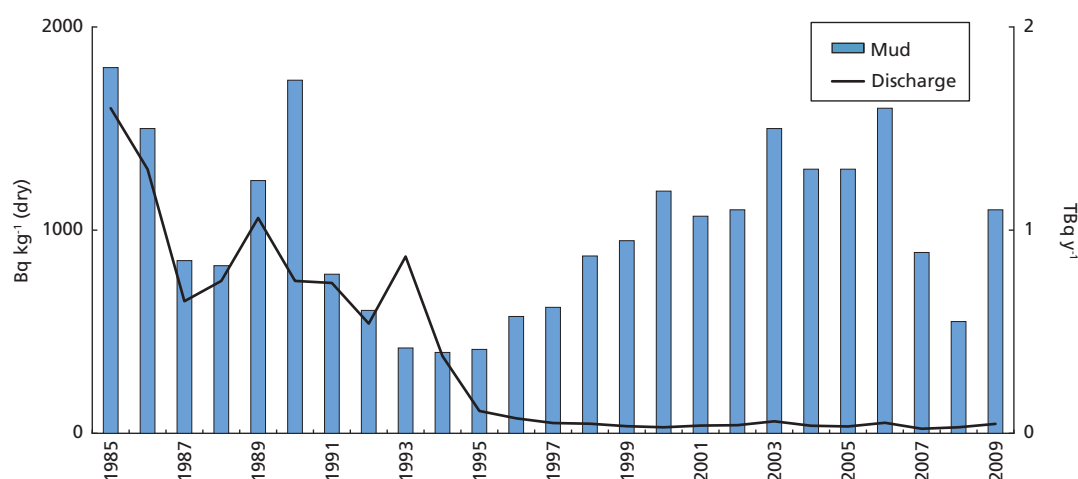


Figure 2.17. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1985-2009 (data prior to 1988 are from BNFL surveys)

enhanced, occupancy by the public, mainly anglers, is low in this area (unlikely to be more than a few tens of hours per year). On this basis the resulting doses were much less than those at other intertidal areas as discussed later in this section.

Gamma dose rates above mud and salt marshes, from a range of coastal locations in the vicinity of Sellafield, are shown in Figure 2.19. The general decrease in dose rates with increasing distance from Sellafield, which was apparent under conditions of higher discharges several decades ago, is no longer so prominent in recent years. Spatial variability of dose rates is expected, depending on ground type; generally higher dose rates being recorded over areas with finely divided sediments. For each location, there has been variation over time. Locations that are further afield from Sellafield show dose rate values that only marginally exceed average UK natural background rates.

Over the last 30 years, levels of radioactivity in the environment around Sellafield have declined as a result of reduced

discharges. In more recent years the levels in the Esk have shown a less clear trend, with concentrations of some radionuclides fluctuating from year to year (for example, see Figure 2.15). This effect could be due to the dynamic nature of the sediment in the estuary, which is eroded and transported by tide and freshwater, periodically exposing older deeper sediment containing radioactivity from historic discharges. Due to the variations seen in recent years and local concerns, the Environment Agency initiated a more detailed study of dose rates in the Esk Estuary in 2007. The objectives of the study were to assess the current level of external gamma radiation exposure in the estuary, and changes in the measured dose rates, relative to a more detailed survey of the estuary undertaken in 1989 (Kelly and Emptage, 1991). In July and August 2007, a six week intensive survey of gamma dose rates was undertaken at a total of 576 locations in the Esk Estuary. The University of Liverpool (Institute for Sustainable Water Integrated Management and Ecosystem Research (SWIMMER)) undertook the study.

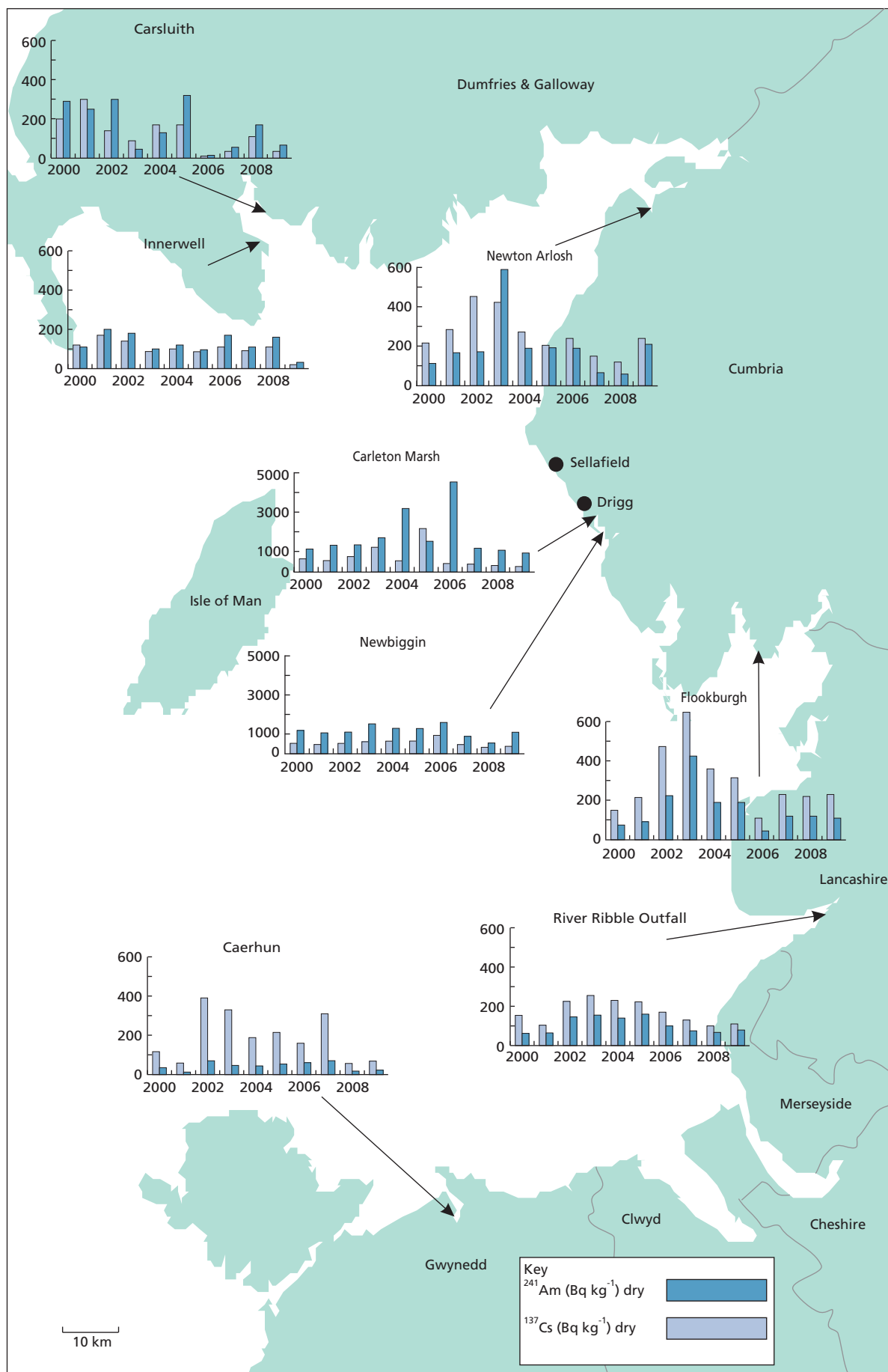


Figure 2.18. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2000-2009 (Note different scales used for Newbiggin and Carleton Marsh)

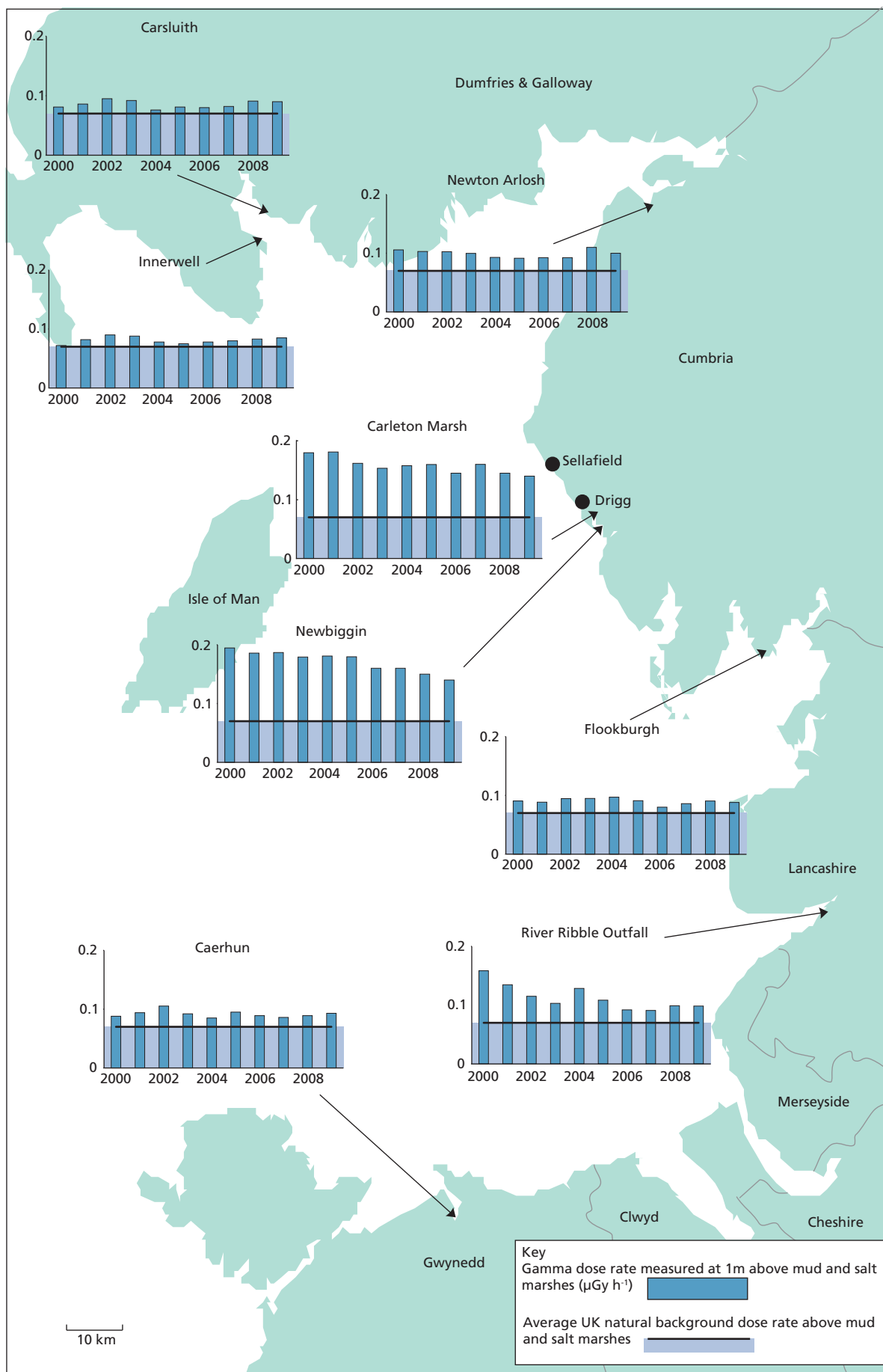


Figure 2.19. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2000-2009

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

Monitoring of fishing gear

During immersion in seawater, particles of sediment on which radioactivity is adsorbed may become trapped on fishing gear. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination meters. Results for 2009 are given in Table 2.10. Overall, measured dose rates in 2009 were increased in comparison to rates in 2008, but generally similar to those in recent years.

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments (using contamination monitors), to allow estimation of exposure for people who handle sediments regularly, are given in Table 2.11. In 2009, positively detected dose rates at the majority of sites were generally similar in comparison to recent years, with some measurements below the LoD (limit of detection) or not detecting beta activity.

More general beta/gamma monitoring for the Environment Agency of contamination on beaches using portable probes continued to establish whether there are any localised 'hot spots' of activity, particularly in strand lines and beach debris. In 2009, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1} .

In February 2008, the Environment Agency published a formal programme of work for the assessment of contamination by radioactive particles on and around the west Cumbrian coastline. The assessment is focussed on public protection from high activity discrete radioactive particles that have been released to the environment from activities at Sellafield site (Environment Agency, 2008c). In June 2009, the Environment Agency reported on the current status of the work, in the context of delivery against the original objectives, and the focus and direction that are needed to take the work forward, ultimately to a point of completion (Environment Agency, 2009b). The work reported here included investigating the distribution and behaviour of Sellafield-related particles, particle analysis and identification, risks from particles, and a review of particle dispersion and transport models focused on the Eastern Irish Sea and Solway Firth. In March 2010, the Environment Agency provided an update on further progress

of the enhanced beach monitoring (Environment Agency, 2010b).

Since vehicle-mounted beach survey work began in November 2006, and up to March 2010, a total of around 900 Ha of beach area has been surveyed by the Sellafield site operator's contractors, stretching from the north Solway coastline (at the request of SEPA), down to Silecroft (south of Drigg). The survey equipment used to date is the Groundhog™ Evolution system (up to August 2009), which was developed for Dounreay, and has specific capability in relation to the detection of medium/high energy gamma emitting radionuclides. Starting in August 2009, large area beach monitoring has been undertaken using the latest development in the Groundhog™ system – the Synergy. This new system provides improved detection capability for low energy gamma emissions. Up to March 2010, the total number of finds that have been identified since 2006 comprise 847 stones, pebbles and particles, with around 50 per cent being less than 2 mm in diameter. All have been removed from the beaches. The numbers of radioactive finds identified were 178 in 2009. The vast majority of the finds are concentrated on the 3 km stretch of beach running NW from the Sellafield site.

The work carried out between 2006 and 2008 has been previously summarised (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2008; 2009). Initial dose measurements and gamma spectrometry results indicate that these finds fit within the broad scope of particle characteristics identified during the previous year's beach surveys.

Monitoring along the Cumbrian coast will continue, with a further 250 Ha to be surveyed between April 2010 and March 2011, as part of the operator's routine environmental monitoring programme, and will include enhanced strandline and large area beach monitoring capability in relation to the detection of americium-241, strontium-90 and plutonium isotopes.

The Health Protection Agency (HPA) has restated the advice that it originally offered to the Environment Agency in 2007, that no special precautionary measures or interventions are necessary regarding access to or use of beaches in the area. In relation to food safety and following an assessment of the particles frequency and the activity concentrations, the Food Standards Agency's guidance to the Environment Agency supported HPA's advice. The HPA has continued to monitor the situation, and will report in 2010 on a detailed assessment of the health risks from particles on the beaches in the vicinity of the Sellafield site. The Environment Agency will also continue to work with relevant authorities to keep the situation under review.

Periodic updates on the beach monitoring and Sellafield radioactive particles are available from the Environment Agency (Environment Agency, 2010b). Further detail on the monitoring data compiled so far can be obtained from Sellafield Limited <http://www.sellafieldsites.com/what-we->

do/environment-health-safety—quality/environment/particles-in-the-environment.

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

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials (concentrating particular radionuclides), facilitating assessments and assisting the tracing of these radionuclides in the environment. Table 2.12 presents the results of measurements in 2009 of seaweeds from shorelines of the Cumbrian coast and further afield.

Fucus seaweeds are particularly useful indicators of most fission product radionuclides; samples of *Fucus vesiculosus* were collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. The effects of technetium-99 discharges from Sellafield on concentrations in seaweed, between 1989 and 2009, are shown in Figure 2.20. In the north-east Irish Sea there has been a continued decrease in technetium-99 levels, over the last few years, concurrent with a reduction in discharges; the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s. In general, there is still a large reduction in concentrations of technetium-99 in *Fucus vesiculosus* with distance from Sellafield, as the effect of the discharges becomes diluted in moving further afield. Technetium-99 concentrations in *Fucus* were generally lower in 2009, including at some specific locations (Cemaes Bay, Carlingford Lough and Auchencairn) previously known to have had fluctuating levels over recent years. Activity concentrations at these specific locations have declined consecutively over the last two years. Variations in levels in the past were most likely the result of complex hydrographic transport patterns in the Irish Sea, with technetium-99 being dispersed to a variable degree before arriving at distant locations (Leonard *et al.*, 2004). It may also be noted that as the effects of the high technetium discharges of the 1990s continue to disperse, there is the potential for areas distant from Sellafield to exhibit concentrations greater than those in closer proximity, such as Auchencairn, and as observed in seawater in Liverpool Bay for 1998 (McCubbin *et al.*, 2002).

Seaweeds are sometimes used as fertilisers and soil conditioners and this potential pathway for the transfer of radionuclides into the food chain continues to be investigated. The results

in 2009 are shown in Table 2.13 (together with data for Hinkley Point). The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al.*, 2000). Although seaweed harvesting in the Sellafield area continues to be rare, several plots of land were identified and investigated further. Samples of soil were analysed by gamma-ray spectrometry and for technetium-99. The Sellafield soil (compost) data show enhanced concentrations of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Where comparisons can be made, technetium-99 concentrations in edible parts of the vegetables grown in these soils were smaller than those found in 2008. Concentrations of gamma-emitting radionuclides were close to or below the LoD in vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2009; this pathway has, therefore, remained dormant. However, monitoring of *Porphyra* has continued in view of its potential importance, historical significance and the value of *Porphyra* as an environmental indicator material. Samples of *Porphyra* are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2009 are given in Table 2.12. In 2009, ruthenium-106 concentrations in *Porphyra* from the Cumbrian coast were at or below the LoD, and reduced in comparison with recent years (due to the decreased discharges of this radionuclide in 2005 and 2006). Results for analyses of laverbread, from the major manufacturers that are regularly collected from markets in South Wales, are also given in Table 2.12. In 2009, activity concentrations in laverbread were at or below the LoD.

Monitoring of seawashed pasture

The potential transfer of technetium-99 to milk, meat and offal from animals grazing tide-washed pasture was considered using a modelling approach in the report for 1997 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998). The maximum potential dose was calculated to be 0.009 mSv at that time. Follow-up sampling of tide-washed pastures at Newton Arlosh, Cumbria and Hutton Marsh, Lancashire in 2006 suggested that this dose estimate remains valid (Environment Agency, Environment and Heritage Service, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2007).

Monitoring of sea to land transfer

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

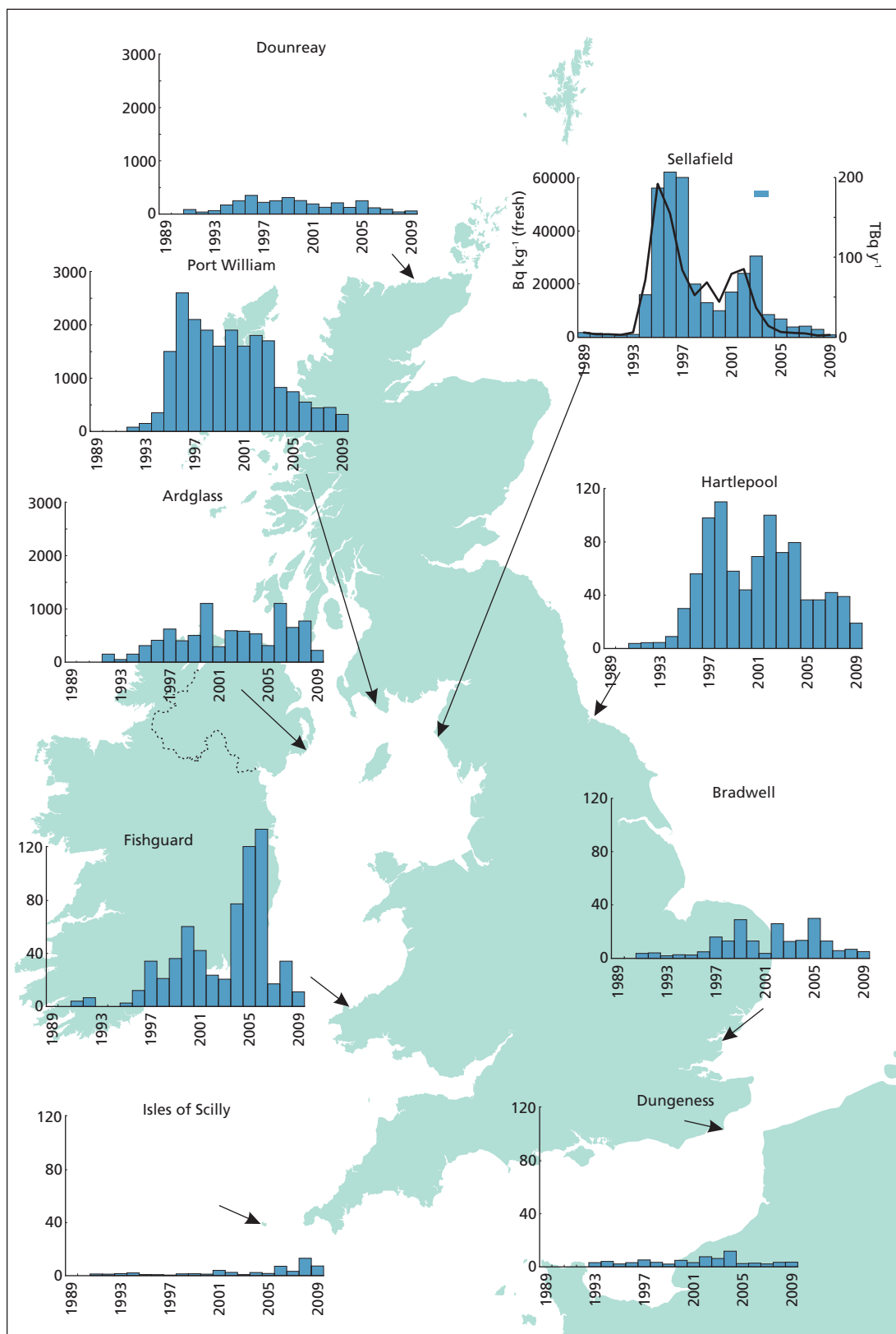


Figure 2.20. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2009

The results of measurements in 2009 are given in Table 2.14. In general, the data are similar to those for 2008 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. As in 2008, the evidence for sea to land transfer is very limited in 2009. In comparison to the positively detected data in 2007, technetium-99 levels in blackberries and grass were very low in 2009. 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 $^{239+240}\text{Pu}$: ^{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 2009 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 given in Section 8.

Sampling of fresh water from rivers and lakes in west Cumbria is conducted as part of the regular environmental monitoring programme around Sellafield; however, other environmental materials would be likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2009 are included in Table 2.15. The gross alpha and beta activities for drinking waters were below the World Health Organisation (WHO) recommended values of 0.5 Bq l^{-1} and 1.0 Bq l^{-1} respectively.

Small amounts of activity are discharged from Sellafield under permit via the factory sewer outfall to the Ehen Estuary, at the confluence with the River Calder. There was some evidence of tritium at the outfall (Table 2.15). However, the waters are not potable and the low concentrations are of no radiological significance. Table 2.15 also includes the results of monitoring from the Ehen Spit (Figure 2.6) near Sellafield where water issues from the ground at low tide. This release is not due to regulated 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 2009 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 $110,000 \text{ Bq kg}^{-1}$) were found in feral pigeons sampled in Seascale by the Ministry of Agriculture, Fisheries and Food (MAFF). Consumption of the breast meat of only 20 birds contaminated at the highest concentration would have given a dose of 1 mSv to high-rate consumers. Advice issued by MAFF in 1998 was that people should not handle, slaughter or consume pigeons within a 10 mile radius of the site. A full review of the incident was published in 1999 (Copeland Borough Council *et al.*, 1999). It was found that pigeons had access to the roof spaces in buildings on the Sellafield site and had become contaminated with radionuclides including caesium-137. The pigeons were also congregating in large numbers at a bird sanctuary in Seascale village and the environment around had become contaminated. Since then, the site operator has undertaken remedial measures, including a substantial cull of feral pigeons in the area and preventing access to the loft spaces in buildings on the Sellafield site. Results of the analysis of wood pigeon samples collected in 2009 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon decreased in 2009 (2.2 Bq kg^{-1}), in comparison to the value reported in 2008 (22 Bq kg^{-1}), and similar to the value in 2007 (0.35 Bq kg^{-1}). Concentrations of artificial radionuclides were low and would add little to the exposure of local consumers. The Food Standards Agency will continue to monitor this pathway. In view of the limited numbers of feral pigeons now on the site, the Food Standards Agency will be reviewing the need for the precautionary advice to continue.

Following the review of the pigeon incident, the Environment Agency began to sample and analyse sediments from road drains (gully pots) in Seascale and Whitehaven in 1999. Gully pots in road drains collect sediments washed off road surfaces and provide good indicators of contamination of urban environments. The results of analyses in 2009 are shown in Table 2.16 and are similar to those in 2008. In recent years, concentrations have generally fallen significantly since remedial measures to reduce contamination were taken.

2.3.4 Doses to the public

Doses from gaseous discharges

The dose to people who consume terrestrial food at high-rates and are exposed to external and inhalation pathways from gaseous discharges was calculated using the methods and data given in Appendix 1. The results are given in Table 2.18. Calculations were performed for four age groups (adult, 10y, 1y and prenatal); doses received by adults were found to be the highest, at 0.028 mSv (1y: 0.024 ; 10y: 0.021 ; prenatal: 0.016). The most significant contributions to adults' dose

were from caesium-137 (as total caesium) in game and strontium-90 in domestic fruit. The most important foodstuff in 2009 was game, which accounted for 62 per cent of the dose. In 2008, the critical age group was 1-year-old infants and the dose was 0.027 mSv. The change in the critical age group from infants to adults was mostly due to an increase in the total caesium activity (0.44 Bq kg^{-1} in 2008; 86 Bq kg^{-1} in 2009) in game. The decrease in infants' dose from 2008 was largely attributed to a decrease in the concentration of carbon-14 and a lower LoD for cobalt-60, both in milk. The environmental impact associated with the increased antimony-125 discharge (from the increased releases from the Sellafield Fuel Handling Plant) was not significant. The dose to people, who consume terrestrial food at high-rates, from the release of antimony-125 in 2009 was less than 0.005 mSv. Doses from non-food pathways (mostly inhalation of radionuclides and external dose from noble gases) were very low and less than 0.005 mSv.

The pathway (food and external/inhalation) and radionuclide contributions to dose from gaseous discharges from Sellafield for the period 2002 – 2009 are shown in Figure 2.21. Prior to 2008, the trend has been a generally declining one with reductions in doses of about 10 per cent over the last 5 years. The relative increases to the 2007 value were mostly attributed to the inclusion of the LoD for cobalt-60 in milk and the increase of total caesium in game in 2008 and 2009, respectively. The downward trend is mainly due to the permanent shut down of Calder Hall and the resulting cessation of discharges of argon-41 and sulphur-35.

Doses from liquid discharges

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

Doses from seafood consumption

The high-rate consumption of fish and shellfish by local people and their intertidal occupancy rates were reviewed in 2009 further to the habits survey in 2008. Two sets of habit data were used in the assessments. One was based on the habits seen in the area each year (2009 habits survey). The second was based on a five-year rolling average using habit data gathered from 2005 to 2009. Small changes were found in the amounts and mixes of species consumed. Overall, there was a decrease in mollusc and crustacean consumption for both 2009 and 2005 – 2009 data sets. Occupancy rates over sediments increased for 2009 and decreased for 2005 – 2009. Occupancy rates over intertidal areas also slightly increased in 2009, relevant to the Ravenglass nature warden. The revised habits data are given in detail in Appendix 1. Aquatic pathway habits are normally the most important in terms of dose at Sellafield and are surveyed every year. This allows generation

of a unique yearly set of data and also rolling five-year averages. The rolling averages are intended to smooth the effects of sudden changes in habits and provide an assessment of dose that follows more closely changes in radioactivity concentrations in food and the environment. These are used for the main assessment of doses from liquid discharges, and follow the recommendations of the report of the Consultative Exercise on Dose Assessments (Food Standards Agency, 2001a).

Table 2.18 summarises doses to seafood consumers in 2009. The doses to people, who consume a large amount of seafood, from artificial radionuclides were 0.19 mSv and 0.20 mSv, using annual and five-year rolling average habits data, respectively. These doses each include a contribution due to external radiation exposure over sediments. Both the annual and the rolling average derived doses were lower than the corresponding dose in 2008 (both 0.23 mSv). Although concentrations of americium-241 and plutonium radionuclides in mollusc (winkles and mussels) samples were lower in 2009, the decrease in dose from 2008 was mostly due to the reduction in the mussel consumption rate. The breakdown, by nuclide, of the contributions to dose is shown in Figure 2.22. Most of the dose was due to historic discharges from Sellafield. Recent and current discharges of technetium-99 contributed approximately 1 per cent (~1 per cent in 2008) of the dose (from artificial radionuclides) to the Sellafield seafood consumers. The radionuclides giving the largest contribution to the food component of the dose (~70 per cent) were plutonium-239/240 and americium-241.

Data for naturally-occurring radionuclides in fish and shellfish are discussed in Section 7. However, the effects on Sellafield's high-rate consumers of fish and shellfish from historic discharges of naturally-occurring radionuclides from non-nuclear industrial activity from the former phosphate works at Whitehaven (Cumbria) are also considered here. These works were demolished in 2004 and the permit to discharge radioactive wastes revoked. The increase in concentrations of naturally-occurring radionuclides due to the historic discharges is difficult to determine above a variable background (see Appendix 1). However, using maximising assumptions for the dose coefficients, and the five-year rolling average habits data, the dose to local people (who consume seafood at high-rates) due to the enhancement of concentrations of naturally-occurring radionuclides from former non-nuclear industrial activity in the Sellafield area was estimated to be 0.18 mSv in 2009. Most of this was due to polonium-210 (93 per cent). Small decreases in concentrations of polonium-210 in mollusc (winkles, and to lesser extent mussels) and crustacean (crab) samples in 2009 contributed to the decrease in dose from 2008 (0.39 mSv). For comparison with the assessment using the five-year average habits data, the dose from the single-year assessment for the Sellafield seafood consumers (based on consumption rates and habits survey data in 2009) was 0.18 mSv (Table 2.18). The origin of the polonium-210 in shellfish and its variation in recent years is considered in more detail in Section 7. Using estimates from the five-year average habits data for both artificial and naturally-occurring radionuclides, the combined dose, when rounded again to two significant figures, was 0.38 mSv in 2009. These doses

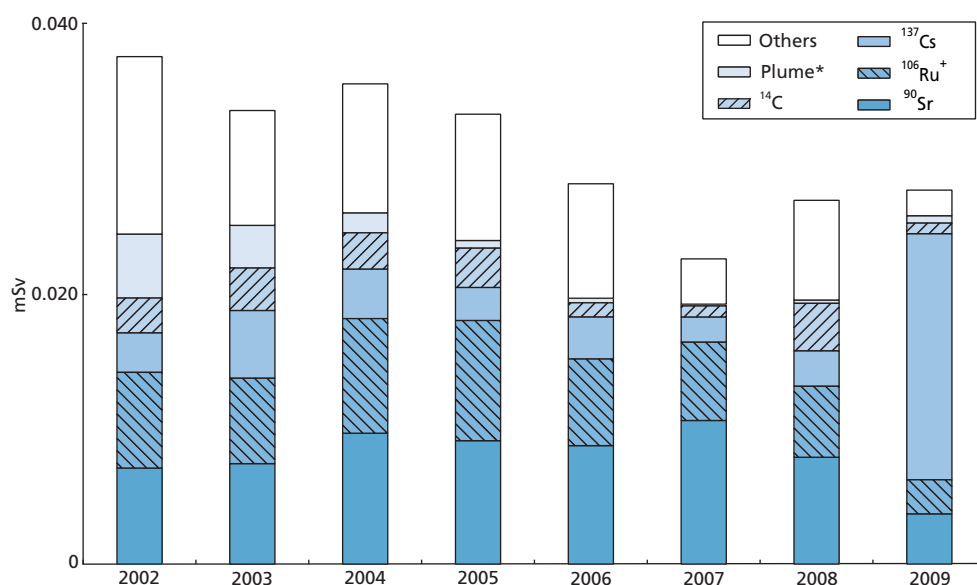


Figure 2.21. Contributions to dose from gaseous discharges from Sellafield, 2002-2009
(* External and inhalation pathways, +based on limits of detection for concentrations in foods)

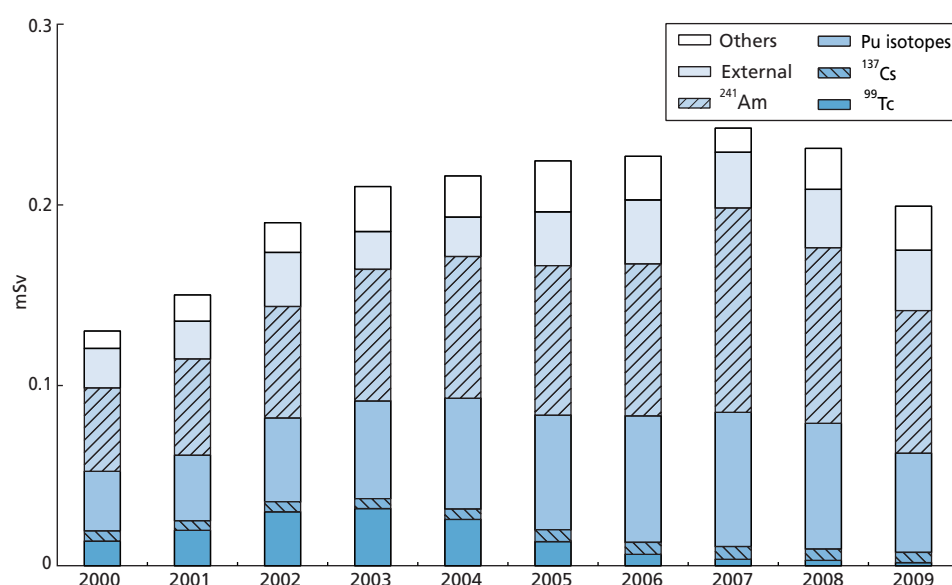


Figure 2.22. Contributions to dose to seafood consumers at Sellafield, 2000-2009

may be compared with an average dose of approximately 2.2 mSv to members of the UK public from all natural sources of radiation (Watson *et al.*, 2005) and to the annual dose limit to members of the public of 1 mSv.

Exposures representative of the wider communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland, North Wales and the Isle of Man have been kept under review (Table 2.18). Where appropriate, the dose from consumption of seafood has been summed with a contribution from external exposure over intertidal areas. The doses received by people in the wider communities are significantly less than for the local Sellafield people because of the lower concentrations

and dose rates further afield. There were generally small changes in the doses in each area when compared with those in 2008 (given in Figure 2.23 and Table 2.17). For the Northern Ireland coast, the dose decreased from 0.017 mSv in 2008 to 0.012 mSv in 2009, due to a combination of small reductions in several radionuclide concentrations (including carbon-14, caesium-137 and americium-241) in fish samples. At the North Wales coast, in 2009, the dose was 0.015 mSv (0.018 mSv in 2008). The decrease was largely attributed to a slight decrease in carbon-14 concentrations in fish in 2009. 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

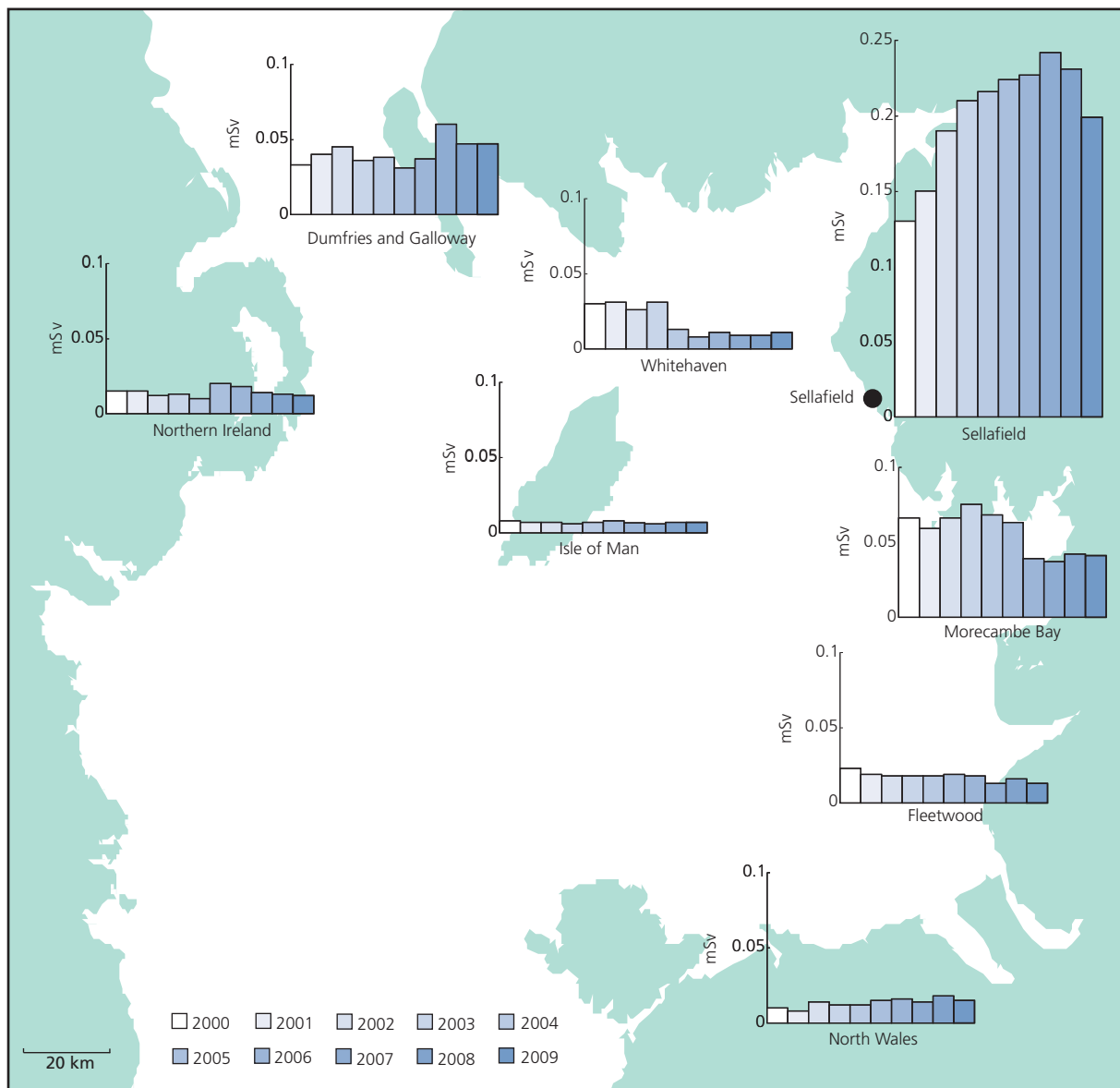


Figure 2.23. Individual radiation exposures to seafood consumers from artificial radionuclides in the Irish Sea, 2000-2009

seafood, their effect is relatively minor. All doses were well within the dose limit for members of the public of 1 mSv.

The dose to people, who typically consume 15 kg of fish per year from landings at Whitehaven and Fleetwood, is also given in Table 2.18. This consumption rate represents an average for a typical seafood consumer in Cumbria. The dose to such a person was very low, less than 0.005 mSv in 2009.

The environmental impact associated with the increased caesium-137 detected in indigenous brown trout from the River Calder, which flows through the Sellafield site, was assessed. Using a consumption rate of 2.3 kg y⁻¹ (information collected from the latest habits survey, for the River Calder), the dose to consumers was 0.009 mSv or less than 1 per cent of the dose limit.

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 people, 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 2009 are given in Table 2.9. The results of the assessment of external exposure pathways are included in Table 2.18. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, are received by people who live in houseboats in the Ribble Estuary in Lancashire. In 2009, their dose was 0.13 mSv or 13 per cent of the dose limit for members of the public (see Section 2.2). Other people received lower external doses in 2009. The most important of these was found in the Ravenglass estuary, where exposures are represented by the occupancy of a nature warden, and the dose was 0.048 mSv. In 2008, this dose was 0.046 mSv. Overall, gamma dose rate measurements were lower than in 2008 in the Ravenglass estuary, however the increase in dose in 2009 was due to the inclusion of new habits data, resulting in an increase in occupancy rates (see Appendix 1). Prior to 2008, doses in areas relevant to the Ravenglass nature warden have remained broadly similar over recent years (Figure 2.4).

In 2009, the estimated dose to wildfowls along the Dumfries and Galloway coast, including their external dose from occupancy over salt marshes, was just less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.18). No wildfowl were sampled in 2009 and estimates of activity concentrations have been based on earlier data. The decrease in dose from 0.005 mSv in 2008 was attributed to a small reduction in measured dose rates at Skyreburn Bay.

The doses to people from a number of other activities were also estimated in 2009. Assessments were undertaken for typical residents using local intertidal areas for recreational purposes, and for the typical tourist visiting the coast of Cumbria. The use by residents for two different environments, at a number of locations at a distance from the Sellafield influence, have been assessed; residents that visit and use beaches and residents that visit local muddy areas or salt marsh. Typical occupancy rates have been assumed and appropriate gamma dose rates used from Table 2.9. The activities for the typical tourist included consumption of local seafood and occupancy on beaches. Typical occupancy rates have been assumed, concentrations of radioactivity in fish and shellfish used from Table 2.5, and appropriate gamma dose rates used from Table 2.9. The consumption and occupancy rates for activities of typical residents and tourists are provided in Appendix 1.

The dose to people from recreational use of beaches varied from 0.007 to 0.013 mSv with the higher doses being closer to the Sellafield source. The equivalent doses for use of salt marsh and muddy areas had a greater variation from <0.005 to 0.018 mSv but were of a similar order of magnitude. The values for these activities were generally similar to those for 2008. These doses are given spatially in Figure 2.24. The dose to the typical tourist visiting the coast of Cumbria, including a contribution from external exposure, was estimated to be less than 0.005 mSv (and similar to that of 0.005 mSv in 2008).

Doses from handling fishing gear and sediment

Exposures can also arise from contact with beta-emitters during handling of sediments, or fishing gear on which fine particulates have become entrained. Habits surveys keep under review the amounts of time spent by fishermen handling their fishing gear, and by bait diggers and shellfish collectors handling sediment. For those most exposed, rates for handling nets, pots and sediments are provided in Appendix 1. The skin dose to fishermen from handling their gear in 2009, including a component due to naturally-occurring radiation, was 0.061 mSv, which was less than 0.5 per cent of the appropriate annual dose limit of 50 mSv specifically for skin. The skin dose to bait diggers and shellfish collectors, from handling sediment was 0.043 mSv in 2009 which was also less than 0.5 per cent of the skin dose limit. Therefore, both handling of fishing gear and sediments continued to be minor pathways of radiation exposure.

Doses from atmospheric sea to land transfer

At Ravenglass, the infant age group received the highest dose from consuming terrestrial foods that were potentially affected by radionuclides transported to land by sea spray. In 2009, their dose (including contributions from Chernobyl and weapon test fallout) was estimated to be 0.012 mSv, which was approximately 1 per cent of the dose limit for members of the public. The largest contribution of dose was from strontium-90 in milk and ruthenium-106 in fruit. The ruthenium-106 concentration was at the LoD. This represents a small decrease in the dose in comparison to the value obtained in 2008 (0.014 mSv). The decrease in dose in 2009 was mostly attributed to lower concentrations of carbon-14 in milk. Sea-to-land transfer therefore is not of radiological importance in the Ravenglass area.

Doses from seaweed and seawashed pasture

Although small quantities of samphire, *Porphyra* and *Rhodomenia* (a red seaweed) may be eaten, the dose to people in South Wales who consume laverbread at high-rates was 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 2009 (as in 2008) was estimated to be 0.009 mSv. Unlike in 2008, the adult age group received the highest dose, in 2009. The change in the critical age group from infants to adults was due to the relative contributions resulting from a small decrease in technetium-99 concentrations in cabbage and an increase in the LoD for americium-241 in potatoes. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales are

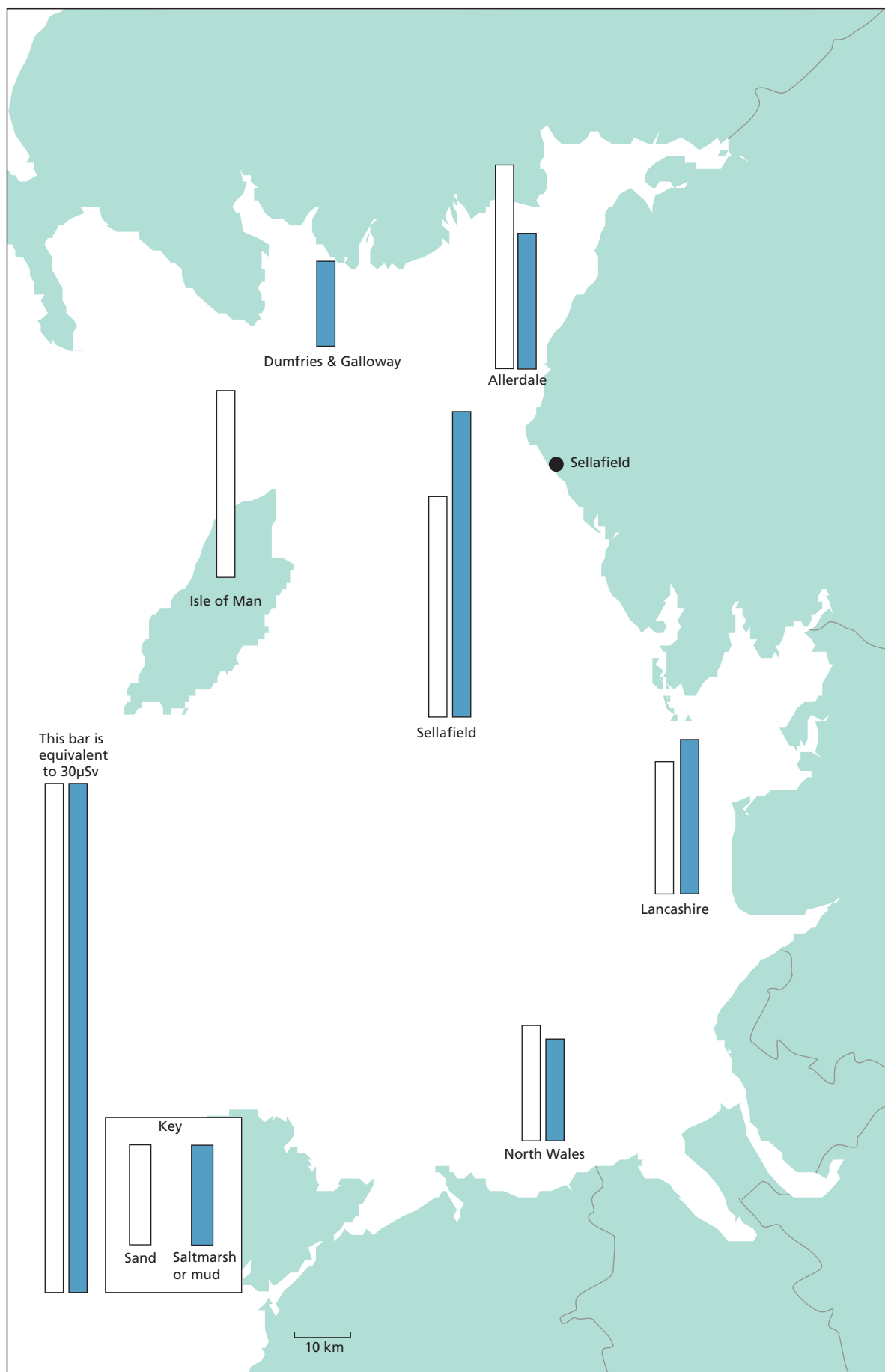


Figure 2.24. Individual radiation exposures to typical residents visiting beaches and other intertidal areas, 2009

expected to be much lower than near Sellafield. Exposure of vegetable consumers at Hinkley Point is given in Section 4.6. The seaweed/vegetable pathway will be kept under review but it is likely that the doses due to direct consumption of seafood and external radiation from intertidal areas will remain more important.

Animals may graze on seaweeds on beaches in coastal areas. However, there is no evidence of this taking place significantly near Sellafield. The Food Standards Agency undertook an assessment of the potential dose to a high-rate consumer of meat and liver from sheep grazing the seaweed using data relevant to the Shetlands and Orkneys. This showed that doses would have been well within the dose limit of 1 mSv per year for members of the public in 1998 when concentrations of technetium-99 would have been at substantially higher levels than in 2008 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999).

In the Scottish islands and coastal communities, seaweed is also eaten directly by sheep and cattle grazing on the foreshore. A research study, conducted by the HPA on behalf of the Food Standards Agency and SEPA, investigated the potential transfer of radionuclides from seaweed to meat products and also from crops grown on land where seaweed had been applied as a soil conditioner (Brown *et al.*, 2009). The study concluded that the highest levels of dose to people using seaweed, as a soil conditioner or an animal feed, were in the range of a few microsieverts and the majority of the doses are at least a factor of 100 lower. The report is available on SEPA website http://www.sepa.org.uk/radioactive_substances/publications/other_reports.aspx

Investigations by the Food Standards Agency have shown that this transfer pathway does not take place to a significant extent in the Sellafield area.

Doses from all sources

The *total dose* from all sources (discharges and direct radiation, using methods in Appendix 4) has been assessed using consumption and occupancy data from the full habits survey of 2008 and the review in 2009. The maximum dose was received by people, who consume molluscs at high-rates, and in 2009 this was assessed to be 0.28 mSv or 28 per cent of the dose limit to members of the public. This represents a

considerable decrease in the dose in 2008 (0.47 mSv), and this is mainly due to lower concentrations of natural radionuclides in molluscs and crustaceans. The *total dose* was made up of 0.15 mSv from radionuclides discharged by Sellafield, and 0.14 mSv from enhanced natural radionuclide concentrations (mainly polonium-210) from the legacy of past discharges from the now closed phosphate plant near Whitehaven. In 2008, the enhanced natural activity alone was assessed to be 0.29 mSv.

2.4 Windscale, Cumbria



Windscale is a separate licensed site located on the Sellafield site. The NDA has ownership of the site. In 2008, the Windscale permit was transferred from UKAEA to Sellafield Limited, and combined with the Sellafield site licence.

Windscale comprises of three reactors, two of which were shut down in 1957 and the third in 1981. Most of the radioactive wastes derive from decontamination and decommissioning operations, some of which are of the early Windscale reactor buildings. Decommissioning activities began in the mid 1980s. These activities are expected to continue until 2015, at which stage all nuclear facilities will be in a passively safe condition, with final closure of the site to be completed by 2065. Gaseous wastes are regulated from specific stacks on the Windscale site; liquid radioactive wastes are disposed of, after appropriate treatment, to the Irish Sea via the Sellafield site pipelines. Both gaseous and liquid discharges are included as part of the regulated Sellafield discharges (Appendix 2). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from the rest of the Sellafield site.

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

Table 2.1. Individual radiation exposures Capenhurst and Springfields, 2009

Site	Exposed population ^a	Exposure, mSv per year					
		Total	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Capenhurst	Consumers of locally grown food ^{b,e}	<0.005	-	<0.005	-	-	<0.005
	Children playing at Rivacre Brook ^{d,e}	0.012	-	-	0.011	<0.005	-
	All sources ^{d,f}	0.19	-	-	-	-	-
Springfields	Seafood consumers	0.022	0.007	-	0.015	-	-
	Houseboat occupants	0.13	-	-	0.13	-	-
	Fishermen handling nets or pots ^c	0.062	-	-	0.062	-	-
	Children playing at Lower Penwortham ^{d,e}	<0.005	-	-	<0.005	<0.005	-
	Farmers and wildfowlers	0.036	-	-	0.036	-	-
	Consumers of locally grown food ^e	<0.005	-	<0.005	-	-	<0.005
	All sources ^f	0.15	-	-	-	-	-

^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, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							
			³ H	⁶⁰ Co	⁹⁹ Tc	¹²⁵ Sb	¹³⁷ Cs	²³⁴ Th	²³⁴ U	²³⁵ U
Marine samples										
Flounder	Liverpool Bay	2	<25							
Flounder	Mersey Estuary	2	<25							
Shrimps	Wirral	2	<38	<0.05	0.21	<0.12	1.3			
Mussels	Liverpool Bay	2	<25							
Mussels	Mersey Estuary	2	<25							
Cockles	River Dee	4		<0.09	1.7	<0.20	1.6	<23		
Sediment	Rivacre Brook	2 ^E			450		4.3	150	250	9.1
Sediment	Rivacre Brook	2 ^E			45		2.2	<19	29	1.2
	(1.5 km downstream)									
Sediment	Rossmore	2 ^E			43		<1.2	<9.8	27	1.1
	(3.1 km downstream)									
Sediment	Rivacre Brook	2 ^E			18		<0.96	<15	16	0.79
	(4.3 km downstream)									
Freshwater	Rivacre Brook	2 ^E	<4.0		<0.42				0.15	<0.0080
Freshwater	Rivacre Brook	2 ^E	<4.0		<0.30				0.11	<0.0060
	(1.5 km downstream)									
Freshwater	Rossmore	2 ^E	<4.0		<0.35				0.11	<0.0055
	(3.1 km downstream)									
Freshwater	Rivacre Brook	2 ^E	<4.0		<0.35				0.12	<0.0065
	(4.3 km downstream)									
Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							
			²³⁸ U	²³⁷ Np	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha
Marine samples										
Shrimps	Wirral	2					<0.10			
Cockles	River Dee	4			0.14	0.79	2.1	*	0.0023	
Sediment	Rivacre Brook	2 ^E	120	<2.0						500 1300
Sediment	Rivacre Brook	2 ^E	20	<1.5						200 470
	(1.5 km downstream)									
Sediment	Rossmore	2 ^E	18	<1.5						<220 650
	(3.1 km downstream)									
Sediment	Rivacre Brook	2 ^E	11	<1.5						140 530
	(4.3 km downstream)									
Freshwater	Rivacre Brook	2 ^E	0.085	<0.15						<0.070 0.47
Freshwater	Rivacre Brook	2 ^E	0.063	<0.15						<0.17 0.42
	(1.5 km downstream)									
Freshwater	Rossmore	2 ^E	0.058	<0.15						<0.12 0.38
	(3.1 km downstream)									
Freshwater	Rivacre Brook	2 ^E	0.063	<0.15						<0.15 0.43
	(4.3 km downstream)									

Table 2.2(a). continued

Material	Location or selection ^b	No. of sampling observations ^d	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H ^c	⁹⁹ Tc	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U
Terrestrial samples								
Milk		5	<3.1	<0.0040		<0.0011	<0.00062	<0.00086
Milk		max	<3.5			0.0013	<0.00080	0.0011
Cabbage		1				<0.0015	<0.00070	<0.0013
Gooseberries		1		<0.027		0.016	<0.00050	0.016
Potatoes		1		<0.029		0.0034	<0.00050	0.0017
Grass		4		<0.0095		0.012	<0.00095	0.012
Grass		max		0.013		0.026	0.0020	0.029
Grass/herbage	North of Ledsham	1 ^E		1.4	<1.8	<1.2	<0.50	<1.0
Grass/herbage	South of Capenhurst	1 ^E		<2.0		<0.40	<0.20	<0.40
Grass/herbage	Off lane from	1 ^E		<2.0		<0.40	<0.30	<0.30
	Capenhurst to Dunkirk							
Grass/herbage	East of station	1 ^E		<0.58		<0.50	<0.090	<0.20
Silage		2		<0.0095		0.31	0.013	0.31
Silage		max				0.54	0.022	0.54
Soil		1 [#]				13	0.49	12
Soil	North of Ledsham	1 ^E		<5.0	22	19	0.88	20
Soil	South of Capenhurst	1 ^E		5.7		17	<2.0	18
Soil	Off lane from	1 ^E		4.2		15	<1.3	15
	Capenhurst to Dunkirk							
Soil	East of station	1 ^E		<2.7		19	<1.0	19

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹, and for soil and sediment where dry concentrations apply (except for those soil samples marked with a # which are fresh concentrations)

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

^c In distillate fraction of sample

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

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

[#] Fresh concentrations

Location	Ground type	No. of sampling observations	μGy h ⁻¹
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Mud and grass	1	0.10
Rivacre Brook Plant outlet	Concrete and grass	1	0.10
Rivacre Brook 1.5 km downstream	Grass and mud	1	0.086
Rivacre Brook 1.5 km downstream	Grass	1	0.086
Rossmore Road West 3.1 km downstream	Grass and mud	1	0.085
Rossmore Road West 3.1 km downstream	Grass and stones	1	0.087
Rivacre Brook 4.3 km downstream	Mud and grass	1	0.085
Rivacre Brook 4.3 km downstream	Mud and vegetation	1	0.081

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
			³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁹ Tc	¹²⁵ Sb	¹²⁹ I	¹³⁷ Cs
Marine samples										
Flounder	Ribble Estuary	1			<0.16			<0.42		3.4
Bass	Ribble Estuary	1			<0.12			<0.25		5.8
Grey mullet	Ribble Estuary	2			<0.09			<0.21		2.5
Shrimps	Ribble Estuary	2		69	<0.06		0.26	<0.15		2.0
Mussels	Ribble Estuary	2			<0.07			<0.18		0.97
Wild fowl	Ribble Estuary	1	<25	36	<0.07	0.15		<0.19	<2.0	1.4
Samphire	Marshside Sands	1			<0.07			<0.14		0.42
Sediment	River Ribble outfall	4 ^E			<0.91					110
Sediment	Savick Brook	2 ^E			<1.6					260
Sediment	Lea Gate	2 ^E			<1.7					240
Sediment	Lower Penwortham Park	4 ^E			<1.7					170
Sediment	Penwortham rail bridge	4 ^E			<1.6					250
Sediment	Penwortham rail bridge	2 ^E			<0.81					140
	- West bank									
Sediment	Penwortham position 1	4 ^E			<1.1					130
Sediment	Penwortham position 2	1 ^E			<0.37					24
Sediment	Lytham Yacht Club	1 ^E			<1.9					230
Sediment	Beaconsall	4 ^E			<1.0					180
Sediment	Freckleton	1 ^E			<1.3					290
Sediment	Hutton Marsh	1 ^E			<0.58					590
Sediment	Longton Marsh	1 ^E			<1.4					440
Grass	Hutton Marsh	1 ^E					3.6			
Soil	Hutton Marsh	1 ^E					55			

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
			²²⁸ Th	²³⁰ Th	²³² Th	²³⁴ Th	²³⁴ U	²³⁵ U	²³⁸ U	²³⁷ Np
Marine samples										
Flounder	Ribble Estuary	1				*				
Bass	Ribble Estuary	1				*				
Grey mullet	Ribble Estuary	2				*				
Shrimps	Ribble Estuary	2	0.0052	0.0023	0.0017	*				0.00017
Mussels	Ribble Estuary	2	0.00097	0.16	0.17	*				
Wild fowl	Ribble Estuary	1	0.0047	0.0084	0.0020	*				
Samphire	Marshside Sands	1				*				
Sediment	River Ribble outfall	4 ^E	17	51	18	<410	18	<1.4	17	
Sediment	Savick Brook	2 ^E	37	92	32	2200	29	<2.2	29	
Sediment	Lea Gate	2 ^E	32	88	25	2000	30	<1.8	29	
Sediment	Lower Penwortham Park	4 ^E	28	88	26	1300	26	<1.8	25	
Sediment	Penwortham rail bridge	4 ^E	33	110	30	1500	27	<2.0	28	
Sediment	Penwortham rail bridge	2 ^E	20	65	18	1200	21	<2.0	21	
- West bank										
Sediment	Penwortham position 1	4 ^E	27	83	24	290	23	<1.5	22	
Sediment	Penwortham position 2	1 ^E	13	23	12	69	14	<2.0	14	
Sediment	Lytham Yacht Club	1 ^E	31	77	30	500	24	<2.0	24	
Sediment	Beaconsall	4 ^E	26	52	22	310	19	<1.7	20	
Sediment	Freckleton	1 ^E	26	27	12	360	29	<2.0	27	
Sediment	Hutton Marsh	1 ^E	24	160	30	46	34	1.2	33	
Sediment	Longton Marsh	1 ^E	42	230	37	<24	31	1.1	28	

Table 2.3(a). continued

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹						
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples									
Flounder	Ribble Estuary	1			<0.33				
Bass	Ribble Estuary	1			<0.10				
Grey mullet	Ribble Estuary	2			<0.09				
Shrimps	Ribble Estuary	2	0.0011	0.0068	0.012	0.000056	*		
Mussels	Ribble Estuary	2			0.88				
Wild fowl	Ribble Estuary	1	0.0011	0.0080	0.013	*	*		
Samphire	Marshside Sands	1			0.11				
Sediment	River Ribble outfall	4 ^E			79			450	1000
Sediment	Savick Brook	2 ^E			86			630	3700
Sediment	Lea Gate	2 ^E			160			600	3300
Sediment	Lower Penwortham Park	4 ^E			110			570	1700
Sediment	Penwortham rail bridge	4 ^E			170			530	2100
Sediment	Penwortham rail bridge	2 ^E			75			430	1500
	- West bank								
Sediment	Penwortham position 1	4 ^E			65			600	1300
Sediment	Penwortham position 2	1 ^E			24			350	830
Sediment	Lytham Yacht Club	1 ^E			170			530	1700
Sediment	Beconsall	4 ^E			120			560	1200
Sediment	Freckleton	1 ^E			220			480	1500
Sediment	Hutton Marsh	1 ^E			270			890	1700
Sediment	Longton Marsh	1 ^E			90			730	1500

Material	Location or selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹						
			³ H	¹⁴ C	⁹⁰ Sr	¹²⁹ I	¹³⁷ Cs	Total Cs	
Terrestrial samples									
Apples		1	<4.0	19	<0.0070	<0.028			0.062
Beetroot		1	<4.0	14	0.14	<0.028			0.051
Blackberries		1	<4.0	11	0.086	<0.054			0.034
Cabbage		1	<4.0	7.0	0.16	<0.029			0.040
Potatoes		1	<4.0	10	0.023	<0.023			0.030
Rabbit		1	<6.0	24	<0.0080	<0.050			0.66
Runner beans		1	<5.0	5.0	0.085	<0.032			0.05
Sediment	Deepdale Brook	2 ^E						<1.0	
Grass		1						0.78	

Table 2.3(a). continued

Material	Location or selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹						
			²²⁸ Th	²³⁰ Th	²³² Th	²³⁴ Th	²³⁴ U	²³⁵ U	²³⁸ U
Terrestrial samples									
Milk	Max	5					<0.00094	<0.00056	<0.00086
Milk						0.0016	<0.00080	<0.0011	
Apples		1		0.0052	<0.00070	0.0011	<0.00050	<0.0011	
Beetroot		1		0.015	0.012	0.020	<0.0020	0.019	
Blackberries		1		0.0023	<0.00090	0.0019	<0.00050	0.0012	
Cabbage		1		0.0093	0.0045	0.0078	0.00070	0.0059	
Potatoes		1		0.0027	<0.00090	<0.0011	<0.00080	0.0015	
Rabbit		1		0.0026	0.0021	0.0032	<0.0012	<0.0018	
Runner beans		1		<0.00090	<0.0011	0.0019	0.00050	0.00080	
Sediment	Deepdale Brook	2 ^E	24	40	18	<42	41	<1.6	43
Grass		1					0.085	0.0037	0.083
Grass	Site fence	1 ^E					0.82	<0.10	0.62
Grass	Opposite site entrance	1 ^E					3.0	<0.20	2.3
Grass	Opposite windmill	1 ^E					1.2	<0.20	1.1
Grass	Deepdale Brook	1 ^E					0.85	<0.20	0.79
Grass	Lea Town	1 ^E					0.86	<0.60	<0.40
Grass	N of Lea Town	1 ^E					0.29	<0.10	0.31
Silage		1					2.7	0.11	2.6
Soil		1 [#]					19	0.90	18
Soil	Site fence	1 ^E					81	2.7	75
Soil	Opposite site entrance	1 ^E					250	10	230
Soil	Opposite windmill	1 ^E					120	5.2	120
Soil	Deepdale Brook	1 ^E					55	2.6	58
Soil	Lea Town	1 ^E					180	7.8	130
Soil	N of Lea Town	1 ^E					49	1.8	50
Freshwater	Deepdale Brook	4 ^E					0.32	0.013	0.30

Material	Location or selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹					
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	Gross alpha	Gross beta
Terrestrial samples								
Apples		1	<0.00010	0.00020	<0.063	<0.00020		
Beetroot		1	<0.00010	0.00040	<0.072	<0.00020		
Blackberries		1	<0.00010	0.00030	<0.098	0.00080		
Cabbage		1	<0.00020	<0.00020	<0.057	<0.00050		
Potatoes		1	<0.00010	<0.00010	<0.059	<0.00020		
Rabbit		1	0.00020	0.0012	<0.074	0.0013		
Runner beans		1	<0.00020	<0.00020	<0.064	<0.00070		
Sediment	Deepdale Brook	2 ^E				1.1	460	1200
Grass		1				0.19		
Freshwater	Deepdale Brook	4 ^E					0.42	0.70

* Not detected by the method used

^a Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

^b Except for milk and freshwater where units are Bq l⁻¹ and for sediment and soil where dry concentrations apply (except for those soil samples marked with a # which are fresh concentrations)

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

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

Fresh concentrations

Table 2.3(b). Monitoring of radiation dose rates near Springfields, 2009

Location	Material or ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Lytham Yacht Club	Grass	1	0.097
Warton Mud Marsh	Salt marsh	1	0.13
Warton Mud Marsh	Grass and salt marsh	1	0.13
Warton Mud Marsh	Salt marsh ^a	1	0.13
Warton Mud Marsh	Grass and salt marsh ^a	1	0.13
Warton Salt Marsh	Salt marsh	1	0.090
Warton Salt Marsh	Grass and salt marsh	1	0.11
Freckleton	Grass	1	0.085
Naze Point	Salt marsh	1	0.11
Naze Point	Grass	1	0.12
Banks Marsh	Grass	2	0.12
Banks Marsh	Grass ^a	1	0.13
Hesketh Bank	Salt marsh and grass	1	0.12
Hesketh Bank	Grass	1	0.11
Becconsall Boatyard	Mud	3	0.089
Becconsall Boatyard	Grass	1	0.087
Becconsall (vicinity of houseboats)	Tarmac	2	0.080
Longton Marsh	Grass	1	0.13
Hutton Marsh	Grass	1	0.15
River Ribble outfall	Mud	1	0.097
River Ribble outfall	Grass and mud	2	0.10
River Ribble outfall	Grass	1	0.098
Savick Brook, confluence with Ribble	Grass and mud	1	0.097
Savick Brook, confluence with Ribble	Grass	1	0.094
Savick Brook, tidal limit	Grass and mud	2	0.10
Savick Brook, Lea Gate	Grass and mud	2	0.10
South bank opposite outfall	Grass	1	0.079
Penwortham Bridge cadet hut	Mud	2	0.10
Lower Penwortham Park	Grass	4	0.083
Lower Penwortham Railway Bridge	Mud	1	0.088
Lower Penwortham Railway Bridge	Mud and stones	3	0.088
River Darwen	Grass	4	0.084
Riverbank Angler location 1	Grass	4	0.079
Riverbank Angler location 2	Mud	1	0.086
Ulnes Walton, BNFL area survey	Grass	3	0.085
Mean beta dose rates			$\mu\text{Sv h}^{-1}$
Lytham – Granny's Bay	Sand	1	*
Ribble Estuary	Gill net	2	<0.045
Ribble Estuary	Shrimp net	2	0.18
Banks Marsh	Grass	2	<0.020
Warton Mud Marsh	Salt marsh	1	0.040
Warton Mud Marsh	Grass and salt marsh	1	0.060
Warton Salt Marsh	Salt marsh	1	0.040
Warton Salt Marsh	Grass and salt marsh	1	0.060

^a 15cm above substrate

* Not detected by the method used

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2009

Material	Selection ^a	No. of sampling observations ^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		17	<4.6	<4.6	16	<0.18	0.060	<0.0045	<1.2	<0.38	<0.0084
Milk	max		<5.3	<5.3	19	<0.20	0.15		<1.5	<0.43	<0.010
Apples		2	<4.5	<4.5	9.0	<0.15	0.094	<0.021	<1.2	<0.30	<0.022
Apples	max		<5.0	<5.0	10	<0.20	0.13		<1.4	<0.40	<0.023
Barley		1		<7.0	110	<0.10	1.4		<0.50	1.3	<0.036
Beef kidney		1	<8.0	<8.0	49	<0.20	0.60	<0.032	<2.0	<0.80	
Beef liver		1	<19	<9.0	30	<0.20	0.38	<0.028	<0.60	<0.40	<0.056
Beef muscle		1	<7.0	<7.0	28	<0.10	0.019	<0.021	<0.90	<0.20	<0.038
Blackberries		1	<11	11	16	<0.20	1.2		<1.6	<0.50	<0.036
Blackcurrants		1	<4.0	<4.0	24	<0.20	0.11		<1.4	<0.30	<0.055
Broccoli		1	<5.0	<5.0	8.0	<0.10	0.12		<0.60	<0.40	<0.022
Cabbage		1	<3.0	<4.0	4.0	<0.10	0.11		<1.6	<0.30	<0.022
Carrots		1	<4.0	<4.0	6.0	<0.10	0.15	<0.039	<1.3	<0.40	<0.026
Cauliflower		1	<4.0	<4.0	3.0	<0.10	0.065		<0.60	<0.30	<0.022
Deer muscle		1	<5.0	<5.0	22	<0.30	<0.021	<0.030	<2.0	<0.60	<0.030
Eggs		1	<3.0	<3.0	33	<0.10	0.036		<1.7	<0.40	<0.028
Elderberries		1	<5.0	<5.0	19	<0.20	0.36		<1.3	<0.50	<0.032
Mushrooms		1	<6.0	<6.0	10	<0.20	0.60		<0.50	<0.40	<0.044
Onions		1	<4.0	<4.0	6.0	<0.10	0.095		<1.1	<0.30	<0.023
Pheasants		1	<5.0	<5.0	27	<0.20	0.013	<0.032	<1.2	<0.20	<0.032
Potatoes		2	<5.0	<5.0	20	<0.30	0.030		<1.9	<0.45	<0.025
Potatoes	max				23		0.041		<2.1	<0.50	<0.027
Rabbit		1	<5.0	<5.0	24	<0.20	0.036	<0.029	<1.0	<0.40	<0.033
Runner beans		2	<3.0	<5.0	11	<0.20	0.13		<1.2	<0.35	<0.030
Runner beans	max		<4.0	6.0	13		0.15		<1.4	<0.40	<0.031
Sheep muscle		2	<6.0	<6.0	23	<0.15	0.035	<0.023	<1.2	<0.40	<0.031
Sheep muscle	max				30	<0.20		<0.026	<1.3		<0.038
Sheep offal		2	<7.5	<7.5	35	<0.25	0.22	<0.023	<1.5	<0.45	<0.035
Sheep offal	max		<8.0	<8.0	38	<0.30	0.23	<0.024		<0.50	<0.037
Sloe berries		1	<7.0	<4.0	23	<0.20	0.25		<1.3	<0.40	<0.048
Strawberries		1	6.0	10	8.0	<0.30	0.059		<1.6	<0.40	<0.029
Swede		1	<5.0	<5.0	9.0	<0.20	0.17		<1.5	<0.40	<0.041
Wheat		1		<8.0	110	<0.20	0.25		<1.5	<0.40	<0.058
Wood pigeon muscle		2	<5.0	<5.0	30	<0.15	0.046		<1.1	<0.35	<0.037
Wood pigeon muscle	max				33	<0.20	0.082		<1.4	<0.40	<0.041
Grass		5				<0.17		<0.023	<0.75	1.1	
Grass	max					<0.20		<0.025	<1.2	1.6	
Soil		3				<0.30			<1.1	<0.47	
Soil	max					0.50			<1.4	<0.70	

Table 2.4. continued

Material	Selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹									
			¹³⁷ Cs	Total Cs	²³⁴ U	²³⁵ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	
Milk	max	17	<0.22	0.18					<0.00010	<0.00013	<0.035	<0.00017
Milk			<0.34	0.33						<0.00017	<0.042	<0.00023
Apples	max	2		0.11					<0.00015	0.00075	<0.070	0.0015
Apples					0.12					0.00020	0.0011	<0.071
Barley		1		0.42					0.0024	0.042	<0.075	0.015
Beef kidney		1		0.58	0.011	<0.0011	0.0095		0.00020	0.00020	<0.12	<0.00040
Beef liver		1		0.54					0.00020	0.0032	<0.071	0.0018
Beef muscle		1		0.89					<0.00020	0.00020	<0.065	<0.00030
Blackberries		1		0.41					0.00030	0.0010	<0.061	0.00090
Blackcurrants		1		0.10					0.00010	0.00070	<0.049	0.0016
Broccoli		1		0.11					0.00010	0.00030	<0.058	<0.00020
Cabbage		1		0.031					<0.00020	<0.00020	<0.071	<0.00030
Carrots		1		0.097								
Cauliflower		1		0.062	0.0026	<0.00040	0.0011		<0.00010	<0.00010	<0.060	<0.00020
Deer muscle		1		86					<0.00020	<0.00030	<0.074	<0.00030
Eggs		1		0.094					<0.00010	<0.00010	<0.046	0.00020
Elderberries		1		0.26					0.0010	0.0036	<0.066	0.0085
Mushrooms		1		0.26					0.0016	0.0096	<0.065	0.024
Onions		1		0.046								
Pheasants		1		0.42					<0.00010	<0.00030	<0.10	<0.00040
Potatoes	max	2		0.11	<0.00060	0.00050	0.0013					
Potatoes					0.14							
Rabbit		1		2.2					<0.00010	0.00030	<0.11	0.0014
Runner beans	max	2		0.11					<0.00015	0.00085	<0.055	0.0018
Runner beans					0.19				<0.00020	0.0010	<0.057	0.0020
Sheep muscle	max	2		1.1					<0.00025	<0.00025	<0.082	<0.00045
Sheep muscle					1.3				<0.00030	<0.00030	<0.087	0.00060
Sheep offal	max	2		0.80	<0.0022	<0.0010	0.0018		0.00050	0.0018	<0.096	0.0015
Sheep offal						0.0026		0.0019		0.0026	<0.097	0.0018
Sloe berries		1		0.32					0.00030	0.0011	<0.085	0.0022
Strawberries		1		0.042					<0.00010	0.00010	<0.052	0.00070
Swede		1		0.080								
Wheat		1		0.24					0.00030	0.00070	<0.10	0.0029
Wood pigeon muscle	max	2		1.2					<0.00010	<0.00050	<0.086	<0.00045
Wood pigeon muscle					2.2					0.00070	<0.096	0.00060
Grass	max	5		2.5								
Grass					9.0							
Soil	max	3		82	14	0.72	14					7.0
Soil					140							

^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 ¹³¹I was <0.0045 (max <0.0052) Bq l⁻¹

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹							
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc
Cumbria										
Maryport	Plaice	4				<0.11		<0.41	<0.54	
Parton	Cod	3				<0.09		<0.30	<0.38	
Whitehaven	Cod	4			82	<0.11	0.067	<0.37	<0.44	
Whitehaven	Plaice	4				<0.11	0.11	<0.45	<0.78	
Whitehaven	Skates / rays	4				<0.12		<0.47	<0.61	
Whitehaven	Sole	4				<0.16		<0.60	<0.87	
River Ehen	Salmon	1				<0.09		<0.35	<0.52	
Sellafield coastal area	Cod	8				<0.12		<0.46	<0.67	
Sellafield coastal area	Plaice	4	<56	62		<0.10		<0.32	<0.41	
Sellafield coastal area	Bass	1				<0.13		<0.55	<0.80	
Sellafield coastal area	Grey mullet	1				<0.13		<0.66	<0.94	
Sellafield offshore area	Cod	2			110	<0.12	0.089	<0.42	<0.50	<0.50
Sellafield offshore area	Plaice ^a	2			140	<0.12	<0.036	<0.44	<0.61	2.9
Sellafield offshore area	Dab	1				<0.14		<0.46	<0.71	
Sellafield offshore area	Lesser spotted dogfish	2				<0.21		<1.3	<0.63	
Sellafield offshore area	Skates / rays	2				<0.18		<0.81	<1.4	
Sellafield offshore area	Turbot	1				<0.11		<0.51	<0.71	
River Calder	Brown trout	1				<0.43		<2.7	<6.9	
Ravenglass	Cod	6				<0.11		<0.48	<0.73	
Ravenglass	Plaice	4	120	120		<0.08		<0.24	<0.28	
Morecambe Bay (Flookburgh)	Flounder	3			85	<0.10		<0.58	<1.3	
Morecambe Bay (Flookburgh)	Plaice	1				<0.10		<0.26	<0.26	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.11		<0.53	<0.94	
Morecambe Bay (Morecambe)	Bass	2				<0.11		<0.41	<0.55	
Morecambe Bay (Morecambe)	Flounder	4	<25	<25		<0.09	0.038	<0.46	<0.75	0.29
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.09	0.082	<1.1	*	
Fleetwood	Cod	4			56	<0.07	0.083	<0.29	<0.38	<0.19
Fleetwood	Plaice	4				<0.06		<0.24	<0.36	
Ribble Estuary	Grey mullet	2				<0.09		<0.41	<0.68	
Ribble Estuary	Flounder	1				<0.16		<1.1	<2.1	
Ribble Estuary	Bass	1				<0.12		<0.47	<0.68	
Liverpool Bay	Flounder	2		<25						
Mersey Estuary	Flounder	2		<25						
Scotland										
Shetland	Fish meal	2				<0.25	0.83	<0.90	<1.1	
Shetland	Fish oil	2				<0.11		<0.46	<0.60	
Minch	Herring	1				<0.11		<0.40	<0.49	
Minch	Mackerel	1			66	<0.12	<0.062	<2.7	*	
West of Scotland	Mackerel	1				<0.14		<4.0	*	
West of Scotland	Farmed salmon	1				<0.11		<0.55	<0.88	
Dumfries	Lemon sole	2 ^s			19	<0.10		<0.19		0.63
Inner Solway	Flounder	4 ^s			<15	<0.10	<0.10	<0.35	<0.37	0.43
Inner Solway	Salmon	1 ^s		<5.0		<0.10		<0.13	<0.11	
Inner Solway	Sea trout	1 ^s		<5.0		<0.10		<0.11	<0.10	

Table 2.5. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹						Gross beta
			¹⁰⁶ Ru	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁵⁵ Eu	
Cumbria									
Maryport	Plaice	4	<0.97	<0.23	<0.10	3.1	<0.44	<0.18	
Parton	Cod	3	<0.86	<0.23	<0.09	6.6	<0.44	<0.20	
Whitehaven	Cod	4	<0.99	<0.26	<0.11	6.3	<0.47	<0.22	
Whitehaven	Plaice	4	<0.99	<0.24	<0.11	4.0	<0.44	<0.20	
Whitehaven	Skates / rays	4	<1.3	<0.31	<0.13	4.8	<0.65	<0.29	
Whitehaven	Sole	4	<1.6	<0.34	<0.16	3.1	<0.58	<0.23	
River Ehen	Salmon	1	<0.85	<0.20	<0.08	0.21	<0.39	<0.15	
Sellafield coastal area	Cod	8	<1.1	<0.30	<0.12	8.1	<0.59	<0.26	210
Sellafield coastal area	Plaice	4	<0.84	<0.20	<0.09	3.3	<0.36	<0.14	150
Sellafield coastal area	Bass	1	<1.3	<0.28	<0.13	7.1	<0.50	<0.20	
Sellafield coastal area	Grey mullet	1	<1.4	<0.39	<0.14	4.8	<0.91	<0.37	
Sellafield offshore area	Cod	2	<1.2	<0.30	<0.12	5.5	<0.60	<0.28	
Sellafield offshore area	Plaice ^a	2	<1.0	<0.29	<0.11	3.9	<0.56	<0.26	
Sellafield offshore area	Dab	1	<1.2	<0.29	<0.11	3.3	<0.56	<0.19	
Sellafield offshore area	Lesser spotted dogfish	2	<2.3	<0.45	<0.22	5.3	<0.83	<0.28	
Sellafield offshore area	Skates / rays	2	<1.9	<0.41	<0.19	8.1	<0.68	<0.28	
Sellafield offshore area	Turbot	1	<1.2	<0.33	<0.13	7.0	<0.67	<0.30	
River Calder	Brown trout	1	<5.7	<1.9	<0.46	300	<2.2	<0.79	
Ravenglass	Cod	6	<1.1	<0.29	<0.11	7.6	<0.58	<0.27	
Ravenglass	Plaice	4	<0.69	<0.19	<0.07	4.1	<0.38	<0.17	
Morecambe Bay (Flookburgh)	Flounder	3	<0.99	<0.27	<0.10	12	<0.50	<0.20	
Morecambe Bay (Flookburgh)	Plaice	1	<0.84	<0.23	<0.09	7.0	<0.34	<0.15	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<1.1	<0.25	<0.11	6.0	<0.48	<0.19	
Morecambe Bay (Morecambe)	Bass	2	<1.1	<0.27	<0.10	8.4	<0.54	<0.24	
Morecambe Bay (Morecambe)	Flounder	4	<0.93	<0.24	<0.10	6.8	<0.45	<0.18	
Morecambe Bay (Sunderland Point)	Whitebait	1	<1.1	<0.25	<0.10	4.4	<0.61	<0.22	
Fleetwood	Cod	4	<0.72	<0.19	<0.08	5.4	<0.36	<0.17	
Fleetwood	Plaice	4	<0.59	<0.15	<0.06	3.3	<0.32	<0.14	
Ribble Estuary	Grey mullet	2	<0.85	<0.21	<0.09	2.5	<0.41	<0.16	
Ribble Estuary	Flounder	1	<2.0	<0.42	<0.18	3.4	<0.95	<0.36	
Ribble Estuary	Bass	1	<1.1	<0.25	<0.11	5.8	<0.43	<0.18	
Scotland									
Shetland	Fish meal	2	<2.4	<0.55	<0.26	0.88	<1.0	<0.42	
Shetland	Fish oil	2	<1.1	<0.31	<0.12	<0.11	<0.73	<0.30	
Minch	Herring	1	<1.0	<0.23	<0.11	0.29	<0.42	<0.18	
Minch	Mackerel	1	<1.6	<0.33	<0.14	0.08	<0.89	<0.31	
West of Scotland	Mackerel	1	<1.9	<0.32	<0.16	<0.12	<0.80	<0.23	
West of Scotland	Farmed salmon	1	<1.1	<0.23	<0.11	0.24	<0.43	<0.17	
Dumfries	Lemon sole	2 ^S	<0.60	<0.17	<0.10	<0.10	<0.34	<0.17	
Inner Solway	Flounder	4 ^S	<0.77	<0.23	<0.10	13	<0.46	<0.20	
Inner Solway	Salmon	1 ^S	<0.42	<0.12	<0.10	0.28	<0.31	<0.15	
Inner Solway	Sea trout	1 ^S	<0.43	<0.12	<0.10	2.1	<0.26	<0.14	

Table 2.5. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹							
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc
Isle of Man										
Isle of Man	Cod	4				<0.07		<0.29	<0.44	
Isle of Man	Mackerel	4				<0.12		<0.62	<1.1	
Wales										
North Anglesey	Thornback ray	2				<0.12		<0.52	<0.83	
North Anglesey	Lesser spotted dogfish	2				<0.07		<0.54	<0.18	
North Anglesey	Plaice	2	<25	<25	41	<0.09		<0.36	<0.46	
North Anglesey	Bass	1				<0.08		<0.32	<0.51	
Northern Ireland										
North coast	Spurdog	4 ^N				<0.08		<0.34	<0.52	
Ardglass	Herring	2 ^N				<0.10		<0.75	<1.6	
Kilkeel	Cod	4 ^N			40	<0.06		<0.26	<0.37	
Kilkeel	Plaice	4 ^N				<0.06		<0.37	<0.70	
Kilkeel	Spurdog	4 ^N				<0.13		<0.68	<1.2	
Kilkeel	Haddock	4 ^N				<0.07		<0.38	<0.70	
Glenarm	Sea trout	1				<0.06		<0.23	<0.28	<0.66
Further afield										
Baltic Sea	Cod	2				<0.08		<0.29	<0.38	
Baltic Sea	Herring	2				<0.08		<0.33	<0.43	
Barents Sea	Cod	2				<0.07		<0.45	<1.0	
Norwegian Sea	Cod	1				<0.07		<0.31	<0.52	
Norwegian Sea	Herring	1				<0.07		<0.19	<0.18	
Norwegian Sea	Mackerel	1				<0.11		<0.23	<0.20	
Norwegian Sea	Saithe	1				<0.04		<0.23	<0.43	
Norwegian processed	Cod	1			28	<0.04		<0.44	*	
Iceland area	Cod	1				<0.07		<0.64	*	
Skagerrak	Cod	2				<0.06		<0.34	<0.67	
Skagerrak	Herring	2				<0.08		<0.49	<0.94	
Northern North Sea	Plaice	2				<0.05		<0.29	<0.57	
Northern North Sea	Haddock	2			25	<0.08		<0.44	<0.80	
Northern North Sea	Herring	1				<0.12		<0.62	<1.1	
Northern North Sea	Whiting	2				<0.05	0.034	<0.18	<0.23	
Mid North Sea	Cod	2			17	<0.04	0.048	<0.16	<0.22	
Mid North Sea	Plaice	2			29	<0.05	0.051	<0.24	<0.35	
Gt Yarmouth (retail shop)	Cod	2				<0.04		<0.17	<0.26	
Gt Yarmouth (retail shop)	Plaice	2				<0.06		<0.29	<0.53	
Southern North Sea	Cod	2				<0.05	0.046	<0.20	<0.27	
Southern North Sea	Plaice	1				<0.04	0.056	<0.16	<0.23	
Southern North Sea	Dab	1				<0.06		<0.41	<0.82	
Southern North Sea	Herring	1				<0.10		<1.7	*	
English Channel-East	Plaice	2				<0.07		<0.48	<1.1	
English Channel-East	Whiting	2				<0.05		<0.27	<0.49	
English Channel-West	Plaice	2			14	<0.06		<0.47	<0.08	
English Channel-West	Mackerel	2				<0.08		<0.32	<0.47	
English Channel-West	Whiting	2				<0.07		<0.39	<0.75	
Celtic Sea	Cod	2			35	<0.07	0.057	<0.35	<0.56	
Celtic Sea	Haddock	2				<0.06		<0.26	<0.42	
Northern Irish Sea	Dab	1				<0.07		<0.48	<1.0	
Northern Irish Sea	Lesser spotted dogfish	1				<0.18		<0.75	<1.2	
Northern Irish Sea	Skates / rays	1				<0.06		<0.43	<0.78	

Table 2.5. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹					
			¹⁰⁶ Ru	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁵⁵ Eu
Isle of Man								
Isle of Man	Cod	4	<0.63	<0.15	<0.07	3.1	<0.32	<0.14
Isle of Man	Mackerel	4	<1.2	<0.26	<0.12	1.4	<0.50	<0.20
Wales								
North Anglesey	Thornback ray	2	<1.1	<0.24	<0.11	1.2	<0.41	<0.15
North Anglesey	Lesser spotted dogfish	2	<0.74	<0.17	<0.07	1.8	<0.44	<0.17
North Anglesey	Plaice	2	<0.98	<0.20	<0.10	1.2	<0.35	<0.14
North Anglesey	Bass	1	<0.69	<0.17	<0.08	3.9	<0.28	<0.12
Northern Ireland								
North coast	Spurdog	4 ^N	<0.80	<0.18	<0.08	1.8	<0.40	<0.17
Ardglass	Herring	2 ^N	<1.1	<0.25	<0.11	1.0	<0.66	<0.26
Kilkeel	Cod	4 ^N	<0.60	<0.15	<0.06	1.2	<0.32	<0.14
Kilkeel	Plaice	4 ^N	<0.63	<0.14	<0.06	0.51	<0.34	<0.13
Kilkeel	Spurdog	4 ^N	<1.3	<0.28	<0.13	1.6	<0.54	<0.21
Kilkeel	Haddock	4 ^N	<0.71	<0.17	<0.07	0.88	<0.39	<0.17
Glenarm	Sea trout	1	<0.60	<0.15	<0.06	0.41	<0.35	<0.15
Further afield								
Baltic Sea	Cod	2	<0.72	<0.19	<0.08	7.6	<0.33	<0.14
Baltic Sea	Herring	2	<0.81	<0.21	<0.08	4.7	<0.41	<0.16
Barents Sea	Cod	2	<0.67	<0.15	<0.07	0.13	<0.36	<0.15
Norwegian Sea	Cod	1	<0.55	<0.11	<0.06	0.13	<0.19	<0.07
Norwegian Sea	Herring	1	<0.67	<0.17	<0.07	0.15	<0.38	<0.18
Norwegian Sea	Mackerel	1	<0.93	<0.23	<0.11	<0.11	<0.41	<0.20
Norwegian Sea	Saithe	1	<0.42	<0.10	<0.05	0.20	<0.28	<0.11
Norwegian processed	Cod	1	<0.49	<0.10	<0.05	0.17	<0.24	<0.08
Iceland area	Cod	1	<0.68	<0.15	<0.07	0.17	<0.39	<0.15
Skagerrak	Cod	2	<0.55	<0.12	<0.06	0.21	<0.26	<0.11
Skagerrak	Herring	2	<0.86	<0.18	<0.08	0.31	<0.39	<0.15
Northern North Sea	Plaice	2	<0.52	<0.12	<0.05	0.14	<0.27	<0.11
Northern North Sea	Haddock	2	<0.87	<0.19	<0.08	0.14	<0.44	<0.17
Northern North Sea	Herring	1	<1.2	<0.26	<0.13	<0.12	<0.49	<0.19
Northern North Sea	Whiting	2	<0.50	<0.12	<0.05	0.28	<0.25	<0.12
Mid North Sea	Cod	2	<0.39	<0.10	<0.04	0.31	<0.22	<0.09
Mid North Sea	Plaice	2	<0.56	<0.13	<0.06	0.12	<0.30	<0.13
Gt Yarmouth (retail shop)	Cod	2	<0.35	<0.08	<0.04	0.17	<0.15	<0.06
Gt Yarmouth (retail shop)	Plaice	2	<0.56	<0.12	<0.06	<0.05	<0.24	<0.09
Southern North Sea	Cod	2	<0.45	<0.10	<0.05	0.22	<0.20	<0.08
Southern North Sea	Plaice	1	<0.33	<0.07	<0.03	0.07	<0.16	<0.06
Southern North Sea	Dab	1	<0.65	<0.13	<0.07	<0.06	<0.27	<0.10
Southern North Sea	Herring	1	<1.2	<0.22	<0.12	<0.22	<0.50	<0.16
English Channel-East	Plaice	2	<0.71	<0.15	<0.08	<0.08	<0.30	<0.11
English Channel-East	Whiting	2	<0.49	<0.11	<0.05	0.22	<0.24	<0.11
English Channel-West	Plaice	2	<0.53	<0.11	<0.06	0.08	<0.24	<0.08
English Channel-West	Mackerel	2	<0.73	<0.18	<0.08	0.17	<0.38	<0.16
English Channel-West	Whiting	2	<0.67	<0.15	<0.07	0.25	<0.36	<0.16
Celtic Sea	Cod	2	<0.68	<0.17	<0.07	1.4	<0.39	<0.17
Celtic Sea	Haddock	2	<0.63	<0.15	<0.06	0.12	<0.36	<0.16
Northern Irish Sea	Dab	1	<0.75	<0.16	<0.08	0.87	<0.31	<0.12
Northern Irish Sea	Lesser spotted dogfish	1	<1.8	<0.36	<0.19	0.88	<0.62	<0.25
Northern Irish Sea	Skates / rays	1	<0.69	<0.17	<0.07	1.5	<0.47	<0.18

* Not detected by the method used

^a The concentrations of ¹²⁹I and ¹⁴⁷Pm were <1.8 and <0.040 Bq kg⁻¹ respectively

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

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

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹								
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru
Cumbria											
Silloth	Mussels	4		<25		0.29		<0.20	<0.20		<1.2
Silloth	Shrimps	4				<0.11		<0.41	<0.61		<0.97
Parton	Crabs	4				<0.25		<0.43	<0.64		<1.1
Parton	Lobsters	4				<0.12		<0.21	<0.28		<0.53
Parton	Winkles	4				1.2		<0.34	<0.33		7.8
Whitehaven	Nephrops	4			86	<0.09	0.082	<0.30	<0.37	43	<0.81
Whitehaven	Cockles	2				<0.05		<0.19	<0.27		<0.47
Whitehaven	Mussels	2				<0.04	0.058	<0.19	<0.28		<0.46
Whitehaven	Mussels	2				0.56		<0.34	<0.42		1.8
outer harbour											
Saltom Bay	Winkles	4				1.2		<0.39	<0.51		<5.0
St Bees	Winkles ^a	4			180	1.9	4.4	<0.48	<0.61	22	13
St Bees	Mussels	4				0.74		<0.36	<0.48		7.2
St Bees	Limpets	4				0.82		<0.49	<0.63		6.8
Nethertown	Winkles	12	<25	<25	180	<2.4	4.9	<0.43	<0.55	17	18
Nethertown	Mussels	4	48	60	250	1.4		<0.30	<0.30	53	14
Sellafield coastal area	Crabs ^b	8			180	0.68	0.26	<0.38	<0.63	11	<1.5
Sellafield coastal area	Lobsters	8			250	0.45	0.082	<0.40	<0.66	250	<1.2
Sellafield coastal area	Nephrops	1				<0.18		<0.85	<1.4	79	<1.9
Sellafield coastal area ^c	Winkles	8			160	1.9	2.1	<0.46	<0.55	20	15
Sellafield coastal area ^c	Mussels	4				0.66	0.65	<0.20	<0.21		2.8
Sellafield coastal area ^c	Limpets	4			110	0.64	3.6	<0.37	<0.39	71	<4.7
Whitriggs	Shrimps	1				<0.22		<1.5	<3.9		<2.2
Drigg	Winkles	3			180	3.4		<0.47	<0.55	52	23
Drigg	Mussels	1				0.73		<0.69	<0.76	56	7.8
Ravenglass	Crabs	4				0.48	0.18	<0.42	<0.75	11	<1.1
Ravenglass	Lobsters	6				<0.15	0.065	<0.44	<0.81	160	<0.84
Ravenglass	Winkles	2				1.1		<0.45	<0.67		4.6
Ravenglass	Cockles	4			160	2.7	1.3	<0.30	<0.41	7.1	8.4
Ravenglass	Mussels	4		<25		1.3		<0.27	<0.32	140	7.7
Tarn Bay	Winkles	4				1.6		<0.32	<0.37		14
Haverigg	Cockles	2				1.2		<0.63	<0.75		<2.1
Millom	Mussels	2				0.15		<0.22	<0.26		<0.76
Millom	Winkles	2				0.60		<0.26	<0.31		3.9
Barrow	Crabs	4				<0.11		<0.30	<0.49		<0.66
Barrow	Lobsters	4				<0.08		<0.39	<0.73	86	<0.74
Roosebeck	Pacific oysters	2				<0.09		<0.27	<0.33		<2.4
Morecambe Bay (Flookburgh)	Shrimps	4			80	<0.11		<0.40	<0.51	0.80	<1.1
Morecambe Bay (Flookburgh)	Cockles	4			76	0.30	0.37	<0.33	<0.52	2.6	<1.2
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2				<0.07		<0.22	<0.27		<0.62
Morecambe Bay (Morecambe)	Mussels	4	48	52	73	<0.10		<0.42	<0.87	31	<1.3
Red Nab Point	Winkles	4				0.25		<0.27	<0.38		<2.1
Morecambe Bay (Middleton Sands)	Cockles	2				<0.17		<0.21	<0.26		<0.56
Knott End	Cockles	2				0.48		<0.50	<0.66		<1.6
Fleetwood	Whelks	1				<0.09		<0.35	<0.54		<0.80
Ribble Estuary	Shrimps	2			69	<0.06		<0.18	<0.18	0.26	<0.60
Ribble Estuary	Mussels	2				<0.07		<0.22	<0.25		<0.69
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<25							
Dee Estuary	Cockles	4				<0.09		<0.32	<0.43	1.7	<0.87
Wirral	Shrimps	2		<38		<0.05		<0.24	<0.39	0.21	<0.49

Table 2.6. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹							Gross beta	
			^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁴⁷ Pm	¹⁵⁵ Eu		
Cumbria											
Silloth	Mussels	4	<0.12	0.54	<0.07	2.6	<0.30		<0.14	210	
Silloth	Shrimps	4	<0.20	<0.25	<0.10	3.8	<0.46		<0.21		
Parton	Crabs	4	<0.20	<0.24	<0.10	1.2	<0.47		<0.18		
Parton	Lobsters	4	<0.11	<0.14	<0.05	1.8	<0.28		<0.12		
Parton	Winkles	4	<0.24	1.1	<0.13	8.3	<0.62		<0.30		
Whitehaven	<i>Nephrops</i>	4	<0.16	<0.21	<0.09	3.0	<0.39		<0.17		
Whitehaven	Cockles	2	<0.09	<0.12	<0.05	<0.05	<0.25		<0.11		
Whitehaven	Mussels	2	<0.09	<0.11	<0.05	<0.06	<0.22		<0.09		
Whitehaven	Mussels	2	<0.17	0.56	<0.10	1.9	<0.46		<0.21		
outer harbour											
Saltom Bay	Winkles	4	<0.20	<0.76	<0.11	6.3	<0.52		<0.23	280	
St Bees	Winkles ^a	4	<0.30	<1.1	<0.14	7.1	<0.70	0.11	<0.34		
St Bees	Mussels	4	<0.18	0.80	<0.10	2.2	<0.48		<0.22		
St Bees	Limpets	4	<0.27	1.7	<0.13	7.1	<0.67		<0.30		
Nethertown	Winkles	12	<0.40	1.1	<0.13	9.6	<0.65	0.52	<0.30		
Nethertown	Mussels	4	<0.19	1.8	<0.11	2.4	<0.46		<0.19		
Sellafield coastal area	Crabs ^b	8	<0.21	<0.34	<0.08	1.5	<0.40	0.095	<0.16		
Sellafield coastal area	Lobsters	8	<0.34	<0.24	<0.09	2.5	<0.39	0.070	<0.16		
Sellafield coastal area	<i>Nephrops</i>	1	<0.35	<0.38	<0.19	3.1	<0.63		<0.24		
Sellafield coastal area ^c	Winkles	8	<0.39	<0.92	<0.15	6.8	<0.68	0.17	<0.31	170	
Sellafield coastal area ^c	Mussels	4	<0.12	0.85	<0.07	3.8	<0.30		<0.13		
Sellafield coastal area ^c	Limpets	4	<0.24	1.5	<0.12	4.9	<0.63		<0.31		
Whitriggs	Shrimps	1	<0.42	<0.42	<0.22	2.4	<0.78		<0.27		
Drigg	Winkles	3	<0.46	1.8	<0.14	7.6	<0.77	0.31	<0.37		
Drigg	Mussels	1	<0.40	1.2	<0.24	1.9	<1.2		<0.53		
Ravenglass	Crabs	4	<0.19	<0.24	<0.09	1.2	<0.38		<0.15		
Ravenglass	Lobsters	6	<0.18	<0.19	<0.08	1.7	<0.43		<0.18		
Ravenglass	Winkles	2	<0.27	<0.40	<0.10	4.3	<0.54		<0.24		
Ravenglass	Cockles	4	<0.15	0.66	<0.08	4.5	<0.38		<0.19	170	
Ravenglass	Mussels	4	<0.15	1.2	<0.08	1.5	<0.36		<0.16		
Tarn Bay	Winkles	4	<0.23	<0.74	<0.12	5.2	<0.62		<0.31		
Haverigg	Cockles	2	<0.33	<0.45	<0.20	4.2	<0.68		<0.26		
Millom	Mussels	2	<0.13	<0.18	<0.07	0.99	<0.34		<0.15		
Millom	Winkles	2	<0.14	0.56	<0.08	5.8	<0.43		<0.19		
Barrow	Crabs	4	<0.14	<0.16	<0.07	1.0	<0.32		<0.13		
Barrow	Lobsters	4	<0.16	<0.17	<0.08	1.5	<0.37		<0.15		
Roosebeck	Pacific oysters	2	<0.15	<0.23	<0.08	0.89	<0.30		<0.12		
Morecambe Bay (Flookburgh)	Shrimps	4	<0.20	<0.28	<0.11	5.0	<0.55		<0.25	240	
Morecambe Bay (Flookburgh)	Cockles	4	<0.14	<0.21	<0.07	3.3	<0.37		<0.16		
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2	<0.12	<0.16	<0.07	3.3	<0.32		<0.14		
Morecambe Bay (Morecambe)	Mussels	4	<0.16	<0.20	<0.09	1.3	<0.36		<0.14		
Red Nab Point	Winkles	4	<0.13	0.45	<0.07	3.9	<0.37		<0.16		
Morecambe Bay (Middleton Sands)	Cockles	2	<0.11	<0.15	<0.06	1.7	<0.30		<0.15		
Knott End	Cockles	2	<0.24	<0.32	<0.15	2.7	<0.52		<0.21		
Fleetwood	Whelks	1	<0.17	<0.19	<0.08	0.21	<0.42		<0.19		
Ribble Estuary	Shrimps	2	<0.12	<0.15	<0.06	2.0	<0.31		<0.14		
Ribble Estuary	Mussels	2	<0.13	<0.18	<0.07	0.97	<0.37		<0.18		
Liverpool Bay	Mussels	2									
Mersey Estuary	Mussels	2									
Dee Estuary	Cockles	4	<0.16	<0.20	<0.09	1.6	<0.40		<0.18		
Wirral	Shrimps	2	<0.09	<0.12	<0.05	1.3	<0.26		<0.11		

Table 2.6. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹								
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru
Scotland											
Lewis	Mussels	1 ^S				<0.11		<0.27	<0.24		<0.90
Skye	Lobsters	1 ^S				<0.10		<0.15		16	<0.48
Skye	Mussels	1 ^S				<0.10		<0.15			<0.44
Islay	Crabs	1 ^S				0.24		<0.29	<0.19		<1.4
Islay	Scallops	1 ^S				<0.10		<0.11			<0.40
Kirkcudbright	Scallops	4 ^S				<0.10		<0.13	<0.11	0.36	<0.45
Kirkcudbright	Queens	4 ^S				<0.10		<0.11	<0.10	0.84	<0.36
Kirkcudbright	Limpets	1 ^S				0.24		<0.39	<0.42		<1.2
Southernness	Winkles	4 ^S		<5.0		<0.26	0.23	<0.27	<0.26	32	<1.2
North Solway coast	Crabs	4 ^S			65	0.17	0.15	<0.30	<0.25	4.0	<1.1
North Solway coast	Lobsters	4 ^S			65	<0.11	<0.10	<0.27	<0.29	95	<0.85
North Solway coast	Winkles	4 ^S				<0.42	0.19	<0.23	<0.24	70	<1.5
North Solway coast	Cockles	1 ^S				0.77		<0.23	<0.16		<0.95
North Solway coast	Mussels	4 ^S		<5.0	51	0.21	0.26	<0.17	<0.16	58	<0.65
Inner Solway	Shrimps	2 ^S		<5.5		<0.10	<0.10	<0.16	<0.13	1.5	<0.57
Isle of Man											
Isle of Man	Lobsters	4				<0.06		<0.25	<0.37	47	<0.55
Isle of Man	Scallops	4				<0.07		<0.26	<0.36		<0.62
Wales											
Conwy	Mussels	2			45	<0.04		<0.10	<0.08		<0.34
North Anglesey	Crabs	2				<0.05		<0.17	<0.20	0.75	<0.49
North Anglesey	Lobsters	2				<0.08		<0.31	<0.44	39	<0.74
Lavernock Point	Limpets	2	36	31	26	<0.18		<0.80	<0.64		<1.8
Northern Ireland											
Ballycastle	Lobsters	2 ^N				<0.03		<0.14	<0.20	30	<0.34
County Down	Scallops	2 ^N				<0.08		<0.34	<0.54		<0.73
Kilkeel	Crabs	4 ^N				<0.10		<0.53	<0.97		<1.0
Kilkeel	Lobsters	4 ^N				<0.05		<0.19	<0.26	14	<0.47
Kilkeel	<i>Nephrops</i>	4 ^N				<0.12		<0.56	<1.0	12	<1.2
Minerstown	Winkles	4 ^N				<0.14		<0.57	<0.84		<1.4
Carlingford Lough	Mussels	2 ^N				<0.10		<0.37	<0.50	6.2	<1.0
Further afield											
Northern North Sea	<i>Nephrops</i>	2				<0.04		<0.18	<0.24	2.4	<0.43
Cromer	Crabs	1				<0.08		<0.36	<0.49		<0.88
Southern North Sea	Cockles	1				<0.05		<0.42	<1.1		<0.58
Southern North Sea	Mussels	2				<0.09		<0.46	<0.68	0.64	<1.0
Southern North Sea	Cockles ^d	1				<0.06		<0.36	<0.75	<0.29	<0.65
Southern North Sea	Mussels ^d	1				<0.06		<0.61	*		<0.71
English Channel-East	Scallops	1			29	<0.05		<0.13	<0.15		<0.35
English Channel-East	Whelks	1				<0.06		<0.33	<0.53		<0.58
English Channel-West	Crabs	2			27	<0.04		<0.23	<0.45		<0.43
English Channel-West	Lobsters	2				<0.09		<0.44	<0.75	0.74	<1.0
English Channel-West	Scallops	2			18	<0.07		<0.25	<0.34		<0.55
Northern Irish Sea	Velvet	1				<0.06		<0.35	<0.73		<0.49
	swimming crabs										
Northern Irish Sea	Octopuses	1				<0.08		<0.39	<0.75		<0.60

Table 2.6. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹						Gross beta	
			^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁵⁵ Eu		
Scotland										
Lewis	Mussels	1 ^S	<0.10	<0.26	<0.10	<0.10	<0.46	<0.21	150	
Skye	Lobsters	1 ^S	<0.10	<0.14	<0.10	0.13	<0.29	<0.13		
Skye	Mussels	1 ^S	<0.10	<0.12	<0.10	<0.10	<0.28	<0.11		
Islay	Crabs	1 ^S	<0.15	<0.38	<0.15	0.22	<0.70	<0.32		
Islay	Scallops	1 ^S	<0.10	<0.12	<0.10	0.31	<0.28	<0.15		
Kirkcudbright	Scallops	4 ^S	<0.10	<0.15	<0.10	<0.19	<0.28	<0.13		
Kirkcudbright	Queens	4 ^S	<0.10	<0.11	<0.10	<0.37	<0.22	<0.11		
Kirkcudbright	Limpets	1 ^S	<0.18	0.51	<0.13	3.5	<0.69	<0.31		
Southernness	Winkles	4 ^S	<0.14	<0.24	<0.11	1.3	<0.55	<0.25		
North Solway coast	Crabs	4 ^S	<0.14	<0.29	<0.11	1.1	<0.60	<0.27		
North Solway coast	Lobsters	4 ^S	<0.13	<0.24	<0.11	1.5	<0.46	<0.21		
North Solway coast	Winkles	4 ^S	<0.13	<0.42	<0.11	1.5	<0.52	<0.24		
North Solway coast	Cockles	1 ^S	<0.15	0.24	<0.12	5.6	<0.53	<0.15		
North Solway coast	Mussels	4 ^S	<0.11	<0.23	<0.10	1.7	<0.36	<0.17		
Inner Solway	Shrimps	2 ^S	<0.10	<0.15	<0.10	3.9	<0.33	<0.14		
Isle of Man										
Isle of Man	Lobsters	4	<0.12	<0.14	<0.06	0.35	<0.29	<0.13		
Isle of Man	Scallops	4	<0.13	<0.15	<0.07	0.33	<0.32	<0.15		
Wales										
Conwy	Mussels	2	<0.07	<0.09	<0.04	0.18	<0.14	<0.06		
North Anglesey	Crabs	2	<0.10	<0.12	<0.06	0.39	<0.21	<0.09		
North Anglesey	Lobsters	2	<0.16	<0.18	<0.08	0.64	<0.36	<0.16		
Lavernock Point	Limpets	2	<0.32	<0.37	<0.19	0.65	<0.61	<0.25		
Northern Ireland										
Ballycastle	Lobsters	2 ^N	<0.07	<0.08	<0.03	0.21	<0.16	<0.06		
County Down	Scallops	2 ^N	<0.15	<0.17	<0.08	0.30	<0.34	<0.15		
Kilkeel	Crabs	4 ^N	<0.20	<0.21	<0.10	0.28	<0.38	<0.15		
Kilkeel	Lobsters	4 ^N	<0.09	<0.11	<0.05	0.24	<0.22	<0.09		
Kilkeel	<i>Nephrops</i>	4 ^N	<0.23	<0.24	<0.12	0.82	<0.43	<0.17		
Minerstown	Winkles	4 ^N	<0.25	<0.31	<0.14	0.31	<0.53	<0.20		
Carlingford Lough	Mussels	2 ^N	<0.18	<0.23	<0.11	0.50	<0.42	<0.18		
Further afield										
Northern North Sea	<i>Nephrops</i>	2	<0.09	<0.11	<0.05	<0.12	<0.25	<0.11		
Cromer	Crabs	1	<0.19	<0.22	<0.09	<0.08	<0.46	<0.22		
Southern North Sea	Cockles	1	<0.12	<0.13	<0.05	<0.05	<0.39	<0.14		
Southern North Sea	Mussels	2	<0.19	<0.23	<0.10	<0.10	<0.44	<0.17		
Southern North Sea	Cockles ^d	1	<0.13	<0.14	<0.07	0.09	<0.36	<0.15		
Southern North Sea	Mussels ^d	1	<0.14	<0.16	<0.07	<0.06	<0.40	<0.16		
English Channel-East	Scallops	1	<0.08	<0.08	<0.04	<0.04	<0.12	<0.05		
English Channel-East	Whelks	1	<0.12	<0.15	<0.06	<0.05	<0.40	<0.16		
English Channel-West	Crabs	2	<0.09	<0.09	<0.04	<0.04	<0.21	<0.08		
English Channel-West	Lobsters	2	<1.8	<0.23	<0.10	<0.08	<0.51	<0.20		
English Channel-West	Scallops	2	<0.13	<0.13	<0.06	<0.06	<0.25	<0.11		
Northern Irish Sea	Velvet	1	<0.11	0.16	<0.06	2.4	<0.19	<0.08		
	swimming crabs									
Northern Irish Sea	Octopuses	1	<0.15	<0.13	<0.07	0.45	<0.21	<0.08		

* Not detected by the method used

^a The concentration of ¹²⁹I was <2.2 Bq kg⁻¹

^b The concentration of ¹²⁹I was <2.0 Bq kg⁻¹

^c Samples collected by Consumer 12

^d Landed in Holland or Denmark

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

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

Table 2.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹						
			²³⁷ Np	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm
Cumbria									
Silloth	Shrimps	1		0.0034	0.020	0.70	0.039	*	0.000037
Silloth	Mussels	1		0.80	4.4		8.7	*	0.0064
Maryport	Plaice	4					<0.17		
Parton	Cod	4					<0.23		
Parton	Crabs	4					1.0		
Parton	Lobsters	4					1.8		
Parton	Winkles	1		2.1	12	80	19	*	0.026
Whitehaven	Cod	1		0.0056	0.032		0.047	*	0.000058
Whitehaven	Plaice	1		0.0087	0.050		0.088	*	*
Whitehaven	Skates / rays	1		0.0038	0.021		0.035	*	0.000037
Whitehaven	Sole	1		0.0032	0.019		0.029	*	0.000030
Whitehaven	Nephrops	1		0.039	0.22		1.2	0.0011	0.0014
Whitehaven	Cockles	1		0.0021	0.0096		0.012	0.000052	0.00057
Whitehaven	Mussels	1		0.0047	0.028	0.41	0.048	0.000041	0.000087
Whitehaven outer harbour	Mussels	2					7.3		
Saltom Bay	Winkles	4					16		
St Bees	Winkles	1	0.010	1.2	6.9	52	14	*	0.031
St Bees	Mussels	2		1.2	5.9	48	13	*	0.026
St Bees	Limpets	1		2.4	12		22	*	0.059
Nethertown	Winkles	4	0.054	2.7	14	100	27	*	<0.021
Nethertown	Mussels	4		1.4	6.6		16	*	0.030
River Ehen	Salmon	1					<0.09		
Sellafield coastal area	Cod	2		0.00044	0.0034		0.0058	*	<0.0000070
Sellafield coastal area	Plaice	1		0.0018	0.0099		0.022	0.000056	0.000030
Sellafield coastal area	Bass	1					<0.12		
Sellafield coastal area	Grey mullet	1					<0.36		
Sellafield coastal area	Crabs	2	0.0020	0.074	0.36	3.2	1.8	<0.0011	0.0037
Sellafield coastal area	Lobsters	2	0.013	0.067	0.30	2.7	4.7	<0.011	0.0084
Sellafield coastal area	Nephrops	1		0.029	0.16		2.1	*	0.0018
Sellafield coastal area ^a	Winkles	2	0.015	2.0	10	81	21	*	<0.019
Sellafield coastal area ^a	Mussels	1		1.2	6.6	47	11	*	0.017
Sellafield coastal area ^a	Limpets	1		1.7	9.5	71	20	*	0.034
Sellafield offshore area	Cod	1		0.00038	0.0021		0.0048	*	*
Sellafield offshore area	Plaice	1	0.00018	0.0028	0.014		0.032	*	0.000024
Sellafield offshore area	Dab	1					0.17		
Sellafield offshore area	Lesser spotted dogfish	2					<0.14		
Sellafield offshore area	Skates / rays	2					<0.16		
Sellafield offshore area	Turbot	1					<0.35		
River Calder	Brown trout	1					<0.41		
Whitriggs	Shrimps	1					<0.14		
Drigg	Winkles	1	0.025	2.2	12	96	24	*	0.039
Drigg	Mussels	1					12		
Ravenglass	Cod	1		0.00053	0.0026		0.0050	*	*
Ravenglass	Plaice	1		0.0046	0.024		0.046	*	*
Ravenglass	Crabs	1		0.064	0.32	2.8	1.6	0.0018	0.0019
Ravenglass	Lobsters	1		0.043	0.23	2.0	3.8	*	0.0050
Ravenglass	Winkles	2					15		
Ravenglass	Cockles	1		2.0	10	77	30	*	0.062
Ravenglass	Mussels	1		1.1	5.2	45	12	0.024	0.034
Tarn Bay	Winkles	1		1.3	6.9	53	14	*	0.022
Haverigg	Cockles	1		1.4	8.1		25	*	0.056
Millom	Mussels	2					3.1		
Millom	Winkles	2					15		
Barrow	Crabs	1		0.016	0.089		0.52	*	0.00074
Barrow	Lobsters	4					0.80		
Roosebeck	Pacific oysters	1		0.14	0.69		0.97	0.0020	0.0016
Morecambe Bay (Flookburgh)	Flounder	1		0.00065	0.0040		0.0075	*	*
Morecambe Bay (Flookburgh)	Plaice	1					<0.09		
Morecambe Bay (Flookburgh)	Shrimps	1		0.0037	0.023	0.42	0.037	*	*
Morecambe Bay (Flookburgh)	Cockles	1		0.30	1.8	12	5.4	*	0.0063

Table 2.7. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹						
			²³⁷ Np	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4					<0.15		
Morecambe Bay (Morecambe)	Bass	2					<0.23		
Morecambe Bay (Morecambe)	Flounder	4					<0.13		
Morecambe Bay (Morecambe)	Shrimps	2					<0.14		
Morecambe Bay (Morecambe)	Mussels	1		0.16	0.92		1.8	*	0.0014
Red Nab Point	Winkles	1		0.33	1.9		3.6	*	0.0042
Morecambe Bay (Middleton Sands)	Cockles	1		0.16	0.96		3.1	*	*
Morecambe Bay (Sunderland Point)	Whitebait	1		0.025	0.16	1.4	0.25	*	*
Knott End	Cockles	1		0.39	2.2		5.7	*	0.0057
Fleetwood	Cod	1		0.00019	0.0010		0.0021	*	*
Fleetwood	Plaice	1		0.00066	0.0040		0.0076	*	*
Fleetwood	Whelks	1					<0.24		
Ribble Estuary	Grey mullet	2					<0.09		
Ribble Estuary	Flounder	1					<0.33		
Ribble Estuary	Bass	1					<0.10		
Ribble Estuary	Shrimps	1	0.00017	0.0011	0.0068		0.012	0.000056	*
Ribble Estuary	Mussels	2					0.88		
Dee Estuary	Cockles	1		0.14	0.79		2.1	*	0.0023
Wirral	Shrimps	2					<0.10		
Scotland									
Shetland	Fish meal	1		0.00011	0.0011		0.00056	*	*
Shetland	Fish oil	2					<0.23		
Minch	Herring	1					<0.10		
Minch	Mackerel	1		0.000041	0.000046		0.000078	*	*
West of Scotland	Mackerel	1					<0.12		
West of Scotland	Farmed salmon	1					<0.10		
Lewis	Mussels	1 ^s					<0.12		
Skye	Lobsters	1 ^s					<0.10		
Skye	Mussels	1 ^s					0.15		
Islay	Crabs	1 ^s					<0.18		
Islay	Scallops	1 ^s					<0.15		
Kirkcudbright	Scallops	1 ^s		0.0042	0.025		0.024		
Kirkcudbright	Queens	1 ^s		0.030	0.16		0.15		
Kirkcudbright	Limpets	1 ^s					5.6		
Southernness	Winkles	1 ^s		<0.27	0.34	3.5	1.1		
Dumfries	Lemon sole	1 ^s		<0.050	<0.050		<0.050		
North Solway coast	Crabs	1 ^s		0.037	0.13	0.69	0.068		
North Solway coast	Lobsters	1 ^s		0.014	0.085	0.37	0.74		
North Solway coast	Winkles	1 ^s		0.34	1.9		3.5		
North Solway coast	Cockles	1 ^s		1.4	7.7		23		
North Solway coast	Mussels	1 ^s		0.36	2.4	13	5.1		
Inner Solway	Flounder	1 ^s		0.0028	0.018		0.030		
Inner Solway	Salmon	1 ^s					<0.11		
Inner Solway	Sea trout	1 ^s					<0.11		
Inner Solway	Shrimps	1 ^s		0.0027	0.016		0.032		
Isle of Man									
Isle of Man	Cod	1		0.00012	0.0010		0.0017	*	*
Isle of Man	Mackerel	1		0.000093	0.00064		0.0012	*	0.000031
Isle of Man	Lobsters	4					<0.13		
Isle of Man	Scallops	1		0.017	0.10		0.026	*	*

Table 2.7. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹				
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm
Wales							
Conwy	Mussels	1	0.020	0.12	0.20	*	0.00013
North Anglesey	Thornback ray	2			<0.08		
North Anglesey	Lesser spotted dogfish	1	0.00010	0.00056	0.0014	*	*
North Anglesey	Plaice	2			<0.08		
North Anglesey	Bass	1			<0.07		
North Anglesey	Crabs	1	0.0028	0.018	0.069	*	0.000090
North Anglesey	Lobsters	2			<0.16		
Lavernock Point	Limpets	2			<0.14		
Northern Ireland							
North coast	Spurdog	4 ^N			<0.14		
Ballycastle	Lobsters	2 ^N			0.12		
County Down	Scallops	2 ^N			<0.14		
Ardglass	Herring	2 ^N			<0.27		
Kilkeel	Cod	4 ^N			<0.16		
Kilkeel	Plaice	4 ^N			<0.10		
Kilkeel	Spurdog	4 ^N			<0.13		
Kilkeel	Haddock	4 ^N			<0.20		
Kilkeel	Crabs	4 ^N			<0.08		
Kilkeel	Lobsters	4 ^N			<0.07		
Kilkeel	<i>Nephrops</i>	1 ^N	0.0032	0.020	0.059	0.000093	0.000056
Minerstown	Winkles	1 ^N	0.025	0.14	0.18	*	0.00025
Carlingford Lough	Mussels	2 ^N			<0.17		
Glenarm	Sea trout	1			<0.14		
Further afield							
Baltic Sea	Cod	2			<0.08		
Baltic Sea	Herring	2			<0.09		
Barents Sea	Cod	2			<0.18		
Norwegian Sea	Cod	1			<0.04		
Norwegian Sea	Herring	1			<0.17		
Norwegian Sea	Mackerel	1			<0.11		
Norwegian Sea	Saithe	1			<0.11		
Norwegian processed	Cod	1	0.000021	0.00010	0.00021	*	*
Iceland area	Cod	1			<0.18		
Skagerrak	Cod	2			<0.11		
Skagerrak	Herring	2			<0.08		
Northern North Sea	Plaice	2			<0.09		
Northern North Sea	Haddock	1	0.00019	0.00081	0.0013	*	*
Northern North Sea	Herring	1			<0.10		
Northern North Sea	Whiting	1	0.000066	0.00064	0.0013	*	*
Northern North Sea	<i>Nephrops</i>	1	0.00012	0.0014	0.0011	*	*
Mid North Sea	Cod	2			<0.07		
Mid North Sea	Plaice	2			<0.15		
Cromer	Crabs	1			<0.24		
Gt Yarmouth (retail shop)	Cod	2			<0.03		
Gt Yarmouth (retail shop)	Plaice	2			<0.05		
Southern North Sea	Cod	2			<0.05		
Southern North Sea	Plaice	1			<0.03		
Southern North Sea	Dab	1			<0.06		
Southern North Sea	Herring	1			<0.08		
Southern North Sea	Cockles	1	0.00058	0.0036	0.0044	*	0.00024
Southern North Sea	Mussels	1	0.0021	0.014	0.0063	*	*
Southern North Sea	Cockles ^b	1	0.0014	0.0081	0.0086	*	0.00050
Southern North Sea	Mussels ^b	1	0.00013	0.0014	0.00085	*	*
English Channel-East	Plaice	2			<0.06		
English Channel-East	Whiting	2			<0.11		
English Channel-East	Scallops	1	0.00048	0.0023	0.00074	*	0.000022
English Channel-East	Whelks	1			<0.15		
English Channel-West	Plaice	2			<0.04		
English Channel-West	Mackerel	2			<0.14		

Table 2.7. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹				
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm
English Channel-West	Whiting	2			<0.18		
English Channel-West	Crabs	1	0.000053	0.00062	0.00067	*	0.000040
English Channel-West	Lobsters	2			<0.16		
English Channel-West	Scallops	1	0.00013	0.0025	0.00031	*	*
Celtic Sea	Cod	2			<0.18		
Celtic Sea	Haddock	2			<0.17		
Northern Irish Sea	Dab	1			<0.07		
Northern Irish Sea	Lesser spotted dogfish	1			<0.13		
Northern Irish Sea	Skates / rays	1			<0.18		
Northern Irish Sea	Velvet swimming crabs	1			1.4		
Northern Irish Sea	Octopuses	1			0.13		

* Not detected by the method used

^a Samples collected by consumer 12

^b Landed in Holland or Denmark

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

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

Table 2.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹									
			⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	¹⁰⁶ Ru	^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce
Cumbria												
Newton Arlosh	Sediment	4	<1.6		<2.8	<0.86	<9.3		<3.8	<1.0	240	<4.2
Maryport Outer Harbour	Sediment	2	<0.99	<2.5	<1.8	<0.59	<5.4		<1.7	<0.56	69	<3.0
Workington Harbour	Sediment	2	<0.95		<2.5	<0.87	<7.0		<2.1	<0.76	56	<3.7
Harrington Harbour	Sediment	2	<1.4		<2.6	<0.89	<7.9		<2.6	<0.86	220	<4.2
Whitehaven Outer Harbour	Sediment	4	<0.95	<1.3	<2.5	<0.79	<6.8		<3.5	<0.80	93	<3.5
St Bees beach	Sediment	4	<1.6		<2.2	<0.66	<6.5		<2.6	<0.74	69	<3.1
Sellafield beach, S of former pipeline	Sediment	2	<1.0		<2.0	<0.74	<7.2		<2.3	<0.86	71	<3.9
River Calder - downstream	Sediment	2	<1.2		<2.4	<0.74	<6.9		<2.1	<0.69	88	<3.4
River Calder - upstream	Sediment	2	<0.91		<2.5	<0.84	<7.0		<2.0	<0.72	48	<3.7
Seascale beach	Sediment	4	<1.2		<1.9	<0.58	<5.6		<2.2	<0.66	39	<2.8
Ravenglass - Carleton Marsh	Sediment	4	6.9		<2.8	<0.89	58		<6.3	<1.1	280	<4.5
River Mite Estuary (erosional)	Sediment	4	5.3	93	<3.3	<1.0	<17		<5.3	<1.2	510	<5.1
River Mite Estuary (depositional)	Sediment	3	<3.0	84	<5.0	<1.5	<16		<6.5	<1.7	510	<6.7
Ravenglass - Raven Villa	Sediment	4	<3.7		<2.7	<0.92	<17		<4.1	<1.1	120	<4.3
Newbiggin (Eskmeals)	Sediment	4	12	130	<3.8	<1.2	<29		<6.0	<1.4	380	<5.6
Haverigg	Sediment	2	<1.8		<2.3	<0.70	<6.9		<2.0	<0.71	71	<3.1
Millom	Sediment	2	<1.5		<3.2	<1.1	<10		<3.2	<1.2	110	<4.8
Low Shaw	Sediment	2	<1.0		<2.3	<0.81	<7.6		<2.3	<0.89	67	<4.0
Walney Channel - N of discharge point	Sediment	2	<1.0		<1.9	<0.61	<6.0		<1.9	<0.62	79	<3.1
Walney Channel - S of discharge point	Sediment	2	<1.4		<1.8	<0.61	<6.3		<1.9	<0.63	110	<3.2
Sand Gate Marsh	Sediment	4	<0.87		<2.2	<0.70	<6.4		<2.5	<0.76	51	<3.2
Kents Bank	Sediment	4	<0.99		<2.5	<0.79	<8.2		<3.4	<0.89	230	<4.0
Lancashire												
Morecambe	Sediment	2	<0.54								3.3	
Half Moon Bay	Sediment	2	<0.86								30	
Red Nab Point	Sediment	1	<1.3								19	
Heysham pipelines	Sediment	1	<0.38								22	
Potts Corner	Sediment	2	<0.80								21	
Sunderland Point	Sediment	4	<0.92		<2.1	<0.77	<6.6		<2.6	<0.78	77	<3.5
Conder Green	Sediment	4	<0.76		<1.8	<0.67	<6.0		<2.4	<0.69	86	<3.4
Hambleton	Sediment	4	<1.5		<2.9	<1.0	<10		<3.8	<1.1	220	<4.8
Skippool Creek	Sediment	4	<1.7		<3.8	<1.3	<13		<4.9	<1.5	280	<5.9
Fleetwood	Sediment	4	<0.47		<1.1	<0.38	<3.4		<1.4	<0.40	8.2	<1.9
Blackpool	Sediment	4	<0.45		<1.0	<0.35	<3.2		<1.4	<0.39	3.4	<1.9
Crossens Marsh	Sediment	4	<1.4		<3.3	<1.1	<11		<4.0	<1.2	220	<5.0
Ainsdale	Sediment	4	<0.44		<1.0	<0.36	<3.2		<1.4	<0.38	5.2	<1.9
Rock Ferry	Sediment	4	<0.94		<2.1	<0.75	<7.2		<2.9	<0.79	120	<4.0
New Brighton	Sediment	4	<0.44		<1.0	<0.36	<3.3		<1.4	<0.38	3.6	<1.8
Scotland												
Campbeltown	Sediment	1 ^S	<0.10		<0.28	<0.37	<0.73	<0.13	<0.21	<0.10	7.9	<0.73
Garlieston	Sediment	1 ^S	1.0		<0.18	<0.12	2.0	<0.13	0.74	<0.12	94	<0.86
Innerwell	Sediment	1 ^S	0.27		<0.19	<0.10	<0.69	<0.11	<0.19	<0.10	20	<0.60
Carluith	Sediment	1 ^S	0.30		<0.14	<0.10	<0.73	<0.11	<0.23	<0.10	35	<0.67
Skyreburn	Sediment	1 ^S	4.7		<0.54	<0.97	3.6	<0.25	3.8	<0.20	310	<1.7
Cutter's Pool	Sediment	1 ^S	4.1		<0.75	<1.9	6.6	<0.54	2.2	<0.43	240	<3.0
Rascarrel Bay	Sediment	1 ^S	0.58		<0.29	<0.15	<1.1	<0.16	<0.28	<0.10	87	<1.0
Palnackie Harbour	Sediment	1 ^S	1.2		<0.18	<0.12	<0.66	<0.13	0.85	<0.12	100	<0.80
Gardenburn	Sediment	1 ^S	1.4		<0.25	<0.27	2.8	<0.14	1.0	<0.12	130	<0.97
Kippford Slipway	Sediment	1 ^S	2.5		<0.33	<0.35	4.8	<0.15	2.0	<0.13	170	<1.1
Kippford Merse	Sediment	1 ^S	2.1		0.54	0.34	3.3	<0.14	1.6	<0.12	210	<1.1
Southernness	Sediment	1 ^S	0.26		<0.13	<0.10	<0.60	<0.10	<0.19	<0.10	25	<0.54
Kirkconnel Merse	Sediment	1 ^S	0.51		<0.50	<0.82	<1.3	<0.15	0.65	<0.11	280	<1.3

Table 2.8. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹							
			¹⁵⁴ Eu	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	Gross alpha	Gross beta
Cumbria										
Newton Arlosh	Sediment	4	<2.9	<1.8				210	530	1100
Maryport Outer Harbour	Sediment	2	<1.9	<1.3	13	74	490	110	450	780
Workington Harbour	Sediment	2	<2.8	<1.6				28	510	980
Harrington Harbour	Sediment	2	<3.0	<1.8				56	470	1300
Whitehaven Outer Harbour	Sediment	4	<2.7	<1.6	9.2	52	340	77	330	840
St Bees beach	Sediment	4	<2.5	<1.4				170	360	480
Sellafield beach, S of former pipeline	Sediment	2	<2.7	<1.8				150	370	700
River Calder - downstream	Sediment	2	<2.9	<1.5				64	300	730
River Calder - upstream	Sediment	2	<3.2	<1.7					410	1200
Seascale beach	Sediment	4	<2.2	<1.3				130	330	580
Ravenglass - Carleton Marsh	Sediment	4	<3.8	<2.0				880	1800	1400
River Mite Estuary (erosional)	Sediment	4	<5.8	<2.3	140	760	5100	1300	3100	2300
River Mite Estuary (depositional)	Sediment	3	<5.4	<2.9	140	750	5800	1400	2300	1900
Ravenglass - Raven Villa	Sediment	4	<3.2	<2.0				390	1000	990
Newbiggin (Eskmeals)	Sediment	4	<4.9	<2.6	110	610	4700	1100	1600	1200
Haverigg	Sediment	2	<2.7	<1.4				230	670	660
Millom	Sediment	2	<3.9	<2.1				230	620	680
Low Shaw	Sediment	2	<2.9	<1.8				98	260	500
Walney Channel - N of discharge point	Sediment	2	<2.2	<1.5				130	360	660
Walney Channel - S of discharge point	Sediment	2	<2.1	<1.5				190	540	810
Sand Gate Marsh	Sediment	4	<2.4	<1.4				39	<150	690
Kents Bank	Sediment	4	<2.6	<1.8				110	380	800
Lancashire										
Morecambe	Sediment	2						<0.89		
Half Moon Bay	Sediment	2			3.1	19		36		
Red Nab Point	Sediment	1						20		
Heysham pipelines	Sediment	1						20		
Potts Corner	Sediment	2						11		
Sunderland Point	Sediment	4	<2.5	<1.6				61	320	700
Conder Green	Sediment	4	<2.1	<1.5				76	290	610
Hambleton	Sediment	4	<3.4	<2.2				180	560	1000
Skippool Creek	Sediment	4	<4.4	<2.6				220	600	1100
Fleetwood	Sediment	4	<1.4	<0.90				9.0	<120	330
Blackpool	Sediment	4	<1.3	<0.88				4.2	<100	<140
Crossens Marsh	Sediment	4	<3.6	<2.2				150	450	1200
Ainsdale	Sediment	4	<1.3	<0.83				3.4	<100	<240
Rock Ferry	Sediment	4	<2.6	<1.8				65	400	1200
New Brighton	Sediment	4	<1.4	<0.88				<2.8	<120	320
Scotland										
Campbeltown	Sediment	1 ^S	<0.16	0.51				0.89		
Garlieston	Sediment	1 ^S	0.38	<0.38	4.5	26		37		
Innerwell	Sediment	1 ^S	<0.15	<0.29				32		
Carluith	Sediment	1 ^S	<0.15	<0.22	5.8	34		67	210	880
Skyreburn	Sediment	1 ^S	2.4	1.3				460		
Cutter's Pool	Sediment	1 ^S	2.5	1.9				400		
Rascarrel Bay	Sediment	1 ^S	<0.24	<0.28				57		
Palnackie Harbour	Sediment	1 ^S	<0.14	0.43	16	91		170		
Gardenburn	Sediment	1 ^S	0.76	<0.38	20	110		210		
Kippford Slipway	Sediment	1 ^S	1.2	<0.27	25	140		280		
Kippford Merse	Sediment	1 ^S	0.79	0.66	26	150		240		
Southernness	Sediment	1 ^S	<0.10	<0.24	3.2	19		34		
Kirkconnel Merse	Sediment	1 ^S	0.62	0.97	12	80		140	200	1200

Table 2.8. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹								
			⁶⁰ Co	⁹⁵ Zr	⁹⁵ Nb	¹⁰⁶ Ru	^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce
Isle of Man											
Ramsey	Sediment	1	<0.98	<2.6	<0.79	<7.3		<4.0	<0.93	6.1	<3.8
Wales											
Rhyl	Sediment	2	<0.84	<2.3	<0.70	<6.8		<2.0	<0.69	79	<3.6
Llandudno	Sediment	2	<0.32	<0.81	<0.27	<2.3		<0.66	<0.24	2.6	<1.5
Caerhun	Sediment	2	<1.1	<3.0	<0.84	<8.1		<2.8	<0.82	69	<3.8
Llanfairfechan	Sediment	2	<0.88	<2.6	<0.76	<6.9		<1.8	<0.70	25	<3.2
Northern Ireland											
Carrichue	Mud	1 ^N	<0.39	<2.0	<3.6	<4.6	<0.85	<1.0	<0.47	0.71	<3.5
Carrichue	Mud and sand	1 ^N	<0.42	<3.5	<8.1	<4.8	<1.1	<1.2	<0.60	2.4	<3.2
Portrush	Sand	2 ^N	<0.34	<2.4	<4.5	<4.0	<0.76	<0.90	<0.46	0.78	<2.3
Oldmill Bay	Mud	2 ^N	<0.78	<3.5	<4.8	<8.7	<1.5	<2.3	<0.95	38	<4.4
Ballymacormick	Mud	2 ^N	<0.58	<5.0	<0.68	<6.4	<1.2	<1.6	<0.76	14	<3.6
Strangford Lough - Nicky's Point	Mud	2 ^N	<0.60	<5.5	<3.7	<7.3	<1.4	<1.9	<0.88	25	<4.3
Dundrum Bay	Mud	2 ^N	<0.65	<4.2	<1.4	<6.9	<1.5	<1.7	<0.88	5.5	<4.2
Carlingford Lough	Mud	2 ^N	<0.72	<5.5	<1.2	<8.1	<1.5	<2.2	<0.96	45	<5.3
Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹								
			¹⁵⁴ Eu	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Isle of Man											
Ramsey	Sediment	1	<2.7	<1.7			<1.3			<100	730
Wales											
Rhyl	Sediment	2	<2.4	<1.5			46			390	940
Llandudno	Sediment	2	<1.1	<0.70			<1.2			<90	200
Caerhun	Sediment	2	<3.0	<1.6			23			370	840
Llanfairfechan	Sediment	2	<2.6	<1.4			15			220	720
Northern Ireland											
Carrichue	Mud	1 ^N	<1.1	<1.5	0.069	0.47	0.76	*	0.00087		
Carrichue	Mud and sand	1 ^N	<1.4	<1.3			1.9				
Portrush	Sand	2 ^N	<1.1	<0.93			<0.90				
Oldmill Bay	Mud	2 ^N	<2.5	<1.9			26				
Ballymacormick	Mud	2 ^N	<1.7	<1.5			12				
Strangford Lough - Nicky's Point	Mud	2 ^N	<1.9	<1.6			9.2				
Dundrum Bay	Mud	2 ^N	<2.0	<1.7			2.5				
Carlingford Lough	Mud	2 ^N	<2.2	<2.3	1.7	11	6.9	*	0.0056		

* Not detected by the method used

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

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

All other measurements are made on behalf of the Environment Agency

Table 2.9. Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2009

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu\text{Gy h}^{-1}$
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Grass	2	0.085
Burgh Marsh	Grass and salt marsh	1	0.086
Burgh Marsh	Grass	1	0.078
Port Carlisle 1	Mud	2	0.089
Port Carlisle 1	Salt marsh	1	0.092
Port Carlisle 1	Grass and mud	1	0.094
Port Carlisle 2	Grass and salt marsh	1	0.090
Port Carlisle 2	Grass	3	0.092
Greenend 1	Mud	1	0.092
Greenend 1	Mud and sand	1	0.099
Greenend 1	Mud and stones	2	0.098
Greenend 2	Grass and salt marsh	1	0.092
Greenend 2	Grass	3	0.093
Cardurnock Marsh	Grass	4	0.081
Newton Arlosh	Grass	4	0.10
Silloth harbour	Mud and stones	1	0.10
Silloth harbour	Mud and shells	1	0.10
Silloth harbour	Mud and pebbles	2	0.10
Silloth silt pond	Grass and sand	2	0.086
Silloth silt pond	Grass	2	0.082
Allonby	Sand	4	0.089
Maryport harbour	Sand	1	0.094
Maryport harbour	Pebbles and sand	1	0.093
Workington harbour	Pebbles and sand	1	0.11
Workington harbour	Pebbles and stones	1	0.12
Harrington harbour	Sand	1	0.12
Harrington harbour	Pebbles and sand	1	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven – outer harbour	Pebbles and sand	4	0.10
St Bees	Sand	3	0.085
St Bees	Pebbles and sand	1	0.083
Nethertown beach	Stones	1	0.14
Nethertown beach	Pebbles and stones	1	0.13
Braystones	Pebbles and sand	1	0.12
Braystones	Pebbles and stones	1	0.12
Sellafield dunes	Grass and sand	1	0.13
Sellafield dunes	Grass	1	0.11
North of former pipeline on foreshore	Sand	2	0.093
South of former pipeline on foreshore	Sand	2	0.089
River Calder downstream of factory sewer	Grass	2	0.093
River Calder upstream of factory sewer	Grass	2	0.10
Seascale beach	Sand	4	0.084
Seascale	Grass	4	0.086

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu\text{Gy h}^{-1}$
Cumbria, Ravenglass-Askam			
Ravenglass – Carleton Marsh	Grass and mud	1	0.14
Ravenglass – Carleton Marsh	Grass	3	0.15
Ravenglass – River Mite estuary (depositional)	Grass	3	0.16
Ravenglass – River Mite estuary (erosional)	Grass	4	0.17
Ravenglass – Raven Villa	Mud and salt marsh	3	0.16
Ravenglass – Raven Villa	Grass and salt marsh	1	0.15
Ravenglass – boat area	Pebbles and sand	1	0.11
Ravenglass – boat area	Sand and stones	2	0.11
Ravenglass – boat area	Pebbles and stones	1	0.11
Ravenglass – ford	Mud	2	0.12
Ravenglass – ford	Mud and sand	2	0.11
Muncaster Bridge	Grass	4	0.13
Ravenglass – salmon garth	Mud and sand	1	0.12
Ravenglass – salmon garth	Mud and pebbles	1	0.11
Ravenglass – salmon garth	Mud and stones	1	0.11
Ravenglass – salmon garth	Pebbles and sand	1	0.12
Ravenglass – Eskmeals Nature Reserve	Mud and salt marsh	2	0.13
Ravenglass – Eskmeals Nature Reserve	Grass and mud	2	0.14
Newbiggin/Eskmeals viaduct	Mud and salt marsh	4	0.13
Newbiggin/Eskmeals viaduct	Salt marsh	4	0.15
Tarn Bay	Sand	1	0.080
Tarn Bay	Pebbles and sand	1	0.10
Silecroft	Pebbles and sand	1	0.12
Silecroft	Pebbles and stones	1	0.12
Haverigg	Mud and pebbles	2	0.097
Millom	Mud	2	0.11
Low Shaw	Grass and mud	1	0.095
Low Shaw	Grass	1	0.092
Askam	Mud and sand	1	0.074
Askam	Sand	1	0.074
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	1	0.097
Walney Channel, N of discharge point	Mud and pebbles	1	0.10
Walney Channel, S of discharge point	Mud	1	0.094
Walney Channel, S of discharge point	Mud and pebbles	1	0.086
Tummer Hill Marsh	Salt marsh	2	0.12
Roa Island	Mud	1	0.096
Roa Island	Pebbles and rock	1	0.099
Greenodd Salt Marsh	Grass	2	0.083
Sand Gate Marsh	Grass and mud	1	0.085
Sand Gate Marsh	Grass	3	0.085
Kents Bank 2	Grass and mud	1	0.088
Kents Bank 2	Grass	3	0.092
High Foulshaw	Grass	4	0.081
Arnside 1	Mud	2	0.088
Arnside 1	Mud and sand	1	0.087
Arnside 1	Grass	1	0.090
Arnside 2	Grass	4	0.10
Lancashire and Merseyside			
Morecambe Central Pier	Sand	2	0.074
Heysham pipelines	Sand	1	0.073
Half Moon Bay	Rock and sand	1	0.083
Half Moon Bay	Rock and shells	1	0.088
Red Nab Point	Sand and stones	1	0.085
Middleton Sands	Sand	2	0.076
Sunderland Point	Mud	2	0.10
Sunderland Point	Mud and salt marsh	2	0.10
Sunderland	Salt marsh	4	0.098
Colloway Marsh	Salt marsh	2	0.14
Colloway Marsh	Grass	2	0.14
Lancaster	Grass	4	0.084

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu\text{Gy h}^{-1}$
Lancashire and Merseyside			
Aldcliffe Marsh	Grass and mud	2	0.12
Aldcliffe Marsh	Grass	2	0.11
Conder Green	Mud	1	0.095
Conder Green	Grass and mud	1	0.098
Conder Green	Salt marsh	1	0.092
Conder Green	Grass	1	0.088
Pilling Marsh	Grass	4	0.10
Knott End	Mud	1	0.078
Knott End	Sand	1	0.082
Heads – River Wyre	Mud and salt marsh	1	0.11
Heads – River Wyre	Grass and mud	2	0.11
Heads – River Wyre	Grass	1	0.11
Height o' th' hill - River Wyre	Grass and salt marsh	1	0.12
Height o' th' hill - River Wyre	Grass	3	0.12
Hambleton	Grass and mud	1	0.11
Hambleton	Grass	3	0.11
Skippool Creek 1	Grass and mud	1	0.11
Skippool Creek 1	Grass	3	0.12
Skippool Creek 1	Wood	4	0.11
Skippool Creek 2	Grass and mud	1	0.12
Skippool Creek 2	Salt marsh	1	0.11
Skippool Creek 2	Grass	2	0.11
Skippool Creek boat 2	Wood	4	0.10
Skippool Creek boat 2 – in vicinity of boats	Mud	4	0.092
Fleetwood Marsh Nature Park	Salt marsh	4	0.13
Fleetwood shore 1	Sand	1	0.085
Fleetwood shore 1	Pebbles and sand	3	0.089
Blackpool	Sand	4	0.068
Crossens Marsh	Mud and salt marsh	1	0.097
Crossens Marsh	Grass and mud	1	0.10
Crossens Marsh	Salt marsh	1	0.10
Crossens Marsh	Grass and salt marsh	1	0.097
Ainsdale	Sand	4	0.068
Rock Ferry	Mud and sand	3	0.096
Rock Ferry	Sand	1	0.093
New Brighton	Sand	4	0.067
West Kirby	Mud	2	0.069
West Kirby	Sand	2	0.073
Little Neston Marsh 1	Mud	1	0.10
Little Neston Marsh 1	Grass	1	0.089
Little Neston Marsh 2	Grass	2	0.084
Flint 1	Mud	2	0.096
Flint 2	Salt marsh	2	0.11
Scotland			
Piltanton Burn	Salt marsh	4 ^S	0.062
Garlieston	Mud	4 ^S	0.076
Innerwell	Mud	4 ^S	0.085
Bladnoch	Mud	4 ^S	0.081
Carsluith	Mud	4 ^S	0.090
Skyreburn Bay (Water of Fleet)	Salt marsh	4 ^S	0.075
Kirkcudbright	Salt marsh	4 ^S	0.082
Cutters Pool	Winkle bed	4 ^S	0.088
Rascarrel Bay	Winkle bed	4 ^S	0.094
Gardenburn	Salt marsh	1 ^S	0.087
Palnackie Harbour	Mud	1 ^S	0.076
Kippford – Slipway	Mud	4 ^S	0.099
Kippford – Merse	Salt marsh	1 ^S	0.090
Southernness	Winkle bed	4 ^S	0.069
Kirkconnell Marsh	Salt marsh	1 ^S	0.099
Isle of Man			
Ramsey	Sand and stones	1	0.095

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu\text{Gy h}^{-1}$
Wales			
Prestatyn	Sand	2	0.065
Rhyl	Mud and salt marsh	1	0.091
Rhyl	Salt marsh	1	0.087
Llandudno	Pebbles and sand	1	0.092
Llandudno	Pebbles	1	0.088
Caerhun	Grass and mud	1	0.093
Caerhun	Grass	1	0.091
Llanfairfechan	Sand and shells	1	0.083
Llanfairfechan	Grass	1	0.078
Northern Ireland			
Lishally	Mud	1 ^N	0.061
Eglington	Shingle	1 ^N	0.053
Carrichue	Mud	1 ^N	0.057
Bellerena	Mud	1 ^N	0.061
Benone	Sand	1 ^N	0.062
Castlerock	Sand	1 ^N	0.061
Portstewart	Sand	1 ^N	0.062
Portrush, Blue Pool	Sand	1 ^N	0.059
Portrush, White Rocks	Sand	1 ^N	0.061
Portballintrae	Sand	1 ^N	0.057
Giant's Causeway	Sand	1 ^N	0.058
Ballycastle	Sand	1 ^N	0.057
Cushendun	Sand	1 ^N	0.062
Cushendall	Sand and stones	1 ^N	0.071
Red Bay	Sand	1 ^N	0.064
Carnlough	Sand	1 ^N	0.063
Glenarm	Sand	1 ^N	0.056
Half Way House	Sand	1 ^N	0.057
Ballygally	Sand	1 ^N	0.058
Drains Bay	Sand	1 ^N	0.059
Larne	Sand	1 ^N	0.062
Whitehead	Sand	1 ^N	0.059
Carrickfergus	Sand	1 ^N	0.061
Jordanstown	Sand	1 ^N	0.058
Helen's Bay	Sand	1 ^N	0.059
Groomsport	Sand	1 ^N	0.070
Millisle	Sand	1 ^N	0.076
Ballywalter	Sand	1 ^N	0.068
Ballyhalbert	Sand	1 ^N	0.067
Cloghy	Sand	1 ^N	0.075
Portaferry	Shingle and stones	1 ^N	0.090
Kircubbin	Sand	1 ^N	0.088
Greyabbey	Sand	1 ^N	0.090
Ards Maltings	Mud	1 ^N	0.083
Island Hill	Mud	1 ^N	0.070
Nicky's Point	Mud	1 ^N	0.093
Strangford	Shingle and stones	1 ^N	0.10
Kilclief	Sand	1 ^N	0.072
Ardglass	Mud	1 ^N	0.089
Killough	Mud	1 ^N	0.084
Rocky Beach	Sand	1 ^N	0.084
Tyrella	Sand	1 ^N	0.078
Dundrum	Sand	1 ^N	0.085
Newcastle	Sand	1 ^N	0.091
Annalong	Sand	1 ^N	0.11
Cranfield Bay	Sand	1 ^N	0.084
Mill Bay	Sand	1 ^N	0.11
Greencastle	Sand	1 ^N	0.087
Rostrevor	Sand	1 ^N	0.12
Narrow Water	Mud	1 ^N	0.097

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

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

Table 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2009

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, $\mu\text{Sv h}^{-1}$
M	Nets	4	0.099
	Rope	4	0.062
S	Nets	4	0.039
	Pots	4	0.081
T	Gill nets	4	0.050
	Pots	4	0.061
W	Gill nets	2	0.031
	Pots	2	0.048
X	Gill nets	4	0.066
	Pots	4	0.090
Z	Nets	4	0.060

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2009

Location	Ground type	No. of sampling observations	Mean beta dose rate in tissue, $\mu\text{Sv h}^{-1}$
Whitehaven – outer harbour	Pebbles and sand	4	<0.035
St Bees	Sand	3	0.093
St Bees	Pebbles and sand	1	0.060
Sellafield pipeline	Sand	2	0.040
Ravenglass – Raven Villa	Mud and salt marsh	3	0.047
Ravenglass – Raven Villa	Grass and salt marsh	1	0.060
Tarn Bay	Sand	1	0.040
Tarn Bay	Pebbles and sand	1	*

* Not detected by the method used

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹					
			⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru
Cumbria								
Silloth	Seaweed	2	<1.1		<1.5	<0.76	110	<6.5
Harrington Harbour	Seaweed	2	<1.2		<1.7	<0.91	180	<7.3
St Bees Seamill	Porphyra	1 ^F	0.18		<0.19	<0.23		4.9
St Bees	Porphyra ^a	4 ^F	<0.13	0.11	<0.35	<0.50	1.2	7.7
St Bees	Seaweed	2	<1.7	<1.5	<1.3	<0.66	570	<6.0
Braystones South	Porphyra	3 ^F	0.25		<0.33	<0.43		8.1
Sellafield	Rhodymenia spp.	2 ^F	0.43		<0.38	<0.47		7.2
Sellafield	Seaweed	2	2.1	3.5	<1.2	<0.59	940	<5.3
Seascale	Porphyra ^b	52 ^F	<0.35		<0.50	<0.29		<11
Ravenglass	Samphire	1 ^F	<0.06		<0.33	<0.66	0.46	<0.63
Ravenglass	Seaweed	2	<1.3		<0.95	<0.49	200	<4.3
Lancashire								
Half Moon Bay	Seaweed	2	<1.1		<1.7	<0.82	300	<7.1
Marshside Sands	Samphire	1 ^F	<0.07		<0.29	<0.42		<0.73
Cockerham Marsh	Samphire	1 ^F	<0.10		<0.65	<1.3		<1.1
Scotland								
Aberdeen	Fucus vesiculosus	1 ^S	<0.10		<0.26	<0.47	72	<0.42
Lerwick	Fucus vesiculosus	1 ^S	<0.10		<0.24	<0.31	7.9	<0.53
Lewis	Fucus vesiculosus	1 ^S	<0.10		<0.11	<0.16	30	<0.23
Islay	Fucus vesiculosus	1 ^S	<0.10		<0.26	<0.32	80	<0.59
Campbeltown	Fucus vesiculosus	1 ^S	<0.10		<0.25	<0.50	180	<0.36
Port William	Fucus vesiculosus	4 ^S	<0.11		<0.38	<0.80	320	<0.52
Garlieston	Fucus vesiculosus	4 ^S	0.22		<0.46	<1.0	270	<0.62
Auchencairn	Fucus vesiculosus	4 ^S	0.26		<0.41	<0.79	450	<0.63
Isle of Man	Fucus vesiculosus	4	<1.0		<1.6	<0.74	240	<6.5
Wales								
Cemaes Bay	Seaweed	2	<0.68		<1.2	<0.49	48	<4.5
Porthmadog	Seaweed	2	<0.64		<1.1	<0.47	7.0	<4.1
Lavernock Point	Seaweed	2	<1.1		<1.6	<0.79	11	<6.4
Fishguard	Seaweed	2	<0.61		<0.93	<0.49	11	<4.2
South Wales, manufacturer A	Laverbread	4 ^F	<0.08		<0.30	<0.39		<0.82
South Wales, manufacturer C	Laverbread	4 ^F	<0.08		<0.28	<0.36		<0.82
South Wales, manufacturer D	Laverbread	4 ^F	<0.08		<0.31	<0.45		<0.81
South Wales, manufacturer E	Laverbread	1 ^F	<0.11		<0.43	<0.61		<1.0
Northern Ireland								
Portrush	Fucus spp.	3 ^N	<0.08		<0.27	<0.35		<0.65
Strangford Lough	Rhodymenia spp.	4 ^N	<0.16		<0.53	<0.74	4.9	<1.4
Ardglass	Ascophyllum nodosum	1 ^N	<0.16		<0.50	<0.58		<1.4
Ardglass	Fucus vesiculosus	3 ^N	<0.10		<0.39	<0.56	220	<0.91
Carlingford Lough	Ascophyllum nodosum	1 ^N	<0.10		<0.42	<0.66		<0.94
Carlingford Lough	Fucus spp.	3 ^N	<0.07		<0.29	<0.45	57	<0.59
Isles of Scilly	Fucus vesiculosus	1	<1.8		<2.8	<1.4	7.2	<12

Table 2.12. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹					
			^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁵⁵ Eu
Cumbria								
Silloth	Seaweed	2	<0.83	<1.7	<0.67	5.9	<2.8	
Harrington Harbour	Seaweed	2	<1.1	<2.0	<0.82	<3.4	<3.2	
St Bees Seamill	<i>Porphyra</i>	1 ^F	<0.11	<0.12	<0.06	0.90	<0.23	<0.10
St Bees	<i>Porphyra</i> ^a	4 ^F	<0.17	<0.44	<0.09	1.5	<0.37	<0.15
St Bees	Seaweed	2	<0.69	<1.6	<0.60	4.5	<2.5	
Braystones South	<i>Porphyra</i>	3 ^F	<0.17	<0.34	<0.09	1.2	<0.36	<0.15
Sellafield	<i>Rhodymenia</i> spp.	2 ^F	<0.23	<0.34	<0.13	7.6	<0.48	<0.22
Sellafield	Seaweed	2	<0.60	<1.5	<0.57	7.3	<2.2	
Seascale	<i>Porphyra</i> ^b	52 ^F	<0.52	<1.2	<0.32	1.4	<1.4	<0.66
Ravenglass	Samphire	1 ^F	<0.11	<0.12	<0.05	0.71	<0.24	<0.08
Ravenglass	Seaweed	2	<0.69	<1.2	<0.51	7.3	<2.0	
Lancashire								
Half Moon Bay	Seaweed	2	<0.94	<1.9	<0.80	4.5	<3.0	
Marshside Sands	Samphire	1 ^F	<0.13	<0.14	<0.07	0.42	<0.24	<0.10
Cockerham Marsh	Samphire	1 ^F	<0.20	<0.20	<0.10	0.89	<0.37	<0.13
Scotland								
Aberdeen	<i>Fucus vesiculosus</i>	1 ^S	<0.10	<0.11	<0.10	<0.10	<0.25	<0.10
Lerwick	<i>Fucus vesiculosus</i>	1 ^S	<0.10	<0.14	<0.10	<0.10	<0.35	<0.15
Lewis	<i>Fucus vesiculosus</i>	1 ^S	<0.10	<0.10	<0.10	0.42	<0.16	<0.10
Islay	<i>Fucus vesiculosus</i>	1 ^S	<0.10	<0.16	<0.10	0.22	<0.35	<0.16
Campbeltown	<i>Fucus vesiculosus</i>	1 ^S	<0.10	<0.10	<0.10	0.56	<0.23	<0.10
Port William	<i>Fucus vesiculosus</i>	4 ^S	<0.11	<0.13	<0.10	1.1	<0.34	<0.15
Garlieston	<i>Fucus vesiculosus</i>	4 ^S	<0.12	<0.22	<0.10	2.6	<0.40	<0.16
Auchencairn	<i>Fucus vesiculosus</i>	4 ^S	<0.13	<0.21	<0.10	2.2	<0.40	<0.17
Isle of Man	<i>Fucus vesiculosus</i>	4	<0.88	<2.1	<0.72	<0.87	<2.8	<1.4
Wales								
Cemaes Bay	Seaweed	2	<0.56	<1.2	<0.48	<0.61	<2.2	
Porthmadog	Seaweed	2	<0.58	<1.1	<0.45	<1.2	<2.0	
Lavernock Point	Seaweed	2	<0.75	<1.8	<0.71	<0.87	<3.0	<1.6
Fishguard	Seaweed	2	<0.47	<1.1	<0.46	<0.50	<2.1	
South Wales, manufacturer A	Laverbread	4 ^F	<0.15	<0.17	<0.08	0.20	<0.30	<0.11
South Wales, manufacturer C	Laverbread	4 ^F	<0.15	<0.17	<0.08	0.19	<0.31	<0.13
South Wales, manufacturer D	Laverbread	4 ^F	<0.15	<0.17	<0.08	<0.14	<0.32	<0.13
South Wales, manufacturer E	Laverbread	1 ^F	<0.19	<0.21	<0.11	0.19	<0.34	<0.14
Northern Ireland								
Portrush	<i>Fucus</i> spp.	3 ^N	<0.15	<0.15	<0.08	0.15	<0.28	<0.13
Strangford Lough	<i>Rhodymenia</i> spp.	4 ^N	<0.27	<0.28	<0.15	0.82	<0.48	<0.21
Ardglass	<i>Ascophyllum nodosum</i>	1 ^N	<0.24	<0.37	<0.17	0.45	<0.73	<0.37
Ardglass	<i>Fucus vesiculosus</i>	3 ^N	<0.19	<0.20	<0.10	0.52	<0.36	<0.15
Carlingford Lough	<i>Ascophyllum nodosum</i>	1 ^N	<0.19	<0.23	<0.11	0.26	<0.50	<0.26
Carlingford Lough	<i>Fucus</i> spp.	3 ^N	<0.13	<0.13	<0.07	0.58	<0.25	<0.11
Isles of Scilly	<i>Fucus vesiculosus</i>	1	<1.3	<3.1	<1.3	<1.4	<4.7	<2.4

Table 2.12. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹							Gross beta
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm		
Cumbria										
Silloth	Seaweed	2				<1.9				
Harrington Harbour	Seaweed	2				<2.7				
St Bees Seamill	<i>Porphyra</i>	1 ^F				5.6				
St Bees	<i>Porphyra</i> ^a	4 ^F	0.40	2.1	17	5.6	*	0.010	220	
St Bees	Seaweed	2	1.5	7.4		3.9				
Braystones South	<i>Porphyra</i>	3 ^F	0.57	3.1	22	6.0	*	0.012		
Sellafield	<i>Rhodymenia</i> spp.	2 ^F	0.68	3.9		10	*	0.012		
Sellafield	Seaweed	2	1.6	7.4		6.0				
Seascale	<i>Porphyra</i> ^b	52 ^F				4.1				
Ravenglass	Samphire	1 ^F				1.4				
Ravenglass	Seaweed	2				19				
Lancashire										
Half Moon Bay	Seaweed	2				<1.0				
Marshside Sands	Samphire	1 ^F				0.11				
Cockerham Marsh	Samphire	1 ^F				0.35			23	
Scotland										
Aberdeen	<i>Fucus vesiculosus</i>	1 ^S				<0.10				
Lerwick	<i>Fucus vesiculosus</i>	1 ^S				<0.10				
Lewis	<i>Fucus vesiculosus</i>	1 ^S				0.11				
Islay	<i>Fucus vesiculosus</i>	1 ^S				<0.10				
Campbeltown	<i>Fucus vesiculosus</i>	1 ^S				<0.10				
Port William	<i>Fucus vesiculosus</i>	4 ^S				0.82				
Garlieston	<i>Fucus vesiculosus</i>	4 ^S				4.2				
Auchencairn	<i>Fucus vesiculosus</i>	4 ^S				1.5				
Isle of Man	<i>Fucus vesiculosus</i>	4				<1.0				
Wales										
Cemaes Bay	Seaweed	2				<0.79				
Porthmadog	Seaweed	2				<0.69				
Lavernock Point	Seaweed	2				<1.1				
Fishguard	Seaweed	2				<0.80				
South Wales, manufacturer A	Laverbread	4 ^F				0.25				
South Wales, manufacturer C	Laverbread	4 ^F				<0.16				
South Wales, manufacturer D	Laverbread	4 ^F				<0.19			140	
South Wales, manufacturer E	Laverbread	1 ^F				0.13				
Northern Ireland										
Portrush	<i>Fucus</i> spp.	3 ^N				<0.12				
Strangford Lough	<i>Rhodymenia</i> spp.	4 ^N	0.042	0.24		0.38	0.00077	0.00062		
Ardglass	<i>Ascophyllum nodosum</i>	1 ^N				<0.47				
Ardglass	<i>Fucus vesiculosus</i>	3 ^N				<0.11				
Carlingford Lough	<i>Ascophyllum nodosum</i>	1 ^N				<0.28				
Carlingford Lough	<i>Fucus</i> spp.	3 ^N				<0.08				
Isles of Scilly	<i>Fucus vesiculosus</i>	1				<1.7				

* Not detected by the method used

^a The concentration of ¹⁴C was 73 Bq kg⁻¹^b Counted fresh^F Measurements labelled "F" are made on behalf of the Food Standards Agency^N Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency^S Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency
All other measurements are made on behalf of the Environment Agency

Table 2.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			¹⁴ C	⁶⁰ Co	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹²⁵ Sb
Sellafield 14 ^b	Cabbage	1		<0.04	<0.25	<0.52	13	<0.42	<0.09
Sellafield 14 ^b	Leeks	1		<0.05	<0.12	<0.12	1.4	<0.49	<0.10
Sellafield 14 ^b	Onions	1		<0.07	<0.79	<0.40	2.3	<0.73	<0.14
Sellafield 14 ^b	Potatoes	1		<0.06	<0.31	<0.57	5.1	<0.60	<0.14
Sellafield 14 ^b	Soil	1		3.1	<4.1	<6.1	820	<8.7	<2.8
Sellafield 154 ^b	Leeks	1		<0.05	<0.16	<0.20	0.048	<0.51	<0.11
Sellafield 154 ^b	Onions	1		<0.06	<0.20	<0.25	<0.88	<0.56	<0.12
Sellafield 154 ^b	Potatoes	1		<0.04	<0.15	<0.18	<0.43	<0.39	<0.10
Sellafield 154 ^b	Sweet potatoes	1		<0.15	<0.53	<0.68	<0.15	<1.6	<0.32
Sellafield 154 ^b	Soil	1		<0.86	<3.7	<4.6	53	<8.5	<2.5
Sellafield 474 ^b	Beetroot	1		<0.02	<0.06	<0.06	<0.12	<0.17	<0.04
Sellafield 474 ^b	Butternut squash	1		<0.04	<0.19	<0.36	<0.23	<0.31	<0.06
Sellafield 474 ^b	French dwarf beans	1		<0.05	<0.19	<0.26	<0.098	<0.51	<0.11
Sellafield 474 ^b	Pak choi	1		<0.05	<0.20	<0.26	<0.13	<0.53	<0.11
Sellafield 474 ^b	Potatoes	1		<0.03	<0.23	<0.52	<0.25	<0.34	<0.07
Sellafield 474 ^b	Soil	1		<0.23	<2.2	<5.3	<0.94	<3.0	<0.74
Hinkley	Beetroot	1	10	<0.13	<0.62	<1.0		<1.4	<0.26
Hinkley	Potatoes	1	17	<0.05	<0.12	<0.13		<0.33	<0.07
Hinkley	Soil	1	9.2	<0.53	<2.2	<3.0		<5.1	<1.2

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	¹⁵⁴ Eu	¹⁵⁵ Eu	²⁴¹ Am
Sellafield 14 ^b	Cabbage	1	<0.04	0.04	<0.20	<0.11	<0.08	<0.07
Sellafield 14 ^b	Leeks	1	<0.05	<0.04	<0.16	<0.16	<0.07	<0.04
Sellafield 14 ^b	Onions	1	<0.07	<0.06	<0.28	<0.20	<0.10	<0.05
Sellafield 14 ^b	Potatoes	1	<0.07	0.29	<0.32	<0.20	<0.14	<0.17
Sellafield 14 ^b	Soil	1	<1.0	64	<5.8	<2.3	<2.7	39
Sellafield 154 ^b	Leeks	1	<0.05	0.07	<0.19	<0.16	<0.07	<0.04
Sellafield 154 ^b	Onions	1	<0.05	<0.05	<0.21	<0.18	<0.08	<0.04
Sellafield 154 ^b	Potatoes	1	<0.04	0.13	<0.19	<0.14	<0.08	<0.05
Sellafield 154 ^b	Sweet potatoes	1	<0.15	0.16	<0.55	<0.44	<0.20	<0.10
Sellafield 154 ^b	Soil	1	<1.1	60	<5.7	<2.6	<2.8	<3.6
Sellafield 474 ^b	Beetroot	1	<0.02	<0.02	<0.08	<0.08	<0.04	<0.02
Sellafield 474 ^b	Butternut squash	1	<0.04	<0.03	<0.11	<0.13	<0.04	<0.03
Sellafield 474 ^b	French dwarf beans	1	<0.05	<0.04	<0.25	<0.15	<0.10	<0.09
Sellafield 474 ^b	Pak choi	1	<0.05	<0.05	<0.20	<0.17	<0.08	<0.04
Sellafield 474 ^b	Potatoes	1	<0.03	<0.03	<0.17	<0.11	<0.06	<0.04
Sellafield 474 ^b	Soil	1	<0.35	3.9	<2.5	<0.68	<1.0	<1.2
Hinkley	Beetroot	1	<0.14	<0.11	<0.45	<0.42	<0.18	<0.09
Hinkley	Potatoes	1	<0.04	<0.03	<0.11	<0.15	<0.05	<0.03
Hinkley	Soil	1	<0.76	6.5	<2.2	<1.9	<1.0	<0.59

^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 Ravensglass, 2009

Material and selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹									
		³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹²⁵ Sb	¹²⁹ I
Milk ^d	3	<4.3	16	<0.18	0.036	<0.32	<0.25	<0.0040	<1.2	<0.38	<0.0084
Milk	max	<4.5		<0.19	0.052	<0.33	<0.27		<1.3	<0.41	<0.0093
Apples		1	<4.0	13	<0.20	0.034	<0.20	<0.20	<0.021	<1.0	<0.20
Barley	1	<8.0	76	<0.20	0.60	<0.40	<0.30	<0.032	<0.80	<0.50	<0.041
Beef kidney	1	16	23	<0.20	0.25	<0.30	<0.20	<0.021	<1.6	<0.60	
Beef liver	1	<6.0	23	<0.20	0.13	<0.20	<0.20	<0.020	<0.60	<0.40	<0.034
Beef muscle	1	<5.0	23	<0.20	<0.0080	<0.30	<0.20	<0.019	<1.0	<0.30	<0.049
Beetroot	1							<0.029			
Blackberries	1	5.0	12	<0.20	0.27	<0.30	<0.30	0.030	<1.7	<0.40	<0.032
Cabbage	1	<4.0	<3.0	<0.10	0.59	<0.30	<0.20	<0.027	<1.1	<0.30	<0.023
Carrots	1	<4.0	7.0	<0.20	0.12	<0.20	<0.20	<0.022	<1.4	<0.30	<0.021
Honey	1	<7.0	77	<0.20	0.040	<0.20	<0.20	<0.030	<0.90	<0.30	<0.016
Onions	1							<0.024			
Pheasants	1	<5.0	23	<0.10	0.037	<0.40	<0.20	<0.022	<1.3	<0.60	<0.036
Potatoes	1	<5.0	19	<0.30	0.049	<0.40	<0.20	<0.022	<0.70	<0.30	<0.021
Runner beans	1	4.0	8.0	<0.20	0.069	<0.30	<0.20	<0.023	<1.2	<0.40	<0.020
Sheep muscle	2	<5.0	38	<0.20	0.012	<0.35	<0.25	<0.026	<1.2	<0.45	<0.034
Sheep muscle	max			<0.30	0.014	<0.40	<0.30		<1.3	<0.50	<0.039
Sheep offal		2	<10	41	<0.20	0.28	<0.40	<0.25	<0.019	<1.6	<0.65
Sheep offal	max	12	43		0.37		<0.30	<0.020		<0.80	<0.046
Grass	2							<0.026			
Grass	max							0.028			

Material and selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹									
		Total Cs	¹⁴⁴ Ce	²³⁴ U	²³⁵ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu + ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	
Milk ^d	3		<0.83				<0.00012	<0.00013	<0.036	<0.00015	
Milk	max		<0.86				<0.00013	<0.00015		<0.00018	
Apples		1	0.11	<0.60				0.00020	0.00030	<0.066	0.0015
Barley	1	0.24	<1.0				0.00060	0.0045	<0.071	0.0098	
Beef kidney	1	0.16	<1.4	0.015	<0.00090	0.014	<0.00020	<0.00030	<0.068	0.00030	
Beef liver	1	0.27	<0.70				<0.00010	0.00030	<0.068	0.00030	
Beef muscle	1	0.19	<0.70				<0.00030	0.00070	<0.24	<0.00020	
Beetroot	1			0.024	0.00080	0.024					
Blackberries	1	0.093	<0.70				<0.00020	<0.00020	<0.067	0.0011	
Cabbage	1	0.10	<0.60				<0.00020	0.00030	<0.055	<0.00050	
Carrots	1	0.43	<0.70				<0.00010	0.00020	<0.061	<0.00020	
Honey	1	0.18	<1.0				<0.00030	<0.00040	<0.091	<0.00040	
Onions	1			0.0011	<0.00040	0.00080					
Pheasants	1	0.29	<1.5				<0.00020	<0.00030	<0.084	<0.00040	
Potatoes	1	0.18	<0.70				<0.00010	<0.00020	<0.063	0.00030	
Runner beans	1	0.081	<0.70				<0.00030	0.00070	<0.061	0.00090	
Sheep muscle	2	1.3	<0.85				<0.00020	<0.00040	<0.088	0.00040	
Sheep muscle	max	1.6	<0.90				0.00030	0.00060	<0.093		
Sheep offal		2	0.70	<1.2				0.00015	<0.00045	<0.075	0.00080
Sheep offal	max	0.81	<1.6				0.00020	0.00060	<0.077	0.0012	
Soil	1			12	0.41	11					

^a Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

^b Except for milk where units are Bq l⁻¹

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

^d The mean concentrations of ¹³⁴Cs and ¹³⁷Cs were <0.19 (max <0.21) and <0.20 (max <0.21) Bq l⁻¹

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2009

Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹								
		³ H	⁶⁰ Co	⁹⁰ Sr	¹³⁴ Cs	¹³⁷ Cs	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	Gross alpha	Gross beta
Ehen Spit beach	4	220	<0.32	<0.068	<0.25	<0.29	<0.0068	<0.0063	<2.5	14
River Ehen (100m downstream of sewer outfall)	4	<11	<0.32	<0.052	<0.26	<0.26	<0.0058	<0.0055	<0.078	0.35
River Calder (downstream)	4	<4.3	<0.31	<0.053	<0.26	<0.27	<0.010	<0.0050	<0.032	0.19
River Calder (upstream)	4	<4.0	<0.34	<0.055	<0.26	<0.29	<0.0068	<0.0053	<0.020	<0.10
Wast Water	1	<4.0	<0.36			<0.30			<0.020	<0.10
Ennerdale Water	1	<4.0	<0.13		<0.11	<0.11			<0.030	<0.10
Devoke Water	1	<4.0	<0.13		<0.10	<0.11			<0.020	<0.10
Thirlmere	1	<4.0	<0.38			<0.29			<0.020	<0.10

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2009

Location	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹							
		⁶⁰ Co	⁹⁰ Sr	¹³⁴ Cs	¹³⁷ Cs	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	
Seascale SS 204	1	<1.4	<5.0	<1.3	400	2.1	19	26	
Seascale SS 233	1	<1.1	5.0	<1.0	310	4.0	30	31	
Seascale SS 209	1	<0.85	<2.0	<0.79	31	<3.0	7.0	16	
Seascale SS 232	1	<0.96	<2.0	<0.84	52	<2.0	7.9	28	
Seascale SS 231	1	<1.0	<3.0	<0.91	47	4.3	23	35	
Whitehaven SS 201	1	<2.7	<2.0	<2.0	24	0.71	2.0	2.5	

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2005 2009

Group	Exposure, mSv per year				
	2005	2006	2007	2008	2009
Isle of Man	0.008	0.007	0.006	0.007	0.007
Northern Ireland	0.020	0.018	0.015	0.017	0.012
Dumfries and Galloway	0.031	0.037	0.060	0.047	0.047
Whitehaven	0.008	0.011	0.009	0.009	0.011
Sellafield (5 year average consumption)	0.22	0.23	0.24	0.23	0.20
Morecambe Bay	0.063	0.038	0.037	0.042	0.041
Fleetwood	0.019	0.018	0.013	0.016	0.013
North Wales	0.015	0.016	0.014	0.018	0.015

Table 2.18. Individual radiation exposures, Sellafield, 2009

Exposed population ^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 2005-09)	0.38 ^d	0.17	0.18	-	0.033	-	-
Local seafood consumers (habits for 2009)	0.40 ^e	0.15	0.21	-	0.039	-	-
Whitehaven seafood consumers	0.011	0.011	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.047	0.035	-	-	0.012	-	-
Morecambe Bay seafood consumers	0.041	0.011	-	-	0.030	-	-
Fleetwood seafood consumers	0.013	0.013	-	-	-	-	-
Isle of Man seafood consumers	0.007	0.007	-	-	-	-	-
Northern Ireland seafood consumers	0.012	0.009	-	-	<0.005	-	-
North Wales seafood consumers	0.015	0.008	-	-	0.007	-	-
Other groups							
Ravenglass Estuary, nature warden	0.048	-	-	-	0.040	0.008	-
Fishermen handling nets or pots ^c	0.061	-	-	-	0.061	-	-
Bait diggers and shellfish ^c collectors	0.043	-	-	-	0.043	-	-
Ribble Estuary houseboats	0.13	-	-	-	0.13	-	-
Local consumers at Ravenglass ^b	0.012	-	-	0.012	-	-	-
Local consumers of vegetables							
grown on land with seaweed added	0.009	-	-	0.009	-	-	-
Local consumers at LLWR near Drigg ^b	0.013	-	-	0.013	-	-	-
Local consumers in the Isle of Man ^b	0.008	-	-	0.008	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food	0.028	-	-	0.027	-	-	<0.005
Dumfries and Galloway wildfowlers	<0.005	<0.005	-	-	<0.005	-	-
Groups with average consumption or exposure							
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Average consumer of locally grown food	0.013	-	-	0.013	-	-	-
Typical visitor to Cumbria	<0.005	<0.005	<0.005	-	<0.005	-	-
Recreational user of beaches							
North Cumbria	0.012	-	-	-	0.012	-	-
Sellafield	0.013	-	-	-	0.013	-	-
Lancashire	0.008	-	-	-	0.008	-	-
North Wales	0.007	-	-	-	0.007	-	-
Isle of Man	0.011	-	-	-	0.011	-	-
Recreational user of mud/saltmarsh areas							
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-
North Cumbria	0.008	-	-	-	0.008	-	-
Sellafield	0.018	-	-	-	0.018	-	-
Lancashire	0.009	-	-	-	0.009	-	-
North Wales	0.006	-	-	-	0.006	-	-
All sources^f	0.28	-	-	-	-	-	-

^a Adults are the most exposed age group unless stated otherwise

^b Children aged 1 yr

^c Exposure to skin for comparison with the 50 mSv dose limit

^d The total dose due to nuclear industry discharges was 0.20 mSv

^e The total dose due to nuclear industry discharges was 0.19 mSv

^f The total dose due to discharges and direct radiation. See Appendix 4. The doses from man-made and naturally occurring radionuclides were 0.15 and 0.14 mSv respectively.

The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR site into the same area

3. Research establishments

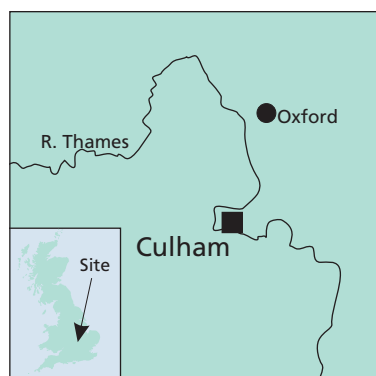
This section considers the effects of discharges from research establishments that hold nuclear site licences.

The NDA has ownership of the majority of such sites, with licensed nuclear sites at Harwell and Winfrith in England, and Dounreay in Scotland. The NDA also owns the non-nuclear site at Culham, which is operated by UKAEA (under contract from Euratom) under the terms of the European Fusion Development Agreement. Previously Harwell, Winfrith and Dounreay sites were operated by UKAEA. Research Sites Restoration Limited (RSRL) and Dounreay Site Restoration Limited (DSRL) (both wholly-owned subsidiaries of UKAEA) have become the site licence companies for Harwell and Winfrith, and Dounreay respectively. UKAEA Ltd itself was sold to Babcock International during the year as a preliminary to NDA starting the Dounreay Parent Body Organisation competition. All of the nuclear sites have reactors that are at different stages of decommissioning. Discharges of radioactive waste are largely related to decommissioning and decontamination operations and the nuclear related research that is undertaken. Tenants, or contractors, such as Nuvia Limited carry out some of this work.

Regular monitoring of the environment was undertaken in relation to all UKAEA sites, which included the effects of discharges from neighbouring sites and tenants where appropriate, i.e. the Vulcan Naval Reactor Test Establishment (NRTE) adjacent to the Dounreay site, and GE Healthcare at Harwell.

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

3.1 Culham, Oxfordshire



Culham hosts an experimental fusion reactor, the Joint European Torus (JET). Under current plans, the assumption is that all the JET facilities will be removed and this area of the Culham site will be landscaped in accordance with the

local authority temporary planning consents by 2020. Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2009. Locations and data are shown in Figure 3.1 and Table 3.2

Key points

- Discharges, environmental concentrations, dose rates and doses in 2009 were broadly similar to those in 2008
- Radiation doses from all sources were less than 7 per cent of the dose limit

Dounreay, Highland

- Dounreay Site Restoration Limited (DSRL) is the site licence company for Dounreay
- The dose from terrestrial food consumption was affected by the presence of caesium-137 in game

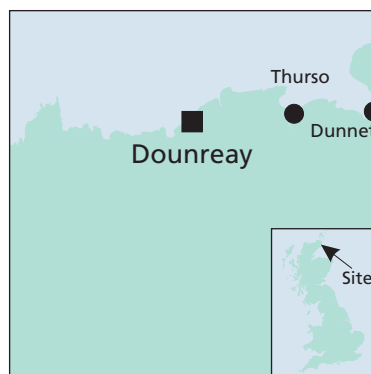
Harwell, Oxfordshire

- GE Healthcare voluntarily surrendered one of its licences on the Harwell site in February 2009

respectively. In recent years, the main effect of the site's operation was the increased tritium concentrations found in grass collected near the site perimeter. In 2009, measurements of tritium were less than the LoD. Overall, no effects due to site operation were detected. The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but are due to past discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986.

The dose from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2009 was also estimated to be much less than 0.005 mSv (Table 3.1).

3.2 Dounreay, Highland



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

decommissioning. The current assumption is that the Dounreay site will achieve an interim end state, at which stage nuclear

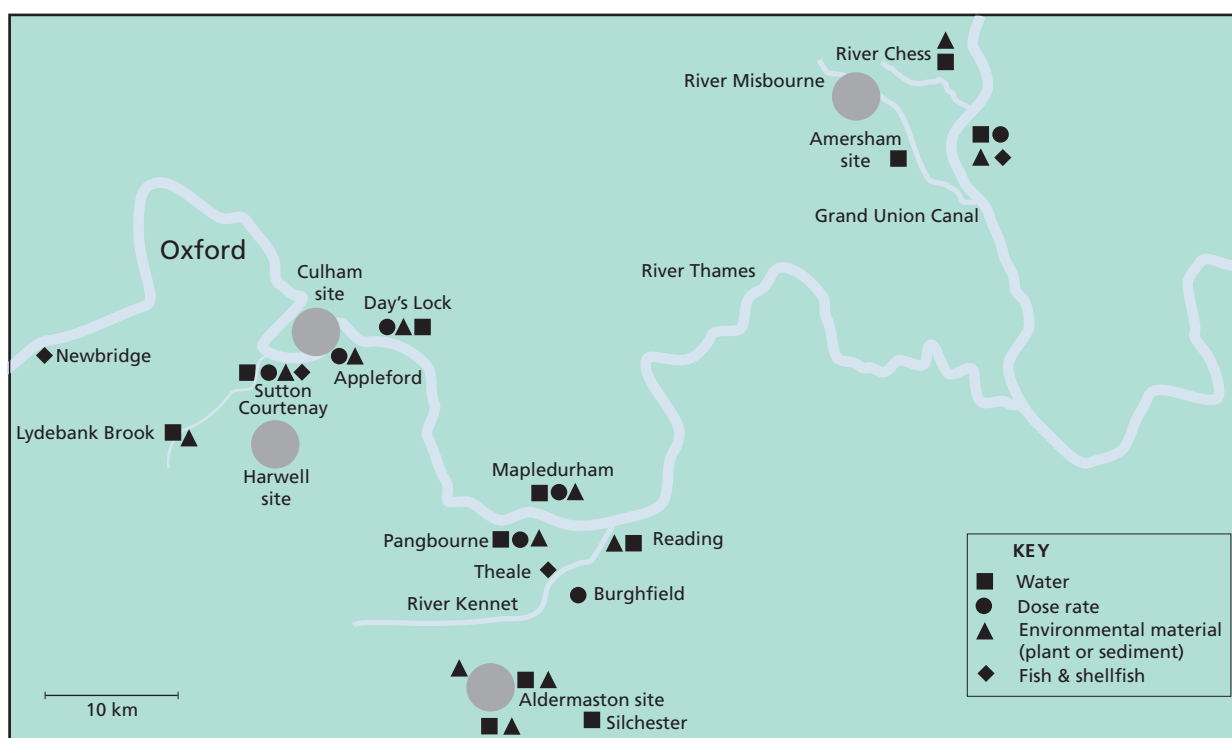


Figure 3.1. Monitoring locations at Thames sites, 2009 (not including farms)

facilities will be in a passively safe condition, as a radiological and industrial brown field site.

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

Construction of the new ventilation extract facility at the Fuel Cycle Area progressed during 2009. In April 2009, SEPA undertook an inspection of the arrangements for the minimisation of particulate ingress into the new extract system.

In September 2008, a leak of radioactive liquor occurred within the ion exchange plant of the Sodium/Potassium (NaK) destruction plant. Although there was no release to the environment, the NaK destruction plant was shut down whilst a number of plant improvements were undertaken. In January, February and August 2009, SEPA and the NII undertook joint inspections of DSRL's progress in addressing the requirements for restart of active commissioning and for the plant to move from commissioning to operations. The active commissioning of the NaK destruction plant was restarted in March 2009 and the plant moved to operations in November 2009.

SEPA is currently determining DSRL's application for an authorisation to construct and dispose of waste to a Low Level Radioactive Waste Disposal facility adjacent to the site.

DSRL continues to intercept contaminated surface water from waste accumulated in the ground and divert it to their authorised discharge route. The source of the contamination has been identified and this has been incorporated into DSRL's contaminated land strategy.

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

SEPA conducted an inspection of the facility level documents, which underpin the identification and consignment of solid radioactive waste. As a result of SEPA identifying several areas for improvement, DSRL commenced an improvement programme.

SEPA conducted an inspection of the work undertaken by DSRL to address the improvement requirement on the inspection of ducting and discharge stacks, and the removal of particulate matter.

In January 2009, an elevated concentration of tritium was detected in a non-radioactive drainage outfall. Initially the gaseous discharge from the Sodium Inventory Disposal (SID) facility at the Prototype Fast Reactor was identified as a potential source of the elevated tritium in the drainage outfall. As a result, a warning letter was sent by SEPA. Subsequent inspection by SEPA has concluded that there is adequate management of the SID process and its potential impact and

the most likely cause of the elevated tritium was an unidentified disposal to drain.

In 2009, radioactive waste discharges from Dounreay were made by DRSL under authorisations granted by SEPA. The quantities of both gaseous and liquid discharges in 2009 were generally similar to those in 2008 (Appendix 2). Sampling locations for the terrestrial and marine monitoring programme are shown in Figure 3.2 (north of Scotland) and Figure 3.3 (Dounreay).

The most recent habits survey was conducted in 2008 (Clyne *et al.*, *in preparation*). Three potentially critical pathways for public radiation exposure in the aquatic environment were confirmed. Figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1. A habit survey to obtain data on activities undertaken on beaches relating to potential public exposure to radioactive particles at Dunnet Bay in Caithness was undertaken in 2009 (Clyne *et al.*, *in preparation*).

Gaseous discharges and terrestrial monitoring

DSRL is authorised by SEPA to discharge gaseous wastes to the local environment via stacks to the atmosphere. Monitoring conducted in 2009 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 2009. The results for terrestrial samples and radioactivity in air are given in Tables 3.3(a) and (c) and generally show low concentrations of radioactivity. Low concentrations of caesium-137, strontium-90, europium-155, uranium, plutonium and americium-241 were reported in samples. In 2009, additional samples of venison and rabbit were taken to obtain a more detailed understanding of caesium-137 variation. The concentration of caesium-137 in venison (69 Bq kg^{-1} , max) was similar to the value for venison (86 Bq kg^{-1}) in 2007, but lower than caesium-137 activity found in rabbit (110 Bq kg^{-1}) in 2008 (venison was not sampled in 2008). Concentrations of caesium-137 in the terrestrial environment in the Dounreay area will have been affected by fallout from weapons testing in the 1960s and from the Chernobyl reactor accident in 1986. Further samples of game will be collected during 2010.

Liquid waste discharges and aquatic monitoring

Low level liquid waste is routed via a Low Level Liquid Effluent Treatment Plant (LLLETP). The effluent is discharged to sea (Pentland Firth) via a pipeline terminating 600 metres offshore at a depth of about 24 metres. The discharges also include

groundwater pumped from the Dounreay Shaft, surface water runoff, leachate from the low level solid waste disposal facility, and a minor contribution from the adjoining reactor site (Vulcan NRTE), which the Defence Procurement Agency operates.

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

Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. The results for marine samples and gamma dose rates (Tables 3.3(a) and (b)) generally show low concentrations of radioactivity in 2009 and are similar to those in recent years. Gamma dose rates in 2009 were generally similar to those in 2008. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were similar to those in 2008. Figure 3.2 also gives time trend information for technetium-99 concentrations (from Sellafield) in seaweed at Sandside Bay (location shown in Figure 3.3), Kinlochbervie and Burwick. They show an overall decline in concentrations over the period at all three locations. Beta dose measurements were less than the LoD (Table 3.3(b)).

During 2009, DSRL 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 2009, access was periodically withdrawn and as a result monitoring was interrupted during the year.

In 2009, 33 fragments were recovered from Sandside Bay and 11 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 4.7 kBq and 130 kBq (similar to ranges observed in 2008).

In May 2009, during additional monitoring performed by DSRL, one fragment was recovered from Murkle beach. The caesium-137 activity measured in this fragment was 9 kBq.

In August 2009, a single minor particle[#] (fuel fragment) and a small amount of caesium-137 contaminated ground was detected and recovered from rough grazing land adjacent to Dounreay. These were detected and removed as part of the monitoring of the footprint for the proposed new Low Level Radioactive Waste Disposal facility. The fuel fragment was recovered 240m inland from the sea cliffs. A patch of contaminated ground was recovered 300m inland of the sea

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

The term, minor, relates to one of the categories developed by the Dounreay Particles Advisory Group to categorise Dounreay fuel fragments.

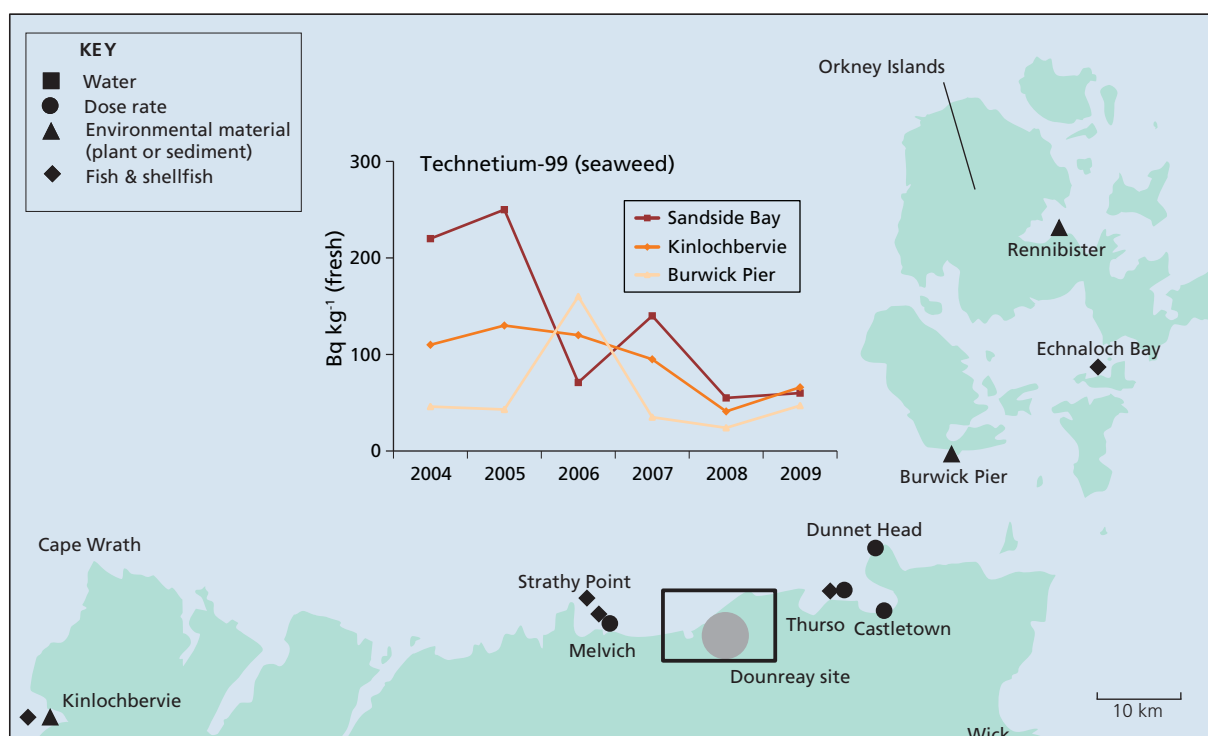


Figure 3.2. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2009 (not including farms)

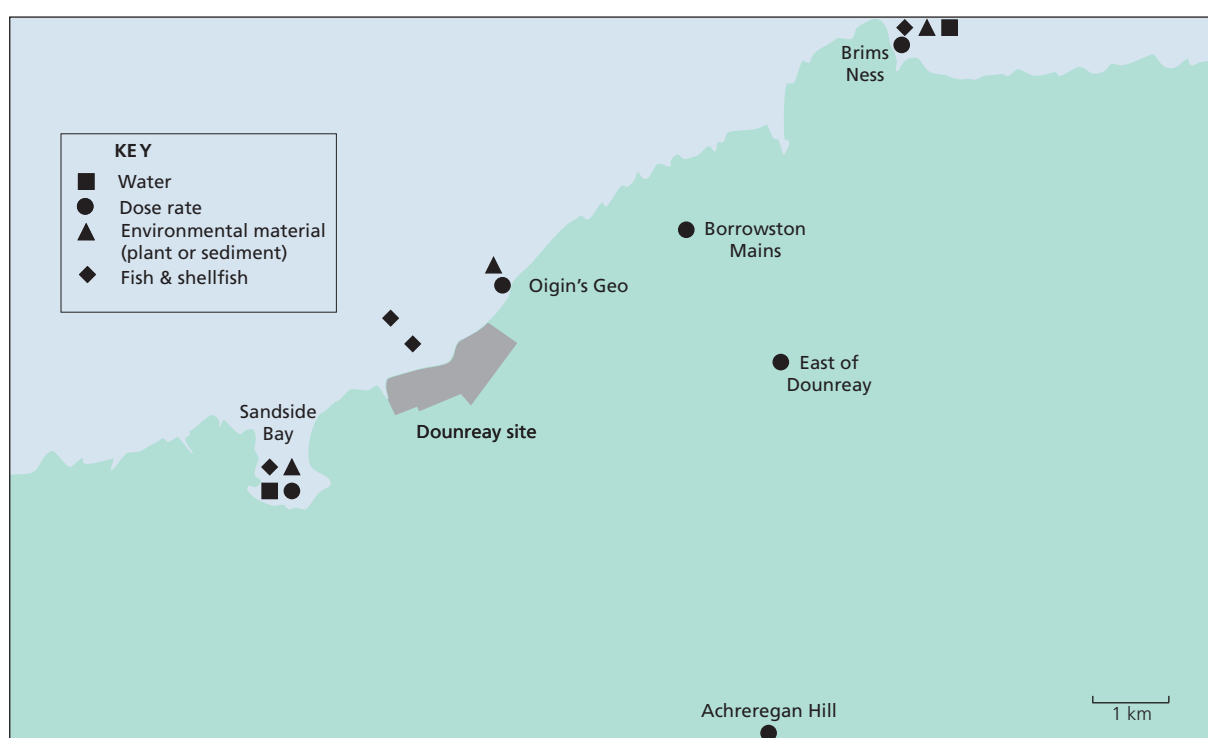


Figure 3.3. Monitoring locations at Dounreay, 2009 (not including farms)

cliffs and from eight areas adjacent to the old taxiway. The contamination associated with the taxiway was similar to enhanced concentrations of caesium-137 alongside the old runway and is considered to be due to historic washout from gaseous discharges. The caesium-137 activity measured in the fragment was 57 kBq. SEPA have asked DSRL to consider the wider implications of the findings, and in particular for any requirement for further monitoring.

SEPA concurred with DSRL's conclusion that the most likely mechanism for the transport of the fragment was windblown transportation. In SEPA's view, the fragment was most likely to have blown from Landfill 42 (probably in the mid 1990s) when the seaward face of the landfill was being pulled back on to the landfill. SEPA is in discussion with DSRL regarding the long term future for this disused landfill. At present, further monitoring is not thought necessary for the purpose

of health and environmental protection. SEPA will take account of this work as part of the radioactive contaminated land assessment that the agency is undertaking in respect of fragments of irradiated nuclear fuel in the local Dounreay environment.

During 2009, particle retrieval operations to recover fragments from the seabed using a remotely operated vehicle were undertaken. The retrieval operations undertaken between June and August recovered 115 fragments from an area of 7.6 hectares of the offshore seabed.

The previously conducted offshore survey work provided data on repopulation rates of particles to areas of the seabed previously cleared of particles. This work has improved the understanding of particle movements in the marine environment. The current state of knowledge is described in the DPAG's[†] Fourth Report, published in November 2008 (Dounreay Particles Advisory Group, 2008).

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

Doses to the public

The dose from the consumption of local terrestrial foodstuffs, including a contribution due to weapon test fallout, was estimated to be 0.029 mSv, which was less than 3 per cent of the annual dose limit for members of the public of 1 mSv (Table 3.1). This includes an assessment of the effects for non-food pathways from discharges to air (see Appendix 1). In 2009, the critical age group was 1-year-old infants, as opposed to adults in 2008. The change in dose and the critical age group from adults (0.036 mSv in 2008) was due to the type of game sample and associated activity concentrations (of the significant contributor) used in the assessment (from rabbit in 2008 to venison in 2009), which had a reduced caesium-137 concentration in 2009. The doses to 1-year-old infants in 2009 and 2008 (0.029 mSv) were unchanged. The annual dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

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

The first potential pathway involves people who consume locally collected fish and shellfish at high-rates, and are exposed to

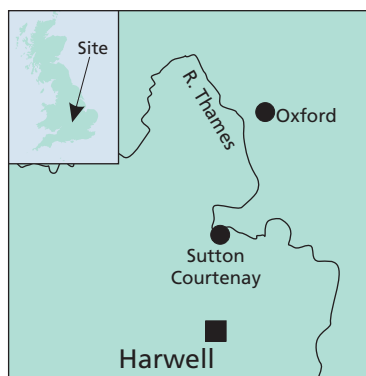
external exposure from occupancy over local beaches. This dose in 2009 was 0.011 mSv or approximately 1 per cent of the dose limit for members of the public of 1 mSv. This is similar to the value in 2008 (0.010 mSv).

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

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

The *total dose* from all sources in 2009, using the integrated habits survey data obtained in 2008, was assessed to have been 0.063 mSv or approximately 6 per cent of the dose limit. The people most exposed were high-rate consumers of game meat. The dose represents a decrease from that in 2008 (0.078 mSv) due to lower levels of caesium-137 in venison, which contributes to the majority of the game meat consumed in the area. Around 90 percent of the dose was from caesium-137 which is present in the environment from a number of sources, such as Chernobyl and weapons testing fallout, historic discharges together with authorised releases from the site. In 2010, SEPA will further investigate the caesium-137 concentrations in the environment.

3.3 Harwell, Oxfordshire



Harwell was established in 1946 as Britain's first Atomic Energy Research Establishment. The site accommodated five research reactors of various types. The UKAEA Harwell nuclear licensed site now forms part of the Harwell Science

and Innovation Campus and is situated approximately 5 km southwest of the town of Didcot. In 2008, UKAEA were the operators under the ownership of the NDA, and GE Healthcare occupied buildings in two small areas embedded within the UKAEA licensed site, each with their own nuclear site licence. One of the buildings is in the process of being decommissioned and the other is an operating radioactive waste management

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

and source refurbishment facility. In February 2009, Research Sites Restoration Limited, (RSRL, a wholly-owned subsidiary of UKAEA) became the site licence company. Also in February 2009, GE Healthcare's permit for B10.23 was revoked as a result of the company surrendering its nuclear site licence for the building. Under current plans, land will be de-licensed when clean-up is complete by 2025, and released for redevelopment for science, technology and innovation uses as part of the Harwell Science and Innovation Campus. The most recent habits survey was conducted during 2007 (Garrod *et al.*, 2008).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via stacks to the local environment. The monitoring programme sampled milk and other terrestrial foodstuffs. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.1. The results of the terrestrial programme are shown in Table 3.4(a). The results of tritium and caesium-137 analyses of terrestrial food samples were all below LoDs.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive wastes from Harwell continued in 2009 to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site. Figure 3.4 shows trends of discharges over time (2000 – 2009) for cobalt-60 and caesium-137. There was an overall reduction in the discharges over the period, particularly for cobalt-60. The aquatic monitoring programme was directed at consumers of freshwater fish, sediments and external exposure close to the liquid discharge point.

Caesium-137 concentrations in freshwater samples were all below the LoD. These concentrations in sediments were slightly enhanced close to the outfall at Sutton Courtenay and at Lydebank Brook but were small in terms of any radiological effect. Concentrations of transuranic elements in local fish (perch and pike) and sediments were either very low or below the LoD. The concentrations of all radionuclides in flounder from the lower reaches of the Thames (from Beckton) were either very close to or below the LoD.

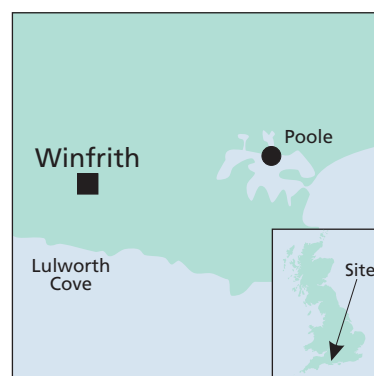
Doses to the public

The estimated dose to high-rate consumers of terrestrial foods was less than 0.005 mSv, including a component due to non-food pathways arising from discharges to air (see Appendix 1), which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 3.1). For aquatic pathways, the most recent habits survey indicated that perch and crayfish were the predominant foods consumed by people. Unlike in 2008, perch were sampled in 2009, allowing an improved dose assessment this year. In 2009, the dose to anglers who consume fish and are exposed to external radiation was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 3.1), and

similar to the dose estimated in previous years. Thames river water is used as a source of drinking water. The annual dose from drinking River Thames water downstream of the discharge point was much less than 0.005 mSv.

The *total dose* from all sources was 0.023 mSv in 2009 (Table 3.1), which is approximately 2 per cent of the dose limit. The most exposed people were the prenatal children of local inhabitants, and the dominant contribution to this dose was direct radiation from the site (Table A4.1). The increase in *total dose* from 0.020 mSv in 2008 is due to a slightly higher estimate of the direct radiation from the site.

3.4 Winfrith, Dorset



The Winfrith site is located near Winfrith Newburgh. At various times there have been nine research and development reactors. The last operational reactor at Winfrith closed in 1995, since then the focus for the site has been on

decommissioning. The decommissioning programme is scheduled for completion in 2040, with site closure by 2048. The Environment Agency reissued a permit to discharge radioactive wastes, effective from February 2009, to reflect the transition from UKAEA to RSRL. Gaseous wastes are disposed of from various stacks on site. Liquid wastes are disposed of under permit to deep water in Weymouth Bay. Figure 3.5 shows trends of liquid discharges over time (2000 – 2009) for tritium and alpha radionuclides. Over the period, alpha radionuclide discharges have generally decreased since the peak in 2003, whilst tritium discharges have varied more between years since declining from the peak in 2004. Discharges of radioactive wastes from this site continued in 2009 at very low rates.

The monitoring programme consisted of samples of milk, crops, fruit, seafood, water and environmental materials. Sampling locations at Winfrith are shown in Figure 3.6. Data are given in Tables 3.5(a) and (b). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. Carbon-14 was detected in locally produced foods, at concentrations just above background values, although this may be due to natural variation. Low concentrations of tritium were found in surface water to the north of the site, similar to previous years. In all cases the gross alpha and beta activities were below the WHO's screening levels for drinking water. The estimated dose to people who consume terrestrial food at high-rates was less than 0.005 mSv. After making an allowance for radionuclides in air, using the methods and data given in Appendix 1, the dose in 2009 was still less than 0.005 mSv which was less than 0.5 per cent of the dose limit for

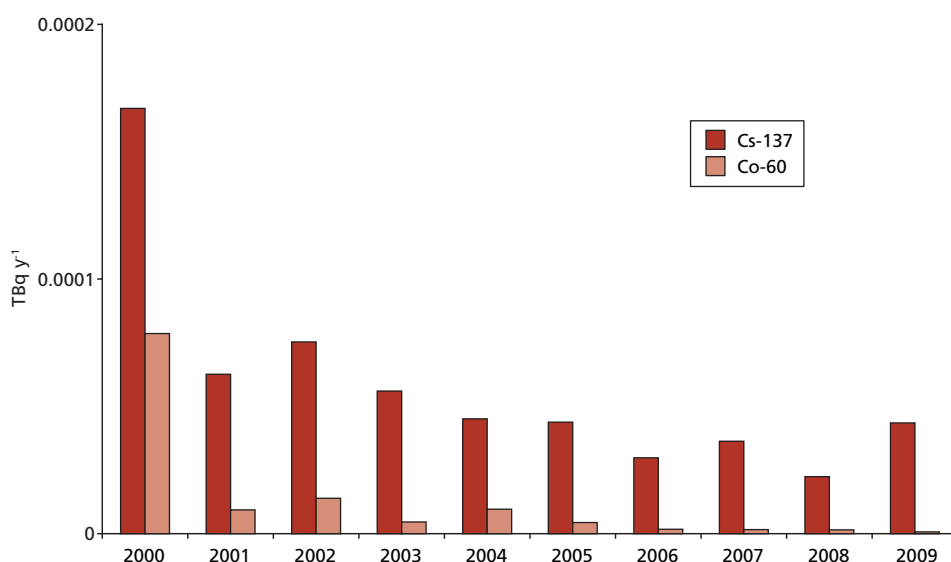


Figure 3.4. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2009

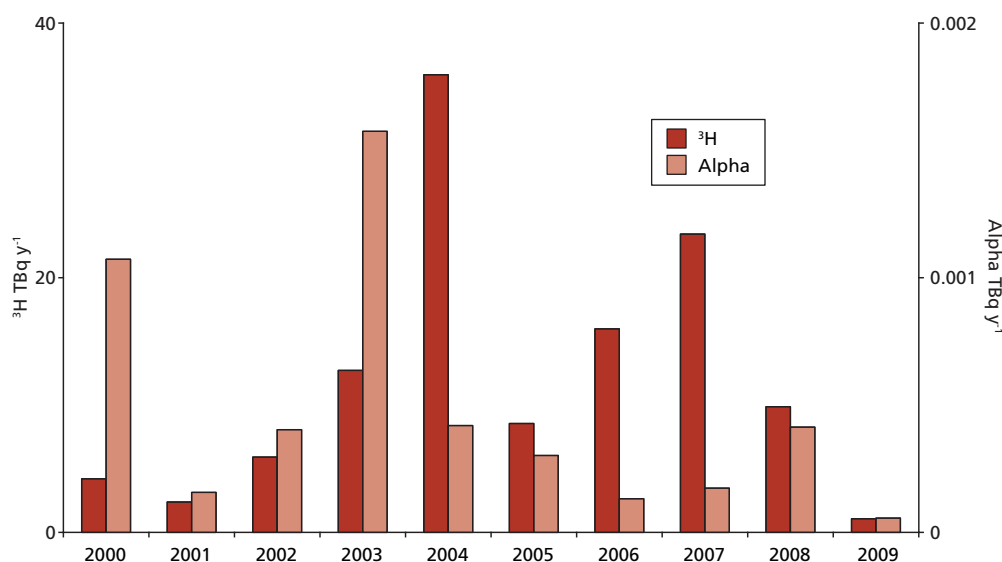


Figure 3.5. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2009

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 high-rate fish and shellfish consumers, including a contribution from external exposure, remained low in 2009 at much less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public. Trends in doses in the area of the south coast (and the Severn Estuary) are shown in Figure 6.5. The *total dose* from all sources (using methods in Appendix 4) was assessed

to have been less than 0.005 mSv, or less than 0.5 per cent of the dose limit. The main component of dose in 2009 was from elevated levels of carbon-14 in potatoes. Prenatal children of high-rate potato consuming mothers were the most exposed people at this site.

3.5 Minor sites

Two minor licensed sites with very low radioactive discharges are monitored using a small sampling programme of environmental materials. The results, given in the following sections, show that there was no detected impact on the environment in 2009 due to operation of these sites.

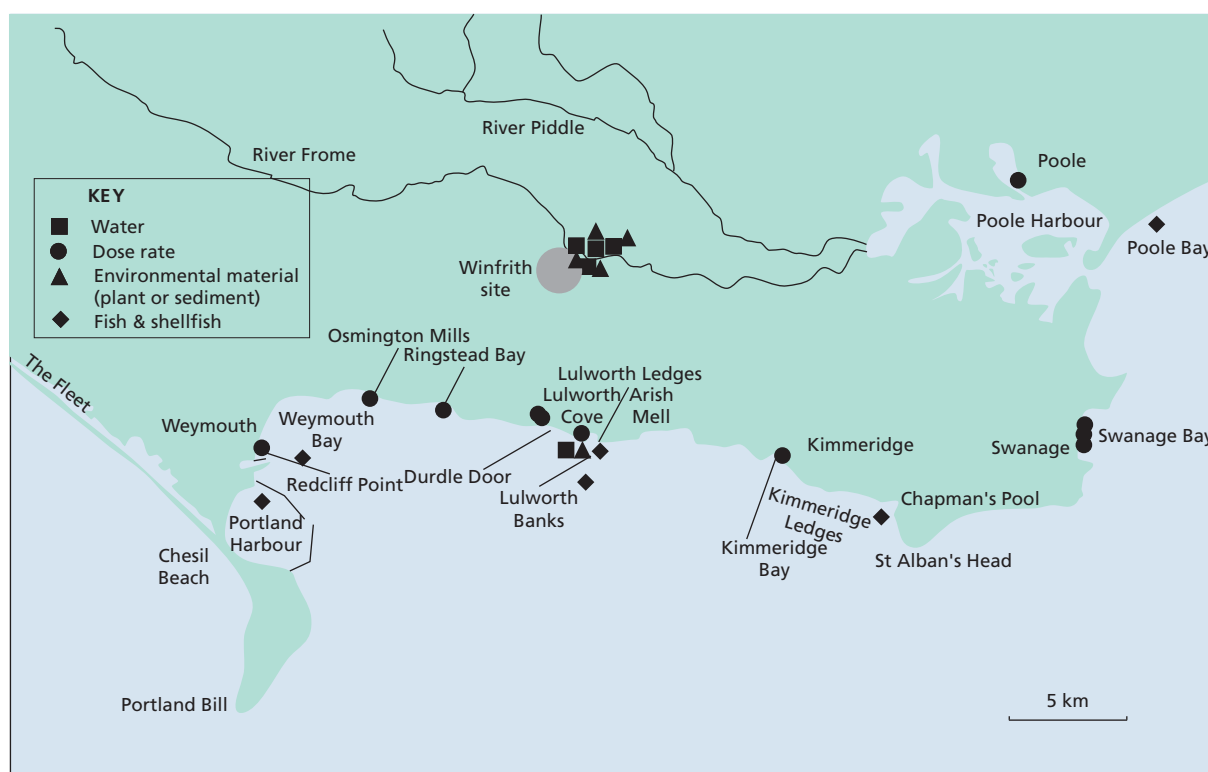


Figure 3.6. Monitoring locations at Winfrith, 2009 (not including farms)

3.5.1 Imperial College Reactor Centre, Ascot, Berkshire

The Reactor Centre provided facilities for the University and other educational institutions for teaching and research in many fields of nuclear science and technology. Imperial College undertook a review of the future of the Reactor Centre at Silwood Park in 2007, which resulted in the temporary closure of commercial operations with the anticipation of decommissioning. Planning, in negotiations with the NDA, is currently underway for the decommissioning of the facility (the Reactor Decommissioning Planning Project; RDPP). During this planning process the reactor is maintained and managed to retain operational capability.

In 2009, gaseous and aqueous discharges were very low (Appendix 2) and environmental monitoring of their effects comprises analysing two grass samples by gamma-ray spectrometry. Both sets of results in 2009 were either close to or less than the limits of detection.

3.5.2 Scottish Universities' Environmental Research Centre, South Lanarkshire

The small research reactor at this site has been decommissioned, with the waste disposed of under the authorisations granted by SEPA in 2001 for its decommissioning. In 2007, SEPA issued a registration for the keeping and use of radioactive sources to cover the on-going laboratory work at the site. Following completion of delicensing activities at the site, the nuclear site licence was revoked by the NII in October 2008. No discharges of radioactivity were made from the premises during the calendar year 2009. Following the de-licensing of the site, this section will no longer appear in subsequent RIFE publications.

Table 3.1. Individual radiation exposures research sites, 2009

Site	Exposed population ^a	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Culham	Drinkers of river water	<0.005	-	-	-	<0.005	-
Dounreay	Seafood consumers	0.011	<0.005	-	0.010	-	-
	Geo occupants	<0.005	-	-	<0.005	-	-
	Consumers of locally grown food ^b	0.029	-	0.029	-	-	<0.005
	All sources ^c	0.063	-	-	-	-	-
Harwell	Anglers	0.006	<0.005	-	0.006	-	-
	Consumers of locally grown food ^b	<0.005	-	<0.005	-	-	<0.005
	All sources ^{c,d}	0.023	-	-	-	-	-
Winfrith	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food ^d	<0.005	-	<0.005	-	-	<0.005
	All sources ^{c,d}	<0.005	-	-	-	-	-

^a Adults are the most exposed group unless stated otherwise

^b Children aged 1y

^c The total dose due to discharges and direct radiation. See Appendix 4

^d Prenatal children

Table 3.2. Concentrations of radionuclides in the environment near Culham, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	¹⁴ C	³⁵ S	⁹⁰ Sr	¹³⁷ Cs	Gross alpha Gross beta
Freshwater	River Thames (upstream)	2	<4.0				<0.24	<0.050 0.38
Freshwater	River Thames (downstream)	2	<4.0				<0.30	<0.040 0.33
Grass	1 km East of site perimeter	1	<25	25	<9.4	<1.0	<1.0	230
Sediment	River Thames (upstream)	2					13	
Sediment	River Thames (downstream)	2					56	
Soil	1 km East of site perimeter	1	<10	<10	<5.7	<1.0	3.9	630

^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, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	⁶⁰ Co	⁹⁰ Sr	⁹⁹ Tc	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs
Marine samples									
Crabs	Pipeline inner zone	4		<0.12	<0.10	6.3	<0.30	<0.12	<0.12
Crabs	Pipeline	4		<0.11			<0.26	<0.11	<0.15
Crabs	Strathy	4		<0.11			<0.26	<0.11	<0.17
Crabs	Kinlochbervie	4		<0.11		<0.39	<0.21	<0.11	<0.12
Crabs	Melvich Bay	4		<0.12		2.4	<0.23	<0.12	<0.16
Winkles	Brims Ness	4		<0.10	<0.13		<0.20	<0.10	<0.11
Winkles	Sandside Bay	4		<0.10	<0.10	2.8	<0.18	<0.10	<0.12
Mussels	Echnaloch Bay	4		<0.13		11	<0.30	<0.12	<0.12
Mussels	Thurso East Mains	4		<0.12			<0.29	<0.13	<0.31
<i>Fucus vesiculosus</i>	Kinlochbervie	4		<0.10		66	<0.20	<0.10	0.28
<i>Fucus vesiculosus</i>	Brims Ness	4		<0.10			<0.16	<0.10	0.26
<i>Fucus vesiculosus</i>	Sandside Bay	4		<0.10		60	<0.15	<0.10	0.17
<i>Fucus vesiculosus</i>	Burwick Pier	4		<0.10		47	<0.13	<0.10	<0.14
Sediment	Oigins Geo	2		<0.10			<0.25	<0.11	4.0
Sediment	Brims Ness	1		<0.10			<0.17	<0.10	1.4
Sediment	Sandside Bay	1		<0.10			<0.16	<0.10	2.2
Sediment	Rennibister	1		<0.14			<0.33	<0.16	6.5
Seawater	Brims Ness	4	<1.2	<0.10			<0.13	<0.10	<0.10
Seawater	Sandside Bay	4	<1.1	<0.10			<0.13	<0.10	<0.10
Spume	Oigins Geo	2		<2.9			<6.8	<2.1	10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			¹⁵⁴ Eu	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	Gross alpha	Gross beta
Marine samples									
Crabs	Pipeline inner zone	4	<0.13	<0.26	0.0044	0.020	0.030	<2.5	470
Crabs	Pipeline	4	<0.12	<0.23			<0.13		
Crabs	Strathy	4	<0.13	<0.21	<0.0039	0.014	<0.14		
Crabs	Kinlochbervie	4	<0.12	<0.18	<0.0056	0.0082	<0.020		
Crabs	Melvich Bay	4	<0.12	<0.20	<0.050	<0.050	<0.050		
Winkles	Brims Ness	4	<0.11	<0.17	0.013	0.053	0.073		
Winkles	Sandside Bay	4	<0.10	<0.15	<0.021	0.082	0.17		
Mussels	Echnaloch Bay	4	<0.14	<0.26	<0.012	0.033	0.038		
Mussels	Thurso East Mains	4	<0.14	<0.24	0.0098	0.052	0.046		
<i>Fucus vesiculosus</i>	Kinlochbervie	4	<0.11	<0.21			<0.13		
<i>Fucus vesiculosus</i>	Brims Ness	4	<0.10	<0.16			<0.10	5.2	400
<i>Fucus vesiculosus</i>	Sandside Bay	4	<0.10	<0.14			<0.22	3.6	400
<i>Fucus vesiculosus</i>	Burwick Pier	4	<0.10	<0.13			<0.11		
Sediment	Oigins Geo	2	<0.21	<0.58	0.75	2.9	19		
Sediment	Brims Ness	1	0.37	0.18	2.9	11	16		
Sediment	Sandside Bay	1	0.30	0.25	2.9	12	13		
Sediment	Rennibister	1	<0.21	0.81	0.16	0.60	0.45		
Seawater	Brims Ness	4	<0.10	<0.12			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.12			<0.10		
Spume	Oigins Geo	2	<2.8	<5.5	<0.011	0.026	3.0		

Table 3.3(a). continued

Material	Location or selection ^b	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							
			³ H	⁹⁰ Sr	⁹⁵ Nb	¹⁰⁶ Ru	¹²⁹ I	¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce
Terrestrial samples										
Beef muscle		1	<5.0	<0.17	<0.16	<0.42	<0.050	<0.05	0.11	<0.25
Beef liver		1	<5.0	<0.12	<0.22	<0.63	<0.050	<0.06	<0.05	<0.36
Deer muscle		3	<5.0	<0.10		<0.60	<0.050	<0.05	58	<0.48
Deer muscle	max								69	
Goats' milk		1	<5.0	<0.10	<0.11	<0.32	<0.050	<0.05	0.05	<0.19
Hawthorn berries		1	<5.0	1.3	<0.07	<0.19	<0.050	<0.05	0.05	<0.11
Lamb muscle		1	<5.0	<0.12	<0.07	<0.24	<0.050	<0.05	0.11	<0.15
Leafy greens		1	<5.0	0.79	<0.07	<0.28	<0.050	<0.05	0.17	<0.18
Maize		1	<5.0	2.0	<0.50	<0.40	<0.050	<0.05	0.07	<0.28
Pheasants		1	<5.0	<0.10		<1.2	<0.074	<0.12	0.40	<0.69
Potatoes		1	<5.0	<0.10	<0.05	<0.18	<0.050	<0.05	0.21	<0.09
Rabbits		5							<0.10	
Rosehips		1	<5.0	0.72	<0.08	<0.37	<0.050	<0.05	0.70	<0.26
Rowan berries		1	<5.0	0.73	<0.07	<0.26	<0.050	<0.05	0.06	<0.15
Turnips		1	<5.0	0.33	<0.08	<0.34	<0.050	<0.05	0.14	<0.21
Wild mushrooms		1	<5.0	<0.10	<0.13	<0.28	<0.055	<0.05	0.54	<0.17
Grass		6	<5.0	0.59	<0.18	<0.30	<0.046	<0.05	<0.13	<0.20
Grass	max			0.80	<0.23	<0.40	<0.050		0.23	<0.25
Soil ^c		6	<5.0	<1.3	<1.1	<1.1	<0.12	<0.13	20	<1.0
Soil ^c	max			2.1	<1.9	<1.4	<0.27	<0.18	27	<1.3
Freshwater	Loch Calder	1	<1.2						<0.01	
Freshwater	Loch Shurrey	1	<1.2						<0.01	
Freshwater	Loch Baligill	1	<1.2						<0.01	
Freshwater	Heldale Water	1	<1.2						<0.01	

Material	Location or selection ^b	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							Gross alpha	Gross beta
			²³⁴ U	²³⁵ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am			
Terrestrial samples											
Beef muscle		1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Beef liver		1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050			
Deer muscle		3				<0.050	<0.050	<0.050			
Goats' milk		1					<0.058				
Hawthorn berries		1				<0.050	<0.050	<0.050			
Lamb muscle		1	<0.050	<0.050	0.077	<0.050	<0.050	<0.050			
Leafy greens		1				<0.050	<0.050	<0.050			
Maize		1				<0.050	<0.050	<0.050			
Pheasants		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			
Turnips		1				<0.050	<0.050	<0.050			
Wild mushrooms		1				<0.050	<0.050	<0.050			
Grass		6	<0.12	<0.050	<0.12	<0.050	<0.055	<0.050			
Grass	max		0.41		0.39		0.079				
Soil ^c		6	32	1.2	30	<0.060	0.44	<0.24			
Soil ^c	max		47	2.0	42	0.090	0.68	0.34			
Freshwater	Loch Calder	1							<0.010	0.084	
Freshwater	Loch Shurrey	1							<0.010	0.047	
Freshwater	Loch Baligill	1							<0.010	0.034	
Freshwater	Heldale Water	1							<0.010	0.047	

^a Except for water and goats' milk where units are Bq l⁻¹, and for soil and sediment where dry concentrations apply

^b Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima

If no 'max' value is given the mean value is the most appropriate for dose assessments

^c The concentrations of ¹²⁵Sb and ¹⁵⁵Eu were 0.31 and 1.5 (max 2.2) Bq kg⁻¹

Table 3.3(b). Monitoring of radiation dose rates near Dounreay, 2009

Location	Material or ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.053
Sandside Bay	Winkle bed	2	0.15
Oigin's Geo	Spume/sludge	4	0.15
Brims Ness	Shingle and stones	2	0.092
Melvich	Salt Marsh	2	0.074
Melvich	Sand	2	0.055
Strathy	Sand	2	0.052
Thurso	Riverbank	2	0.090
Achreregan Hill	Soil	2	<0.047
Thurso Park	Soil	2	0.082
Borrowston Mains	Soil	2	0.088
East of Dounreay	Soil	2	0.079
Castletown Harbour	Sand	2	0.078
Dunnet	Sand	2	0.058
Mean beta dose rates			$\mu\text{Sv h}^{-1}$
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Thurso	Riverbank	2	<1.0
Castletown Harbour	Surface sediment	2	<1.0

Table 3.3(c). Radioactivity in air near Dounreay, 2009

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	7	<0.012	<0.010	<0.19
Reay	8	<0.010	<0.0068	<0.14
Balmore	10	<0.010	<0.0068	<0.16

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			Organic ³ H	³ H	⁶⁰ Co	¹³⁷ Cs	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu
Freshwater samples								
Pike	Outfall (Sutton Courtenay)	1	<25	<25	<0.06	0.29		
Pike	Newbridge	1	<25	<25	<0.04	<0.04	0.000049	0.00030
Perch	Outfall (Sutton Courtenay)	1	<25	<25	<0.08	<0.08	0.000026	0.000057
Flounder	Beckton	1		<25	<0.07	0.09		
Sediment	Appleford	4 ^E			<0.88	10	<0.50	<0.40
Sediment	Outfall (Sutton Courtenay)	4 ^E			<1.2	20	<2.0	1.2
Sediment	Day's Lock	4 ^E			<0.97	4.0	<0.50	<0.30
Sediment	Lydebank Brook	4 ^E			<1.7	4.3	<0.50	<0.60
Freshwater	Day's Lock	4 ^E		<4.0	<0.38	<0.31		
Freshwater	Lydebank Brook	4 ^E		<4.3	<0.39	<0.33		
Freshwater	R Thames (above discharge point)	4 ^E		<4.8	<0.34	<0.29		
Freshwater	R Thames (below discharge point)	4 ^E		<4.0	<0.36	<0.29		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross Beta
Freshwater samples							
Pike	Outfall (Sutton Courtenay)	1	<0.18				
Pike	Newbridge	1	0.00047	*	*		
Perch	Outfall (Sutton Courtenay)	1	0.00016	0.000026	*		
Flounder	Beckton	1	<0.18				
Sediment	Appleford	4 ^E	0.98			<200	360
Sediment	Outfall (Sutton Courtenay)	4 ^E	0.80			<140	450
Sediment	Day's Lock	4 ^E	<1.2			<120	430
Sediment	Lydebank Brook	4 ^E	<1.0			140	420
Freshwater	Day's Lock	4 ^E				<0.095	0.40
Freshwater	Lydebank Brook	4 ^E				<0.055	0.18
Freshwater	R Thames (above discharge point)	4 ^E				<0.065	0.32
Freshwater	R Thames (below discharge point)	4 ^E				<0.050	0.29

Material	Location or selection ^b	No. of sampling observ- ations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹		
			Organic ³ H	³ H	¹³⁷ Cs
Terrestrial samples					
Milk		4	<4.3	<4.3	<0.20
Milk	max		<5.0	<5.0	
Apples		1	<4.0	<4.0	<0.20
Beetroot		1	<4.0	<4.0	<0.20
Blackberries		1	<4.0	<4.0	<0.20
Cabbage		1	<4.0	<4.0	<0.20
Honey		1		<7.0	<0.20
Potatoes		1	<5.0	<5.0	<0.20

* Not detected by the method used.

^a Except for milk where units are Bq l⁻¹, and for sediment where dry concentrations apply

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

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

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

Table 3.4(b). Monitoring of radiation dose rates near Harwell, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Appleford	Grass and mud	2	0.069
Sutton Courtenay	Grass and mud	2	0.076
Day's Lock	Grass and mud	2	0.067

Table 3.5 (a). Concentrations of radionuclides in food and the environment near Winfrith, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			¹⁴ C	⁶⁰ Co	⁹⁹ Tc	¹³⁷ Cs	²³⁸ Pu
Marine samples							
Plaice	Weymouth Bay	2		<0.04		0.08	
Bass	Weymouth Bay	2		<0.06		0.61	
Crabs	Chapman's Pool	1		<0.10		<0.07	0.000056
Crabs	Lulworth Banks	1	31	<0.05		0.04	0.00044
Pacific Oysters	Poole	1		<0.12		<0.10	
Cockles	Poole	1		0.16		<0.06	
Whelks	Poole Bay	1		<0.17		<0.13	0.000058
Whelks	Lyme Regis	1		<0.08		<0.06	0.00039
Scallops	Lulworth Ledges	1		0.04		<0.01	0.00056
Clams	Portland Harbour	1		<0.10		<0.07	
Seaweed	Lulworth Cove	1 ^E		<0.89	4.6	<0.70	
Seaweed	Bognor Rock	2 ^E		<0.85	7.2	<0.64	
Seawater	Lulworth Cove	1 ^E		<0.32		<0.29	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Weymouth Bay	2		<0.04				
Bass	Weymouth Bay	2		<0.11				
Crabs	Chapman's Pool	1	0.00041	0.0010	*	0.000021		
Crabs	Lulworth Banks	1	0.0022	0.0046	*	0.000053		
Pacific Oysters	Poole	1		0.06				
Cockles	Poole	1		<0.17				
Whelks	Poole Bay	1	0.00051	0.00045	*	0.000015		
Whelks	Lyme Regis	1	0.0027	0.0019	*	0.000031		
Scallops	Lulworth Ledges	1	0.0027	0.00084	*	0.000030		
Clams	Portland Harbour	1		<0.06				
Seaweed	Lulworth Cove	1 ^E		<0.96				
Seaweed	Bognor Rock	2 ^E		<0.78				
Seawater	Lulworth Cove	1 ^E		<0.36			<2.0	10

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	¹³⁷ Cs	Gross alpha
Terrestrial samples								
Milk		4	<4.4	<4.4	17	<0.16	<0.19	
Milk		max	<4.8	<4.8	19	<0.20	<0.20	
Apples		1	<4.0	<4.0	14	<0.20	<0.20	
Blackberries		1	<5.0	<4.0	16	<0.10	<0.20	
Carrots		1	<4.0	<4.0	7.0	<0.20	<0.20	
Chard		1	<5.0	5.0	14	<0.20	<0.20	
Honey		1		<7.0	78	<0.10	0.20	
Potatoes		1	<4.0	<4.0	46	<0.30	<0.20	
Grass		2	<5.0	<6.0	36	<0.25	<1.0	
Grass		max	<6.0		52	<0.30	1.7	
Sediment	North of site (Stream A)	1 ^E				<0.24	5.3	<100 210
Sediment	R Frome (upstream)	1 ^E				<2.2	6.0	300 310
Sediment	R Frome (downstream)	1 ^E				<1.7	4.1	180 260
Sediment	R Win, East of site	1 ^E				<0.24	<0.24	100 100
Freshwater	North of site (Stream A)	2 ^E		24		<0.28	<0.25	<0.055 0.15
Freshwater	R Frome (upstream)	2 ^E		<4.0		<0.36	<0.29	<0.045 0.11
Freshwater	R Frome (downstream)	2 ^E		<4.0		<0.31	<0.28	<0.035 0.12
Freshwater	R Win, East of site	2 ^E		<5.1		<0.33	<0.29	<0.050 0.19

* 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, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand	1	0.066
Red Cliffe Point to Black Head	Shingle	1	0.053
Osmington Mills	Pebbles and shingle	1	0.075
Ringstead Bay	Sand	1	0.053
Durdle Door	Shingle	1	0.051
Lulworth Cove	Sand	1	0.061
Kimmeridge Bay	Pebbles and sand	1	0.074
Swanage Bay 1	Sand	1	0.053
Swanage Bay 2	Sand	1	0.054
Swanage Bay 3	Sand	1	0.056
Poole Harbour	Sand	1	0.055

4. Nuclear power stations

Key points

- Electricity production continued in 2009 at two Magnox stations (Oldbury and Wylfa) and all the British Energy power stations
- In 2009, British Energy Generation Limited became a subsidiary of EDF
- Discharges, environmental concentrations, dose rates and doses in 2009 were broadly similar to those in 2008
- Concentrations of radiocaesium and transuranic elements were enhanced around some sites. These were mainly due to discharges from Sellafield
- Radiation doses from all sources were mostly less than 10 per cent of the dose limit (exceptions stated below)

Berkeley, Gloucestershire and Oldbury, South Gloucestershire

- There were small decreases in radiation doses due to reduced gamma dose rates in intertidal areas
- Gaseous discharges increased and liquid discharges decreased, from Oldbury, in 2009
- There were small decreases in radiation doses due to reduced gamma dose rates in intertidal areas

Bradwell, Essex

- *Total dose* from all sources was approximately 10 per cent of the dose limit and increased in 2009. This was due to direct radiation from the power station

Chapelcross, Dumfries and Galloway

- Concentrations of tritium in milk have dropped since closure of the tritium plant in 2005. Previous gaseous releases of tritium have been detected in surface water around the site

Dungeness, Kent

- Gaseous sulphur-35 and argon-41 discharges increased from Dungeness B. Liquid discharges of tritium and cobalt-60 increased from Dungeness B
- *Total dose* from all sources was approximately 32 per cent of the dose limit and decreased in 2009. This was due to direct radiation from the power station

Hartlepool, Cleveland

- Gaseous and liquid discharges increased in 2009
- Concentrations of technetium-99 in seaweed were the lowest in over a decade

Heysham, Lancashire

- Gaseous discharges of carbon-14 and liquid discharges of tritium and sulphur-35 increased from Heysham 1. Gaseous discharges of argon-41 increased from Heysham 2

Hinkley Point, Somerset

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

Hunterston, North Ayrshire

- Gaseous discharges increased, and liquid discharges of tritium and sulphur-35 increased, from Hunterston B
- Concentrations of technetium-99 in lobster decreased
- *Total dose* from all sources was approximately 7 per cent of the dose limit and decreased in 2009. This was due to direct radiation from the site

Sizewell, Suffolk

- Environmental Scoping Report submitted, outlining British Energy's proposed spent fuel management strategy for Sizewell B
- Gaseous discharges of tritium decreased from Sizewell A, and iodine-131 increased from Sizewell B
- *Total dose* from all sources was approximately 3 per cent of the dose limit and decreased in 2009. This was due to cessation of power generation at Sizewell A

Trawsfynydd, Gwynedd

- Concentrations of carbon-14 in milk and offal and caesium-137 in fish increased

Wylfa, Isle of Anglesey

- A new survey of local consumers' diet and occupancy was conducted to reduce uncertainties in risk assessments
- There were small increases in radiation doses due to revised habits data

This section considers the effects of discharges from nuclear power stations during 2009. There are a total of 19 nuclear power stations at 14 locations, nine in England (Berkeley, Oldbury, Bradwell, Calder Hall, Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell), three in Scotland (Chapelcross, Hunterston and Torness) and two in Wales (Trawsfynydd and Wylfa).

Eleven of the 19 nuclear power stations are older Magnox power stations, owned by the NDA. From 2005, the NDA was formed and became responsible for the UK's civil nuclear liabilities. The NDA is a non-departmental public body with a remit to secure the decommissioning and clean-up of the UK's civil public sector nuclear sites. In 2010, the NDA published their plan which summarises the programme of work that they intend to deliver both within the NDA and at each of their sites during 2010/13 (Nuclear Decommissioning Authority, 2010).

In 2008, Magnox Electric Limited (the nuclear site licence holder) split into two Site Licence Companies: Magnox North Limited and Magnox South Limited. Magnox North Limited became the operator for Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa and Magnox South Limited became the operator for Berkeley, Bradwell, Dungeness A, Hinkley Point A and Sizewell A. Calder Hall is operated by Sellafield Limited. In 2009, only two of these Magnox stations (Oldbury and Wylfa) continued to generate electricity, others are in the process of decommissioning. Discharges from one of the Magnox stations (Calder Hall) are considered in Section 2 because it is located at Sellafield.

Seven advanced gas-cooled reactor (AGR) power stations and one pressurised water reactor (PWR) power station were owned and operated by British Energy Generation Limited in 2009. British Energy Group plc (the parent company) is now a wholly owned subsidiary of Électricité de France (EDF) Energy. British Energy Generation Limited, which operates Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B and Sizewell B Power Stations in England, and Hunterston B and Torness Power Stations in Scotland, became a subsidiary of EDF in early 2009. All of these were generating electricity during 2009.

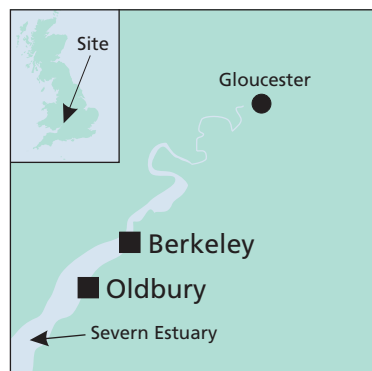
Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency for England and Wales, and by SEPA for Scotland. In 2009, gaseous and liquid discharges were below regulated limits for each of the power stations (see Appendix 2). Independent monitoring of the environment around each of the power stations is conducted by the Food Standards Agency and the Environment Agency for England and Wales, and by SEPA for Scotland.

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

Section according to whether they are in England, Scotland or Wales.

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station is situated on the eastern bank of the River Sever and was powered by two Magnox reactors. Berkeley was the first commercial power station in the UK to enter into

decommissioning, when it ceased electricity generation in 1989. Defuelling was completed in 1992. Decommissioning is still in progress and radioactive wastes are still generated by these operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples. Current plans are for the Berkeley Power Station site to be de-licensed (released from regulatory control), with final closure of the site to be completed by 2083.

The Oldbury Power Station, located on the south bank of the River Sever close to the village of Oldbury-on-Severn has continued operation and has two Magnox reactors. This power station is due to continue to generate electricity until June 2011. The current assumption is that the Oldbury site will be de-licensed and returned to its former use as agricultural land by 2101. In 2009, Magnox North Limited lodged a FEPA licensing application to carry out a dredging program, involving the disposal at sea of sediment from Oldbury Power Station (see Appendix 6).

Berkeley and Oldbury sites are considered together for the purposes of environmental monitoring because the effects of both are on the same area. The most recent habits survey undertaken for the Berkeley and Oldbury sites was in 2007 (Clyne *et al.*, 2008a).

Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. Oldbury discharges were generally higher in 2009, compared to those in 2008. The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Local freshwater samples were also analysed. Data for 2009 are given in Table 4.2(a). Sulphur-35 was

detected at very low levels in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, at concentrations just above background values, although this may be due to natural variation. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

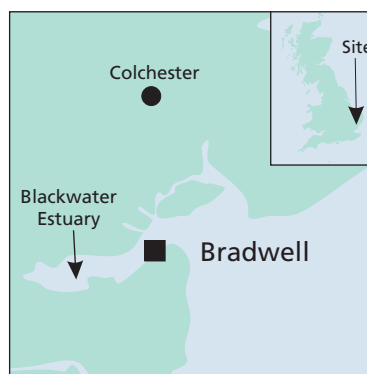
Liquid radioactive wastes are discharged to the Severn estuary. Oldbury discharges were generally lower in 2009, compared to those in 2008. Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from the GE Healthcare radiopharmaceutical plant in Cardiff (see Section 6). Data for 2009 are given in Tables 4.2(a) and (b). Where comparisons can be drawn concentrations in the aquatic environment were generally similar to those in recent years, although gamma dose rates are generally smaller in 2009 compared to 2008. Most of the artificial radioactivity detected was due to tritium and radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have remained reasonably consistent for the last decade (Figure 4.1), with a suggestion of a small peak in 2004 and subsequently decreasing with time. Relatively high concentrations of tritium were detected in fish and shellfish and these were likely to be mainly due to discharges from GE Healthcare, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance.

Doses to the public

The estimated dose to people who consume terrestrial foodstuffs at high-rates was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air, (see Appendix 1), the dose in 2009 for Berkeley and Oldbury sites was still below 0.005 mSv, which was less than 0.5 per cent of the dose limit. The dose to high-rate consumers of fish and shellfish was estimated to be 0.025 mSv, which was less than 3 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This includes external radiation, a component due to the tritium originating from GE Healthcare, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The dose in 2008 was 0.029 mSv, and the decrease in 2009 was mostly due to an overall decrease in gamma dose rates. Recent trends in doses in the area of the Severn Estuary are shown in Figure 6.5. The *total dose* from all sources (using methods in Appendix 4) was assessed to have been 0.058 mSv in 2009, which is less than 6 per cent of the dose limit. This was mostly due to direct radiation from the Berkeley site, which was assessed to be below 0.057 mSv (Table 4.1). In 2008, the *total dose* was 0.041 mSv, mostly due to direct radiation which was assessed to be

below 0.040 mSv. Although the direct radiation was below detectable levels for both years, these are treated as real doses for the assessment of the *total dose*. The increase in *total dose* from 0.041 mSv in 2008 reflects this increase in attributed dose from direct radiation to local inhabitants and the dose assessment identifies the prenatal children of these inhabitants as the most exposed age group.

4.2 Bradwell, Essex



The Bradwell site is located on the south side of the Blackwater Estuary. This Magnox power station ceased electricity production in March 2002 after 40 years of operation, and defuelling was completed in 2006. The station is undergoing

decommissioning, and current plans are for the site to be de-licensed (released from regulatory control), with final closure completed by 2104. The most recent habits survey was undertaken in 2007 (Tipple *et al.*, 2008).

Gaseous discharges and terrestrial monitoring

This power station is permitted to discharge gaseous wastes to the local environment via stacks to the atmosphere. Terrestrial sampling is similar to that for other power stations including analyses of milk, fruit and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch and public supplies. Data for 2009 are given in Table 4.3(a). Concentrations of activity were low in terrestrial food samples, though some enhancements of carbon-14 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. The gross beta activities in water from the coastal ditch continued to be enhanced above background levels, and these were in excess of the WHO screening level for drinking water (1 Bq l⁻¹). Overall, tritium concentrations in coastal ditches were lower than in 2008, and were substantially below the EU reference level for tritium of 100 Bq l⁻¹. The water in the ditches is not known to be used as a source of drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged into the River Blackwater estuary. 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

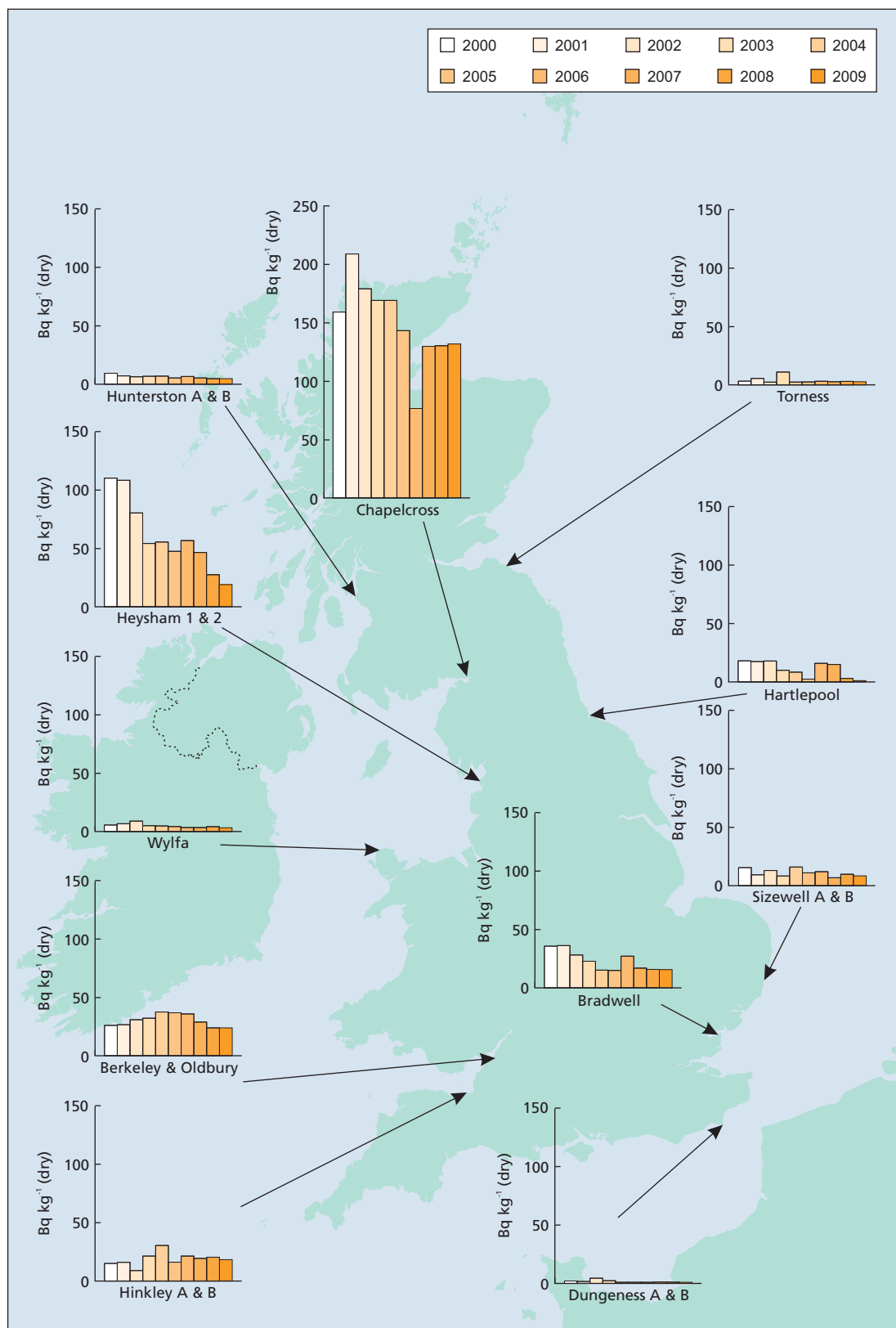


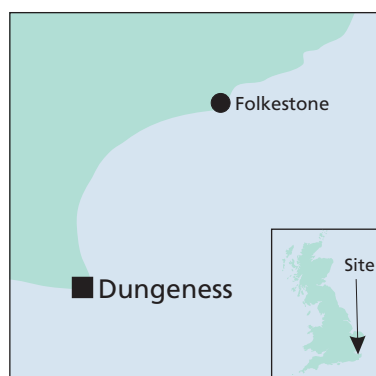
Figure 4.1. Caesium-137 concentration in marine sediments near nuclear power stations between 2000-2009

beet was collected because it is eaten locally and grows in areas that become tidally inundated. Data for 2009 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 2008, however, there is evidence for a small decline in caesium-137 concentrations in biota (Table 4.3(a)) which may be due to reduced discharges in recent years. There is also an overall decline in sediments (Figure 4.1). The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity. Gamma dose rates on beaches were difficult to distinguish from natural background.

Doses to the public

In 2009, the estimated dose to people who consume locally grown foodstuffs at high-rates was estimated to be less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to high-rate seafood consumers was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose in 2008 was similar. The trend in marine doses at Bradwell, and at power stations generally, is shown in Figure 4.2. The variability in dose estimated at Bradwell is predominantly due to the normal variability expected in concentrations and external exposure 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 people would have been similar to those values in other years. The *total dose* from all sources (using methods in Appendix 4) was assessed to have been 0.098 mSv, an increase from 0.070 mSv in 2008. The higher dose in 2009 (less than 10 per cent of the dose limit) was due to an increase in direct radiation to local inhabitants (Table A4.1), and the dose assessment identifies prenatal children of these inhabitants as the most exposed age group.

4.3 Dungeness, Kent



Dungeness Power Station is located on the headland in the south east of Kent. There are two separate A and B nuclear power stations on this site; the A station was powered by two Magnox reactors and the B station has two AGRs. Discharges are

made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered

together. In December 2009, the Environment Agency issued variations in permits (for Dungeness B) to enable the transfer of waste to the Winfrith site in Dorset, for treatment prior to its disposal to LLWR in Cumbria. The variations also permitted additional flexibility in solid waste disposal routes, but did not change gaseous and liquid discharge limits. Dungeness A ceased generating electricity in 2006, and plans are for this power station to be decommissioned, cleared and landscaped to return back to the shingle foreland by 2111. It is estimated that Dungeness B will end power generation by 2018. The most recent habits survey was conducted during 2005 (McTaggart *et al.*, 2006).

Gaseous discharges and terrestrial monitoring

Discharges of sulphur-35 and argon-41 were increased from Dungeness B, in comparison to releases in 2008. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. The results of monitoring for 2009 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the limits of detection. Concentrations of carbon-14 were generally within the range of observed background activity concentrations, including the apparent high concentration reported in beans (91 Bq kg⁻¹, dry). After applying an estimated dry/fresh weight ratio, the activity (as fresh weight) did not exceed the expected background activity for legumes (Appendix 1, Table X4.2). Low concentrations of sulphur-35 were detected in some samples. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium and cobalt-60 increased from Dungeness B, in comparison to releases in 2007. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2009 are given in Tables 4.4(a) and (b). Caesium-137 concentrations in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield and Cap de la Hague. Apportionment is difficult at these low levels. The low concentrations of transuranic nuclides in scallops and sediment were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Gamma dose rates were generally difficult to distinguish from the natural background.

Doses to the public

The infant age group received the maximum dose due to gaseous disposals. Their dose in 2009 was estimated to be 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public. This is similar to the value in 2008. The dose to local bait diggers (who consume large quantities of fish and shellfish and spend long periods of time in the location being assessed) was 0.012 mSv, which was approximately 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). The dose in 2008 was also

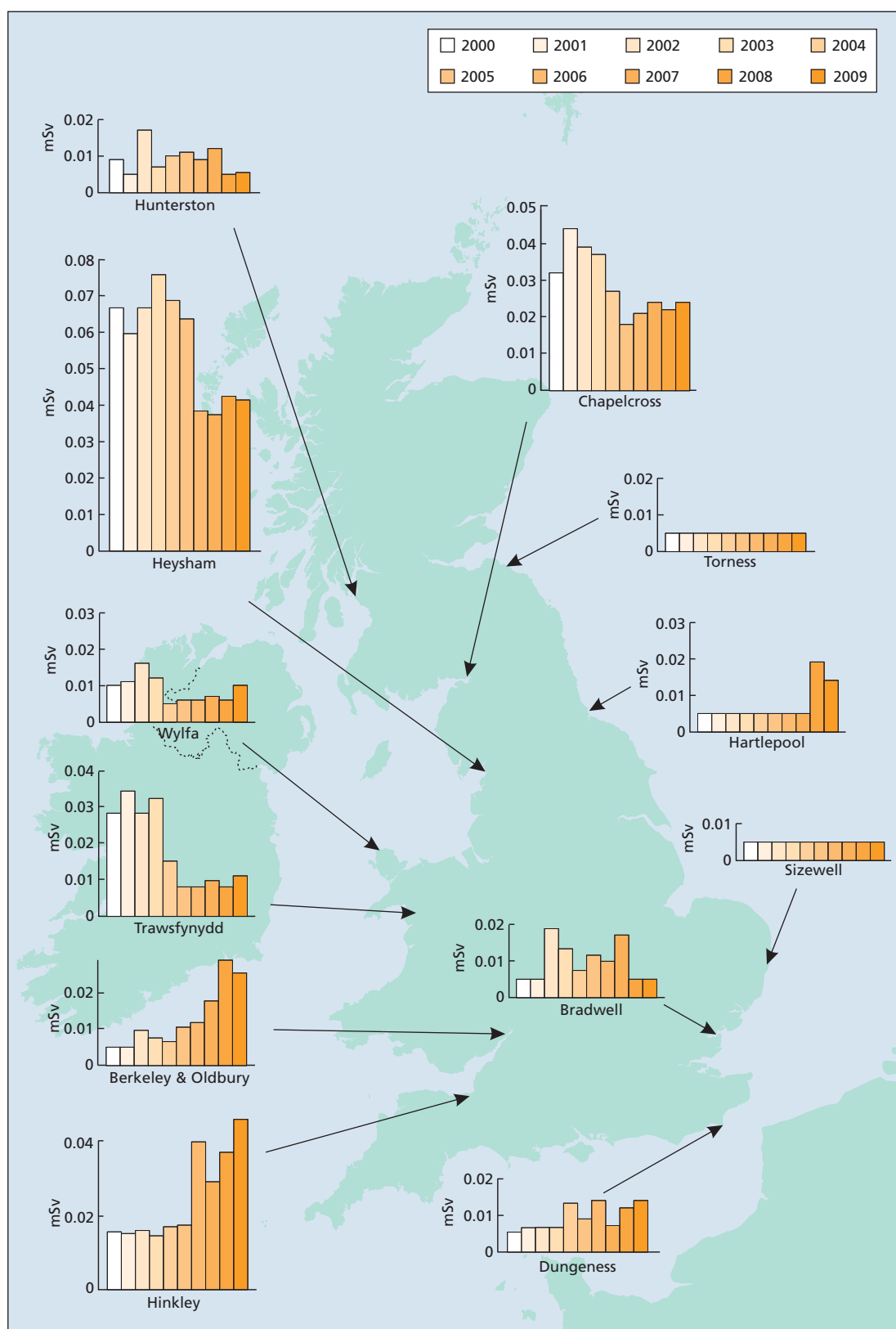


Figure 4.2. Individual radiation exposures at nuclear power stations for artificial radionuclides in England, Wales, and South Scotland, 2000-2009.
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

0.012 mSv, although in 2009 the individual dose contributions were higher from external exposure and lower from food consumption. The trend in marine doses at Dungeness and at other power stations more generally is shown in Figure 4.2. The variability in dose seen at Dungeness is predominantly due to the normal variability expected in concentrations and dose rates in the environment. From available data in 2009, with no gamma dose rate being measured at Rye Harbour, the external radiation dose for local houseboat occupants was estimated to be 0.014 mSv. The *total* dose from all sources (using methods in Appendix 4) was assessed to have been 0.32 mSv (Table 4.1), or 32 per cent of the dose limit of 1 mSv. Adults living near to the site were the most exposed people. As in recent years, this is almost entirely due to direct radiation from the site (Table A4.1).

4.4 Hartlepool, Cleveland



Hartlepool Power Station is situated on the mouth of the Tees estuary, on the north east coast of England, and is powered by twin AGRs. It is estimated that its power generation will end by 2014. The most recent habits survey was conducted in 2008

(Garrod *et al.*, 2009). In December 2009, the Environment Agency issued variations in permits to enable the transfer of waste to the Winfrith site in Dorset, for treatment prior to its disposal to LLWR in Cumbria. The variations also permitted additional flexibility in solid waste disposal routes, but did not change gaseous and liquid discharge limits.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Discharges of some radionuclides increased significantly in 2009, compared with 2008, due to the return to service of both reactors from a significant maintenance outage. Discharges of these radionuclides for 2009 were broadly comparable with discharge levels reported before the maintenance outage. Discharges of tritium were elevated in December 2009 on the return to service of one of the reactors from a maintenance outage. The introduction of new gaseous sampling equipment in the early part of 2009 resulted in increases in the minimum detectable activity in discharges for cobalt-60 particulate and iodine-131.

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 2009 are given in Table 4.5(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs,

though some enhancements of carbon-14 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Liquid discharges of tritium and sulphur-35 increased significantly in 2009, compared with 2008, due to the return to service of both reactors from the maintenance outage. Discharges of these radionuclides in 2009 were lower than (but approached) discharge levels reported before the maintenance outage. Discharges of the other radionuclides in liquid discharges permitted by RSA 93 for the site are dominated by other operations. Discharges of cobalt-60 were elevated in November 2009 due to maintenance operations.

Results of the aquatic monitoring programme conducted in 2009 are shown in Tables 4.5(a) and (b). Small enhancements of carbon-14 concentrations, above expected background (see Appendix 1), were apparent in some seafood samples. This is most likely to be due to carbon-14 discharges from a non-nuclear site since carbon-14 discharges from the power station are low. Technetium-99 analysis in seaweed is used as a specific indication of the far-field effects of disposals to sea from Sellafield.

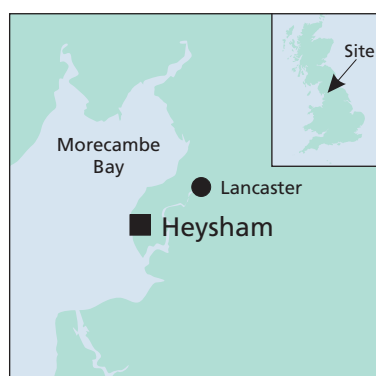
These concentrations in seaweed (*Fucus vesiculosus*) were the lowest in over a decade and much less than the peak observed in 1998 (see also Figure 2.19). They are less than 1 per cent of the equivalent concentrations near Sellafield. In 2009, iodine-131 was positively detected in one of the two samples of seaweed collected around the bottom of the River Tees Estuary in 2009 (reported as LoD, for the mean of the two concentrations). The detected value is believed to originate from the therapeutic use of this radionuclide in a local hospital. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. In 2009, the lead-210 and polonium-210 concentrations were close to natural background (as in 2008). Generally, gamma dose rates were similar to those in 2008, although some small differences (at the same locations) were noted because rates were measured on different types of substrate from one year to the next.

Doses to the public

The estimated dose to people who consume locally grown foodstuffs at high-rates was estimated to be less than 0.005 mSv. After making an allowance for non-food pathways arising from discharges to air (see Appendix 1), the dose in 2009 was still below 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1).

The dose to high-rate local fish and shellfish consumers, including external radiation was 0.011 mSv, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose in 2008 was also 0.011 mSv. As in 2008, the dose received from people collecting sea coal at Carr House was estimated. The dose in 2009 was 0.014 mSv for this activity. The decrease in dose from 0.019 mSv (in 2008) was due to decreased gamma dose rates (above background levels) at this location in 2009. There had been no significant trend in doses from marine pathways prior to 2008 (Figure 4.2); the increase in dose in 2008 and 2009 was due to the additional assessment to determine the external exposure for sea coal collectors at Carr House. In 2009, the *total dose* from all sources (using methods in Appendix 4) was assessed to have been 0.027 mSv (Table 4.1), which is less than 3 per cent of the dose limit. The most exposed people were adults living near to the site (Table A4.2), whose dose was from direct radiation from the site and external exposure from activity in sand and sediment on local beaches. This dose was very similar to that in 2008 (0.026 mSv).

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 two AGRs. It is estimated that Heysham 1 and

2 will end power generation by 2014 and 2023, respectively. Disposals of radioactive waste from both stations are made under permit via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. In December 2009, the Environment Agency issued variations in permits (Heysham 1 and 2) to enable the transfer of waste to the Winfrith site in Dorset, for treatment prior to its disposal to LLWR in Cumbria. The variations also permitted additional flexibility in solid waste disposal routes, but did not change gaseous and liquid discharge limits. The most recent habits survey was conducted in 2006 (McTaggart *et al.*, 2007).

Gaseous discharges and terrestrial monitoring

Gaseous discharges of some radionuclides at Heysham 1 increased significantly in 2009, compared with 2008, due to the return to service of both reactors from a significant maintenance outage. Discharges of these radionuclides for 2009 were lower than (but approached) discharge levels reported before the maintenance outage. Gaseous discharges of most radionuclides from Heysham 2 in 2009 were broadly comparable to those reported in 2007 and 2008; however

discharges of argon-41 became elevated during the year following air ingress to one of the reactors. Discharges of cobalt-60 particulate and iodine-131 are normally dominated by minimum detectable activity measurements. Changes to the methodology for calculating these values (and in the case of cobalt-60 particulate, some assessments of discharges made) have resulted in increases in the reported discharges in 2009, compared with 2008.

The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. Data for 2009 are given in Table 4.6(a). The effects of gaseous disposals were difficult to detect in 2009, and measured activities of cobalt-60 were below the LoD. Small enhancements of concentrations of carbon-14 and sulphur-35 were apparent in some samples.

Liquid waste discharges and aquatic monitoring

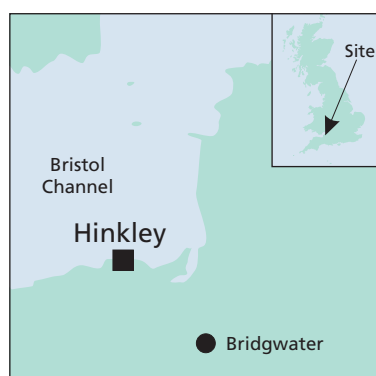
Liquid discharges of tritium and sulphur-35 at Heysham 1 increased significantly in 2009, compared with 2008, due to the return to service of both reactors from the maintenance outage. Discharges of these radionuclides for the year were comparable to, or approached, discharge levels reported before the maintenance outage. Discharges of the other radionuclides permitted by RSA 93 for the site are dominated by other operations. Liquid discharges from Heysham 2 in 2009 were broadly comparable to those reported in 2007 and 2008.

The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates and for completeness the data considered in this section include all of those for Morecambe Bay. A substantial part of the programme is in place in order to monitor the effects of Sellafield disposals. The results for 2009 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2008 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in flounder and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at levels typical of recent years, caused by discharges from Sellafield. Concentrations of caesium-137 in sediments, largely due to Sellafield, are in decline (Figure 4.1). In 2009, concentrations of americium-241 and plutonium radionuclides in molluscs were lower in comparison to 2008. Generally gamma dose rates were similar to those in 2008, although some differences (at the same location) were noted because rates were measured on different types of substrate from one year to the next. Gamma dose rates have increased at Half Moon Bay in 2009, compared to 2008. An elevated tritium concentration was measured in a seawater sample collected during 2009 from the vicinity of the Heysham Harbour inlet. This sample was most likely collected shortly after a permitted discharge of tritiated effluent was made from one of the Heysham stations.

Doses to the public

The estimated dose for high-rate terrestrial food consumers was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air (see Appendix 1), the dose was 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This is similar to the value in 2008. The dose in 2009 to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.041 mSv, which is approximately 4 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This is similar to the value in 2008 (0.042 mSv), however the contribution to dose from gamma dose rates increased whilst the contribution to dose from consumption of molluscs decreased. Trends in aquatic doses from power stations are shown in Figure 4.2. The *total dose* from all sources (using methods in Appendix 4) was assessed to have been 0.049 mSv in 2009 (Table 4.1), up from 0.046 mSv in 2008. This was approximately 5 per cent of the dose limit for members of the public. The most exposed people are those adults who spend a large amount of time on sand and sediments. The increase in dose in 2009 is due to higher gamma dose rates over local beaches.

4.6 Hinkley Point, Somerset



Hinkley Point Power Station is situated on the Somerset coast, west of the River Parrett estuary. There are two separate A and B nuclear power stations which comprise of two Magnox reactors and two AGRs, respectively. Hinkley Point A started

electricity generation in 1965 and ceased in 2000. This station completed defuelling in 2004 and is undergoing decommissioning. Current plans are for the site to be delicensed (released from regulatory control), with final closure to be completed by 2104. It is estimated that Hinkley Point B will end power generation by 2016. Environmental monitoring covers the effects of the two power stations together. The most recent habits survey was undertaken in 2006 (Clyne *et al.*, 2007).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Discharges of carbon-14 and sulphur-35 from Hinkley Point B decreased in 2009 in comparison to 2008, but remained higher than releases in 2007. Discharges of tritium from Hinkley Point B increased in 2009. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and

analysed. The use of seaweeds as fertilisers and soil conditioners was assessed to investigate transfer of radionuclides from sea to land. Data for 2009 are given in Table 4.7(a). Activity concentrations of tritium and gamma emitters (including caesium-137) in terrestrial materials were below the limits of detection. Sulphur-35 from Hinkley Point B was detected at low concentrations in some of the food samples. A few of the carbon-14 concentrations were higher than the default values used to represent background levels (Appendix 1), but this did not include samples in milk in 2009. Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water. Sea to land transfer data for vegetables and soil which had added seaweed (as compost) showed no evidence for uptake of activity concentrations in foodstuffs.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent from both power stations are made via separate outfalls into the Bristol Channel. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were conducted. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the GE Healthcare plant at Cardiff. The environmental results for 2008 are given 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 2008 (see also Figure 4.1). Concentrations of tritium in fish and shellfish were slightly enhanced in comparison to recent years. Further information on tritium concentrations in seawater from the Bristol Channel is given in Section 8. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors to the aquatic environment are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl fallout. Apportionment is generally difficult at the low concentrations detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from GE Healthcare, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Gamma radiation dose rates over intertidal sediment were generally similar to measurements in 2008, although some small differences (at the same locations) were noted because rates were measured on different types of substrate from one year to the next. For example, for this year, the overall rates at Stolford were marginally increased in comparison to 2008 (measurements all taken over mud and rock), due to the inclusion of a measurement over mud in 2009.

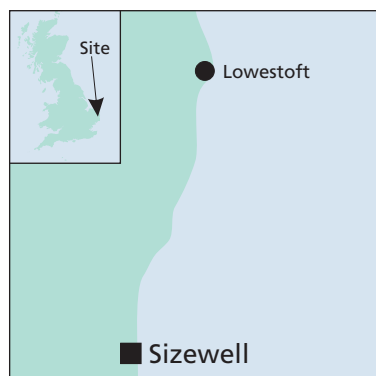
Doses to the public

In 2009, the estimated dose for high-rate terrestrial food consumers was less than 0.005 mSv, which included a component due to non-food pathways arising from discharges to air (see Appendix 1). This was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This represents a small decrease in the dose in comparison to the value

obtained in 2008 (0.006 mSv). The decrease in dose in 2009 was due to lower concentrations of carbon-14 in milk and no detectable activity of caesium-137 in any foods. Assuming that high-rate vegetable consumers obtain all of their supplies from monitored plots near Hinkley, the dose in 2009 from the use of seaweeds as fertilisers and soil conditioners was estimated to be much less than 0.005 mSv.

The dose to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.046 mSv, which was less than 5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This estimate also includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1). The increase in dose, from 0.037 mSv (in 2008), was due to the enhanced gamma dose rates at Stolford. There is no site related reason to account for the variation in dose rates and the change may be due to variations in either or both of the type of substrate measured or natural radiation. Trends in doses in the area of the Severn Estuary are shown in Figure 6.5. The *total dose* at Hinkley, which includes contributions from all relevant sources including direct radiation, was 0.055 mSv (Table 4.1), or less than 6 per cent of the dose limit. Adult mollusc consumers were the most exposed people, although the bulk of their dose was via external gamma dose from spending a large amount of time on local beaches (Table A4.2). The increase in *total dose* from 0.045 mSv in 2008 was due to an increased gamma dose rate on beaches in the area, and continues the upward trend since 2007.

4.7 Sizewell, Suffolk



The two Sizewell Power Stations are located on the Suffolk coast, near Lowestoft. The A station has two Magnox reactors whilst the B station is the UK's only commercial PWR power station. The B station began operation in 1995 and it is estimated

that it will end power generation by 2035. Sizewell A power station ceased to be an electricity generator in 2006 and is due to be decommissioned. Current plans are for Sizewell A to be de-licensed (released from regulatory control), with final closure to be completed by 2110. In September 2009, British Energy submitted an Environmental Scoping Report to DECC. The report outlined the nature and purpose of British Energy's proposed spent fuel management strategy, for Sizewell B, which options included on-site storage in a dry fuel store from 2015, when the current fuel ponds will reach capacity (British Energy, 2009). The most recent habits survey for Sizewell was undertaken in 2005 (Clyne *et al.*, 2006).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. In 2009, discharges of tritium from Sizewell A were reduced in comparison to 2008; discharges of iodine-131 from Sizewell A increased. The results of the terrestrial monitoring in 2009 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 2009. Tritium concentrations in local freshwater were all low. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water, except at the nature reserve. The gross beta activity at the reserve was not below the WHO recommended value 1.0 Bq l^{-1} , but is not known to be used as a source of drinking water. In October 2009, the site operators at Sizewell B reported that the quarterly notification levels for carbon-14 and iodine-131 had been exceeded. The Food Standards Agency carry out additional analyses for iodine-131 on weekly milk samples from routine monitoring. No elevated concentrations of carbon-14 were found in combined monthly samples, and iodine-131 activities were below the LoD during the period.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made via outfalls to the North Sea. In the aquatic programme, analysis of seafood, sediment, sand and seawater, and measurements of gamma dose rates in intertidal areas were conducted. Data for 2009 are given in Tables 4.8(a) and (b). Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium concentrations in seafood were all below the limits of detection. Measured gamma dose rates in intertidal areas were difficult to distinguish from the natural background, including at Sizewell beach where direct radiation from the A station is known to have had a local effect in recent years.

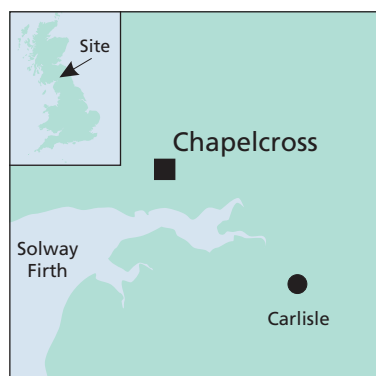
Doses to the public

The estimated dose to people who consume locally grown foodstuffs at high-rates was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air, (see Appendix 1), the dose in 2009 was the same at less than 0.005 mSv which is less than 0.5 per cent of the dose limit for members of the public of 1 mSv. In 2009, the radiation dose to people who consume large quantities of local fish and shellfish was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). There has been no significant variation in doses to seafood consumers in recent years (Figure 4.2). They have remained consistently below 0.005 mSv. The *total dose* from all sources was assessed (using methods in Appendix 4) to be 0.026 mSv in 2009 (Table 4.1) or less than 3 per cent of the dose limit, and a decrease from 0.031 mSv in 2008. The dominant contribution to *total dose* at this site is from direct

radiation (Table A4.1). Dose from this pathway has reduced by a factor of three since Sizewell A ceased generation in 2006. The most exposed people were adults living in the vicinity of the site (Table A4.2).

SCOTLAND

4.8 Chapelcross, Dumfries and Galloway



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

has been preparing for decommissioning. Defuelling of the reactors began in 2008 and completion is expected during 2011, with site clearance to be completed by 2128.

The 2007 application for a revised authorisation for the disposal of radioactive waste arising from the decommissioning of Chapelcross and the 2009 application for a variation to the extant solid waste authorisation were subject to discretionary and public consultation during 2010 and are in the process of being determined.

Last year SEPA reported that the end of the liquid effluent pipeline is fully submerged at high water and for a period prior to and after high water. The pipeline remains exposed during the rest of the time. The pipeline is subject to groundwater ingress and constantly discharges to the Solway Firth. Major improvements to the discharge system were undertaken by Magnox North towards the end of the year. The pipeline was relined with a plastic pipe routinely used within the water industry and grouted in place at strategic points. The aim of the work was to stop the release of "lime-scale particles" by isolating them between the old pipeline and the inserted plastic pipe liner. The work was completed in early 2010 and initial inspection by SEPA noted that the constant discharge from the pipeline when exposed had ceased.

To better understand the legacy of gaseous tritium disposals from the site and to inform on future disposals a programme of surface water sampling in the locality of the premises was undertaken in 2009. SEPA concluded that disposals of tritium to air from the tritium processing plant, has resulted in tritium being ubiquitous in and around the Chapelcross site. A distinctive footprint of these disposals can be observed. The effects can still be seen in and around the site extending to the Winterhope reservoir some 20 km north west of the site. A report was presented to the Site Stakeholder Group (Scottish Environment Protection Agency, 2009b).

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2005 (Sherlock *et al.*, 2006). This survey confirmed the existence of local fishermen who eat large quantities of local seafood and are also exposed to external radiation whilst tending stake nets. A further group was identified consisting of wildfowlers who were exposed to external radiation whilst on salt marshes. In 2007, a habits survey of consumption and occupancy, by members of the public, was completed on the Dumfries and Galloway coast (Clyne *et al.*, *in preparation*). The results of the survey are used to determine the potential exposure pathways relating to authorised liquid discharges from the Sellafield nuclear site in Cumbria (see Section 2.3.4).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Argon-41 was not discharged in 2009, as in recent years, following the end of power generation. Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit and crops, as well as grass and soil samples, for a range of radionuclides. Air samples at three locations were also monitored to investigate the inhalation pathway.

The results of terrestrial food and air monitoring in 2009 are given in Tables 4.9(a) and (c). The activity concentrations of radionuclides in milk and grass were generally similar to those observed in 2008. The maximum concentration of tritium in milk was 11 Bq l⁻¹ and similar to the value in 2008 (<12 Bq l⁻¹), the former being the lowest detectable value since electricity generation ceased in 2004. The results for terrestrial foods show the effects of discharges from Chapelcross in the concentrations of tritium and sulphur-35 in a range of foods, and these are mostly below the LoD. Measured concentrations of radioactivity in air samples, at locations near to the site, were very low.

Liquid waste discharges and aquatic monitoring

Radioactive liquid effluents are discharged to the Solway Firth. Samples of seawater and *Fucus vesiculosus*, as environmental indicators, were collected in addition to seafood, sediments and dose rates. Data for 2009 are given in Tables 4.9(a) and (b). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years. Progressive reductions in concentrations of technetium-99 in biota were observed again in 2009. Surface water sampling in the locality of the premises, showed elevated tritium concentrations (310 Bq kg⁻¹, maximum) in and around the Chapelcross site from the legacy of gaseous tritium disposals. In comparison to 2008 data, gamma dose rates were generally similar, but measurements in a few intertidal areas (including the pipeline) were slightly

increased. Measurements of the contact beta dose rate on stake nets were below the LoD.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are lime-scale and originate from deposits within the pipeline. Magnox North Limited monitors this area frequently. In 2009, a single particle was detected and recovered during the year's routine monitoring. This particle had a beta/gamma contact dose rate of 3 microsieverts per hour. In comparison, three particles with activity above background were detected in 2008, with a total of 130 particles during the period 2000 to 2008. The relatively high number found in 2005 (95 particles) was due to a series of incidents including a flooding event that was the result of exceptionally heavy rainfall in the area. All contaminated items detected are removed.

Doses to the public

The annual dose for high-rate terrestrial food consumers was estimated to be 0.008 mSv in 2009. Approximately two-thirds of the decrease in dose from 0.023 mSv (in 2008) was attributable to the exclusion of the LoD for americium-241 activity in food in the 2009 assessment. In line with the rules on use of results for dose calculations, americium-241 was not included because no detectable activity was observed in other samples from the terrestrial environment in 2009. A decreased value for the maximum carbon-14 activity in milk contributed to the remainder of the reduction in the dose. The dose from consumption of terrestrial foods includes contributions due to weapons testing and Chernobyl fallout. After making an allowance for non-food pathways arising from discharges to air (see Appendix 1) and when rounded again to one significant figure, the dose was 0.009 mSv in 2009, which was less than 1 per cent of the dose limit for members of the public of 1 mSv. No argon-41 was discharged in 2009; the dose was mostly due to the consumption of local foodstuffs. The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv.

The dose to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.024 mSv in 2009, which was approximately 2 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from 0.022 mSv (in 2008) was due to a small increase in gamma dose rate measurements at the pipeline. 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 exposure of high-rate consumers of wildfowl, including their external dose from occupancy over salt marsh was 0.007 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase from 0.006 mSv (in 2008) was due to increased gamma dose rates in some intertidal areas. The dose from consumption of wildfowl was less than 0.005 mSv. Trends in aquatic doses from power stations are shown in Figure 4.2. The reduction

of the dose at Chapelcross, commencing in 2004, was due to lower gamma dose rates reported. In recent years, the observed trend is due to differences in measured gamma dose rates due to the normal variability in the environment. The *total dose* from all sources was assessed (using methods in Appendix 4) to have been 0.017 mSv in 2009 (Table 4.1), which is less than 2 per cent of the dose limit. The most exposed people were adults spending time on local beaches (Table A4.2), a change from 2008 when infant milk consumers were exposed to 0.021 mSv. This change is mostly due to americium-241 not being included in 2009 terrestrial dose assessments at Chapelcross.

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,

part of EDF, while Hunterston A is operated by Magnox North Limited and owned by the NDA. Hunterston A was powered by twin Magnox reactors and Hunterston B is powered by a pair of AGRs. Hunterston A ceased electricity power production in 1990, and Hunterston B is expected to have an operational life to 2016. Environmental monitoring in the area considers the effects of both sites together.

In May 2009, Hunterston B partially discharged one of its low level waste delay tanks outside of the tidal window for radioactive discharges. The release involved liquid effluent that had already been consigned for discharge. This occurrence had no apparent environmental impact, and there was no need to initiate further sampling. A number of procedural issues were identified, and SEPA issued a Final Warning Letter to British Energy in July 2009 in response to this event.

In October 2008, SEPA varied the authorisation for Hunterston A, to reflect the change of operator at the Low Level Waste Repository, near Drigg in Cumbria.

Two main groups for dose assessment have been identified in the recent habits survey: seafood consumers and terrestrial food consumers. The most recent habits survey was undertaken in 2007 (Sherlock *et al.*, *in preparation*).

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. Discharges from Hunterston B were generally increased in comparison

to 2008. There is a substantial terrestrial monitoring programme which includes the analyses 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 2009 are given 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. Discharges from Hunterston B increased for tritium and sulphur-35 in comparison to 2008. Authorised liquid discharges from Hunterston A are also made via the same outfall. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials.

A new modular active effluent treatment plant has been designed and installed at Hunterston A to provide improved treatment of effluent prior to discharge. Commissioning trials, commenced during 2008, were continued in 2009 before the plant's adoption into full operational service.

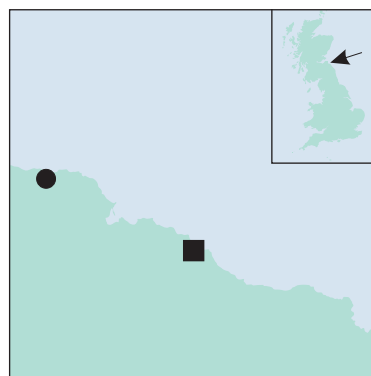
The results of aquatic monitoring in 2009 are shown in Tables 4.10(a) and (b). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs around Hunterston were low (and similar to those in 2008). The technetium-99 concentration in the common lobster significantly decreased in 2009, and is the lowest value reported in recent years. Small concentrations of activation products (such as manganese-54 and cobalt-60) that are likely to have originated from the site were also detected in seaweed but were of negligible radiological significance. Gamma dose rates were similar to those in 2008.

Doses to the public

In 2009, the estimated dose to people consuming terrestrial food at high-rates, including a contribution due to weapon testing and Chernobyl fallout, was 0.006 mSv. The dose in 2008 was also 0.006 mSv. After making an allowance from non-food pathways (arising from discharges to air, see Appendix 1), the dose in 2009 was 0.007 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose from inhaling air containing caesium-137 at the concentrations reported was estimated to be much less than 0.005 mSv. As in 2008, the contribution to dose from consumption of fish and shellfish was less than 0.005 mSv. This includes a contribution from the Sellafield-derived technetium-99 in shellfish. The dose to local fishermen, who

consume a large amount of seafood and are exposed to radiation over intertidal areas, was 0.006 mSv in 2009, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This dose was similar in 2008 0.005 mSv). Trends in aquatic doses at power stations are shown in Figure 4.2. In recent years, the observed trend is due to differences in measured gamma dose rates from normal variability in the environment. The *total dose* from all sources was assessed (using methods in Appendix 4) to have been 0.067 mSv in 2009 (Table 4.1), which is less than 7 per cent of the dose limit, and a decrease from 0.077 mSv in 2008. The dose was mainly from direct radiation from the site (Table A4.1), and the most exposed people were the prenatal children of local inhabitants (Table A4.2). The decrease in *total dose* in recent years reflects a downward trend in the reported direct radiation.

4.10 Torness, East Lothian



Torness Power Station is located near Dunbar on the east coast of Scotland. This station, which is powered by two AGRs, began operation at the end of 1987 and it is estimated that its power generation will end by 2023. Disposals and

discharges of radioactive waste from the site are made in accordance with the Radioactive Substances Act authorisation issued to the site by SEPA in 2007. The liquid and gaseous discharges from the site are given in Appendix 2. There were no amendments made to the authorisation during 2009.

During 2009, there was a leak of radioactive effluent within the fuel handling building; however it is believed that the effluent was retained within the building. SEPA carried out ground water sampling from boreholes around the station which showed no evidence of the effluent leak. Whilst SEPA considers that the incident had no discernable environmental impact it was concerned about the events that lead to the incident and issued a Final Warning Letter in relation to the incident. The power station has since made a number of improvements to the appropriate facilities.

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

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops and fruit as well as grass and soil samples, were measured for a range of radionuclides. Due to supplier issues, goats' milk samples, which have been analysed in previous years, will not be sampled in

2010. Air sampling at two locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2009 are given in Tables 4.11(a) and (c). The effects of discharges from the power station were not observed for concentrations of sulphur-35, which were below the LoD in terrestrial foods and environmental indicator materials. Measured concentrations of radioactivity in air at locations near to the site were below the LoD (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 2009 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout. As in recent years, a few very low concentrations of activation products were detected. These were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2008. Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates on beaches were generally indistinguishable from natural background and were similar to those measured in recent years.

Doses to the public

The estimated dose to high-rate terrestrial food consumers, including a contribution due to weapon testing and Chernobyl fallout, was 0.005 mSv. After making an allowance for non-food pathways, arising from radionuclides in air (see Appendix 1), the dose in 2009 was still 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose is similar to the value obtained in 2008 (0.006 mSv). 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 high-rate consumers of fish and shellfish, including a component due to external radiation, was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). There has been no significant trend in doses from marine pathways in recent years (Figure 4.2). In 2009, the *total dose* from all sources was assessed (using methods in Appendix 4) to have been 0.022 mSv, approximately 2 per cent of the dose limit. Direct radiation (Table A4.1) was the dominant contributor to this dose, and the most exposed people were the prenatal children of local root vegetable consumers. The *total dose* was unchanged from 2008.

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. Trawsfynydd ceased to generate electricity in 1991. Defuelling of the reactors was completed in 1995

and the station is being decommissioned. Current plans are to de-license the site. The site will be used for recreation to reflect its location within the Snowdonia National Park, with site closure scheduled for completion by 2098. Monitoring is conducted on behalf of the Welsh Assembly Government. The most recent habits survey was undertaken in 2005 (Tipple *et al.*, 2006a).

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, including those for local milk, crops and animal samples, are shown in Table 4.12(a). Concentrations of activity in all terrestrial foods were low. In 2009, concentrations of carbon-14 in milk and offal were enhanced in comparison to 2008, although discharge values were similar. As in previous years, caesium-137 was detected in some of the terrestrial foods (blackberries, potatoes and turnips in 2009), at concentrations just above the LoD. The most likely source is fallout from Chernobyl and weapon tests, though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also conducted in crop and animal samples. Detected activities were low and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was no evidence of resuspension of activity in sediment from the lake shore contributing to increased exposure from transuranic radionuclides in 2009.

Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. The aquatic monitoring programme was directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. Freshwater and sediment samples are also analysed. Habits surveys have established that species of fish regularly consumed are brown and rainbow trout. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because

of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than indigenous fish.

Data for 2009 are given in Tables 4.12(a) and (b). Concentrations of radiocaesium in fish in 2009 were generally similar to those in 2008. In comparison to previous years, concentrations of caesium-137 in rainbow trout were elevated in 2009, although much lower than typical concentrations found in indigenous fish. It is possible that local engineering works may have disturbed sub-surface sediment, releasing small amounts of activity into the lake water. The majority of activity concentrations in sediments, and in the fish, result from discharges from much earlier years. Concentrations in the water column are predominately maintained by processes that release activity (such as remobilisation) from near surface sediments. Low concentrations of other radionuclides including transuranics are also detected, particularly in lake sediments (in recent years' monitoring, it has been demonstrated that these increase with depth beneath the sediment surface). However, the transuranic concentrations in fish are very low and it is the effects of caesium-137 that dominate the fish consumption and external radiation pathways.

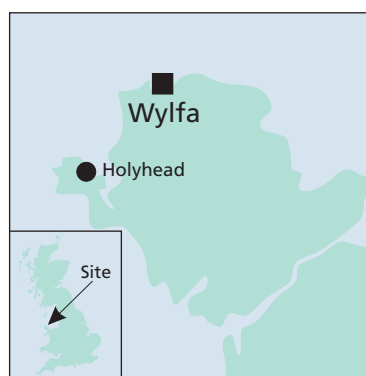
In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where anglers' fish were difficult to distinguish from background levels and were similar to those in earlier years. The predominant radionuclide is caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.3. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. Over the last decade, the observed levels now are mainly affected by sample variability, with the lowest levels reported in recent years.

Doses to the public

Despite elevated concentrations of carbon-14 in milk and offal, high-rate consumers of terrestrial foods at Trawsfynydd still received doses of less than 0.005 mSv in 2009. The infant age group received the maximum dose from milk consumption. This dose is similar to the value obtained in 2008. After making an allowance from non-food pathways, arising from discharges to air (see Appendix 1), the dose was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to anglers (who consume quantities of fish and spend long periods of time in the location being assessed) was 0.011 mSv in 2009, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv. The observed concentrations in lake sediments are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels. The increase from the estimate of 0.008 mSv in 2008 was due to increased caesium-137 concentrations in fish in 2009. Trends in doses at power stations are shown in Figure 4.2. The reduction of the dose in 2004 at Trawsfynydd was due to a reduction in the observed concentrations in lake sediments. There has been no significant trend in doses from aquatic

pathways in recent years. The *total dose* from all sources was assessed (using methods in Appendix 4) to have been 0.018 mSv in 2009, which is approximately 2 per cent of the dose limit. The majority of this dose was direct radiation from the site, with a contribution from locally produced milk. As in 2008, infants living near to the site were the most exposed people. The decrease from 0.031 mSv in 2008 was almost entirely due to a lower direct radiation dose from the site in 2009 (Table A4.1).

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 was the last and largest power station of its type to be built in the UK and commenced electricity generation in 1971. On 25

March 2009, the HSE granted a Consent for Wylfa to start decommissioning operations. The current assumption is that the site will be de-licensed and made available for potential reuse by 2125. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is conducted on behalf of the Welsh Assembly Government. During June and July 2009, a habits survey was conducted to determine the consumption and occupancy rates by members of the public. Increases in the fish, crustacean and mollusc consumption rates have been observed, together with an increase in the occupancy rate, in comparison with those of the previous survey in 2004. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

Gaseous discharges and terrestrial monitoring

The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Local surface water samples were also taken and analysed. Data for 2009 are given in Table 4.13(a). Sulphur-35 was detected at very low concentrations in some of the food samples. Carbon-14 was detected in locally produced foods, but mostly at concentrations expected for background levels. Overall the effects of discharges are very low. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

In 2009, discharges of tritium were further reduced in comparison to 2008 and 2007. The monitoring programme for the effects of liquid disposals included sampling of fish,

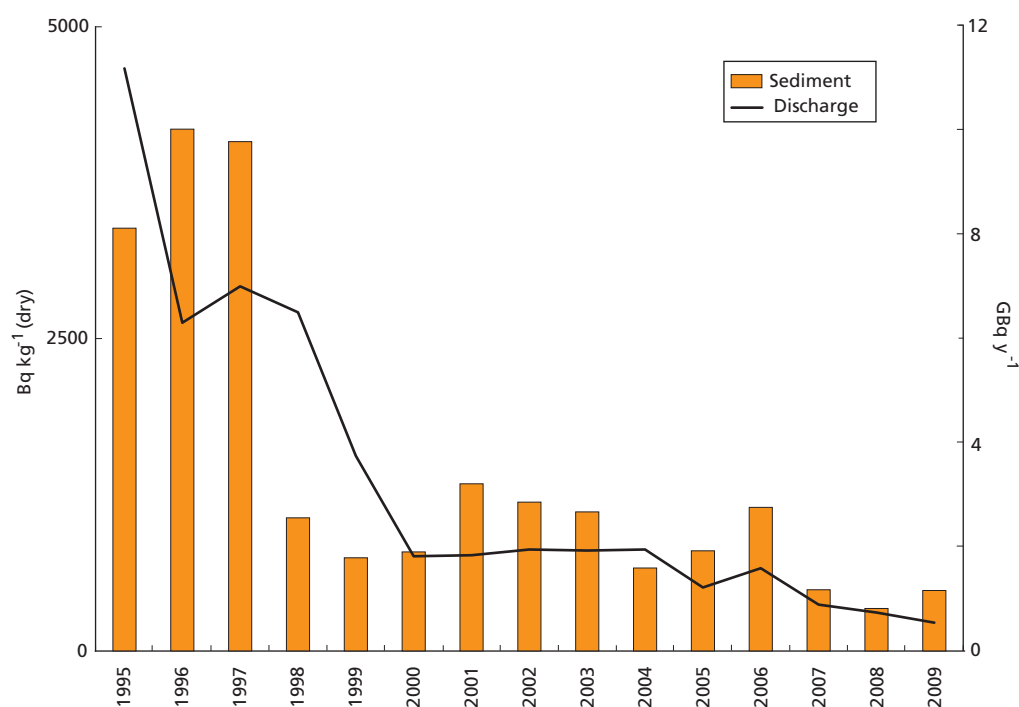


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2009

shellfish, sediment, seawater and measurements of gamma dose rates. The results of the programme in 2009 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 2008, and continued to show the effects of technetium-99 from Sellafield, albeit at lower concentrations than in previous years. Gamma dose rates, measured using portable instruments, were generally similar to those found in 2008.

Doses to the public

The dose to people who consume terrestrial food at high-rates was less than 0.005 mSv. After making an allowance for non-food pathways, arising from discharges to air (see Appendix 1), the dose in 2008 was still less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose to high-rate

consumers of fish and shellfish was 0.010 mSv, which was 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from 0.006 mSv (in 2008) was due to the inclusion of revised habits data. As a result dose contributions from both food consumption and external exposure increased (and by approximately the same amount), although overall the largest dose contribution continued to be from external exposure. Trends in doses at power stations are shown in Figure 4.2. The reduction of the dose in 2004 at Wylfa was due to revised estimates of consumption and occupancy rates. There has been no significant trend in doses from marine pathways in recent years. The *total dose* from all sources of radiation was assessed (using methods in Appendix 4) to have been 0.011 mSv in 2009 (Table 4.1) or approximately 1 per cent of the dose limit, and unchanged from 2008. Local infant inhabitants were the most exposed people, with the majority of the dose coming from direct radiation and milk (Table A4.1)

Table 4.1. Individual radiation exposures nuclear power stations, 2009

Site	Exposed population ^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	0.025	<0.005	-	0.024	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	All sources ^{d,e}	0.058	-	-	-	-
Bradwell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005
	All sources ^{d,e}	0.098	-	-	-	-
Dungeness	Seafood consumers	0.012	<0.005	-	0.010	-
	Houseboat occupants	0.014	-	-	0.014	-
	Inhabitants and consumers of locally grown food ^b	0.005	-	<0.005	-	<0.005
	All sources ^d	0.32	-	-	-	-
Hartlepool	Seafood consumers ^c	0.011	<0.005	-	0.010	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	Sea coal collectors	0.014	-	-	0.014	-
	All sources ^d	0.027	-	-	-	-
Heysham	Seafood consumers	0.041	0.011	-	0.030	-
	Inhabitants and consumers of locally grown food ^b	0.005	-	<0.005	-	<0.005
	All sources ^d	0.049	-	-	-	-
Hinkley Point	Seafood consumers	0.046	<0.005	-	0.044	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	Local consumers of vegetables grown on land with seaweed added	<0.005	-	<0.005	-	-
	All sources ^d	0.055	-	-	-	-
Sizewell	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	All sources ^d	0.026	-	-	-	-
Scotland						
Chapelcross	Seafood consumers	0.024	<0.005	-	0.023	-
	Wildfowlers	0.007	-	<0.005	0.007	-
	Inhabitants and consumers of locally grown food ^b	0.009	-	0.008	-	<0.005
	All sources ^d	0.017	-	-	-	-
Hunterston	Seafood consumers	0.006	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food ^b	0.007	-	0.006	-	<0.005
	All sources ^{d,e}	0.067	-	-	-	-
Torness	Seafood consumers	<0.005	<0.005	-	<0.005	-
	Inhabitants and consumers of locally grown food ^b	0.005	-	0.005	-	<0.005
	All sources ^{d,e}	0.022	-	-	-	-
Wales						
Trawsfynydd	Anglers	0.011	0.009	-	<0.005	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	All sources ^{b,d}	0.018	-	-	-	-
Wylfa	Seafood consumers	0.010	<0.005	-	0.007	-
	Inhabitants and consumers of locally grown food ^b	<0.005	-	<0.005	-	<0.005
	All sources ^{b,d}	0.011	-	-	-	-

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

Table 4.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	¹⁴ C	⁹⁹ Tc	¹³⁴ Cs	¹³⁷ Cs	²³⁸ Pu
Marine samples								
Salmon	Beachley	2	<31			<0.09	<0.15	
Bass	River Severn	2	210			<0.11	2.2	
Elvers	River Severn	1	<25			<0.10	<0.09	
Shrimps	Guscar	2	260	27		<0.05	0.37	0.00037
Seaweed	Pipeline	2 ^E			9.8	<0.82	<1.0	
Sediment	Hills Flats	2 ^E					15	
Sediment	1 km south of Oldbury	2 ^E				<0.74	25	
Sediment	2 km south west of Berkeley	2 ^E				<1.2	27	
Sediment	Sharpness	2 ^E					20	
Seawater	Local beach	2 ^E				<0.31	<0.33	
Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples								
Salmon	Beachley	2		<0.14				
Bass	River Severn	2		<0.15				
Elvers	River Severn	1		<0.07				
Shrimps	Guscar	2	0.0022	0.0026	*	0.000057		
Seaweed	Pipeline	2 ^E		<1.1				
Sediment	Hills Flats	2 ^E		<1.1				
Sediment	1 km south of Oldbury	2 ^E		<1.2				
Sediment	2 km south west of Berkeley	2 ^E		<1.6				
Sediment	Sharpness	2 ^E		<1.6				
Seawater	Local beach	2 ^E		<0.41			<2.5	8.3
Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	¹⁴ C	³⁵ S	¹³⁷ Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk	max	9	<4.6	16	<0.29	<0.20		
Milk			<5.3	18	<0.45			
Apples		1	<4.0	13	<0.10	<0.20		
Blackberries		1	<4.0	19	0.40	<0.20		
Cabbage		1	<4.0	5.0	<0.20	<0.10		
Honey		1	<7.0	94	<0.20	<0.20		
Onions		1	<4.0	15	0.30	<0.20		
Potatoes		1	<5.0	24	0.40	<0.20		
Runner beans		1	<4.0	10	0.80	<0.10		
Wheat		1	<7.0	80	1.1	<0.20		
Freshwater	Gloucester and Sharpness Canal	2 ^E	<4.0		<0.75	<0.28	<0.075	0.32
Freshwater	Public supply	2 ^E	<4.0		<0.75	<0.23	<0.050	0.28

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹, and for sediment where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

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

Table 4.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud	1	0.099
1 km south of Oldbury	Grass and mud	1	0.094
2 km south west of Berkeley	Mud and stones	1	0.075
2 km south west of Berkeley	Mud and rock	1	0.081
Guscar Rocks	Mud and salt marsh	2	0.087
Lydney Rocks	Mud and salt marsh	1	0.098
Lydney Rocks	Mud and rock	1	0.091
Sharpness	Mud	1	0.078
Sharpness	Grass and mud	1	0.082
Hills Flats	Mud and sand	1	0.086
Hills Flats	Grass and mud	1	0.086

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2009

Material	Location	No. of sampling observations	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			<0.10	0.22		
Bass	Pipeline	1			<0.07	0.66		
Thornback ray	Pipeline	1			<0.07	0.48		
Lobsters	West Mersea	1			<0.08	<0.08		
Native oysters	Tollesbury N. Channel	1			<0.09	0.17	0.00014	0.0012
Pacific oysters	Goldhanger Creek	2			<0.07	0.07		
Winkles	Pipeline	2			<0.13	0.24		
Winkles	Heybridge Basin	2			<0.19	<0.18		
Seaweed	Bradwell	2 ^E		5.1	<0.88	<1.1		
Leaf beet	Tollesbury	1			<0.12	<0.10		
Samphire	Tollesbury	1			<0.05	0.05		
Sediment	Pipeline	2 ^E	<1.0			7.7		
Sediment	Waterside	2 ^E	<1.5			12		
Sediment	West Mersea Beach Huts	2 ^E	<1.0			<2.2		
Sediment	West Mersea Boatyard	2 ^E	<1.5			8.8		
Sediment	Maldon	2 ^E	<1.2			36		
Sediment	N side Blackwater Estuary	2 ^E	<1.0			14		
Seawater	Bradwell	2 ^E			<0.30	<0.32		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples							
Sole	Bradwell	2	<0.14				
Bass	Pipeline	1	<0.17				
Thornback ray	Pipeline	1	<0.18				
Lobsters	West Mersea	1	<0.22				
Native oysters	Tollesbury N. Channel	1	0.0029	*	0.00010		
Pacific oysters	Goldhanger Creek	2	<0.10				
Winkles	Pipeline	2	<0.09				
Winkles	Heybridge Basin	2	<0.14				
Seaweed	Bradwell	2 ^E	<1.1				
Leaf beet	Tollesbury	1	<0.08				
Samphire	Tollesbury	1	<0.09				
Sediment	Pipeline	2 ^E	<0.98				
Sediment	Waterside	2 ^E	<1.6				
Sediment	West Mersea Beach Huts	2 ^E	<0.94				
Sediment	West Mersea Boatyard	2 ^E	<1.6				
Sediment	Maldon	2 ^E	<1.6				
Sediment	N side Blackwater Estuary	2 ^E	<1.6				
Seawater	Bradwell	2 ^E	<0.39			<4.0	20

Table 4.3(a). continued

Material	Location or selection ^b	No. of sampling observ- ations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					Gross alpha	Gross beta	
			³ H	¹⁴ C	³⁵ S	¹³⁷ Cs				
Terrestrial samples										
Milk		4	<4.3	15		<0.20				
Milk		max	<4.5	17						
Apples		1	<4.0	19		<0.20				
Blackberries		1	<4.0	15		<0.20				
Cabbage		1	<4.0	15		<0.20				
Carrots		1	<4.0	11		<0.20				
Lucerne		1	<4.0	21		<0.20				
Potatoes		1	<5.0	16		<0.20				
Rabbit		1	<5.0	21		<0.20				
Wheat		1	<7.0	79		<0.20				
Freshwater	Public supply	2 ^E	<4.0		<0.75	<0.36	<0.065	0.36		
Freshwater	Coastal ditch 1	1 ^E	<6.0		<0.60	<0.31	<0.40	3.4		
Freshwater	Coastal ditch 2	1 ^E	<5.0		<1.0	<0.38	<0.50	3.8		
Freshwater	Coastal ditch 3	1 ^E	11		3.4	<0.23	<0.30	2.1		
Freshwater	Coastal ditch 4	1 ^E	14		3.7	<0.28	<0.60	10		

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹, and for sediment where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

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

Table 4.3(b). Monitoring of radiation dose rates near Bradwell, 2009

Location	Ground type	No. of sampling observations	μGy h ⁻¹
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and sand	1	0.082
Bradwell Beach	Sand and shells	1	0.088
Beach opposite power station, N side of estuary	Mud	1	0.079
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.077
Waterside	Mud	2	0.073
Maldon	Mud	2	0.069
West Mersea Beach Huts	Sand and shells	1	0.073
West Mersea Beach Huts	Sand and shingle	1	0.071
West Mersea	Sand and shells	1	0.056
West Mersea	Sand and shingle	1	0.067

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2009

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									
Cod	Pipeline	2		<25		<0.07			0.18
Bass	Pipeline	1		<25		<0.11			0.34
Sole	Pipeline	2	<25	<25		<0.13			<0.15
Crabs	Eastbourne /								
	Folkestone landed	1				<0.09			<0.07
Shrimps	Pipeline	2	<25	<26	21	<0.08			<0.07
Scallops	Pipeline	2				<0.07	0.040		<0.05
Sea kale	Dungeness Beach	1				<0.05			0.15
Seaweed	Folkestone	2 ^E				<0.82		3.5	<0.72
Sediment	Rye Harbour 1	2 ^E				<0.77			<0.66
Sediment	Camber Sands	2 ^E				<0.69			<0.56
Sediment	Pilot Sands	2 ^E				<0.51			<0.48
Seawater	Dungeness South	2 ^E		<4.0		<0.46			<0.37

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	Gross alpha	Gross beta
Marine samples									
Cod	Pipeline	2			<0.19				
Bass	Pipeline	1			<0.09				
Sole	Pipeline	2			<0.09				
Crabs	Eastbourne /								
	Folkestone landed	1			<0.08				
Shrimps	Pipeline	2			<0.07				
Scallops	Pipeline	2	0.00030	0.0018	0.00082	*	0.000033		
Sea kale	Dungeness Beach	1			<0.04				
Seaweed	Folkestone	2 ^E			<0.90				
Sediment	Rye Harbour 1	2 ^E	<0.060	<0.060	<1.7				690
Sediment	Camber Sands	2 ^E			<0.76				
Sediment	Pilot Sands	2 ^E			<0.85				
Seawater	Dungeness South	2 ^E			<0.43			<4.0	15

Material	Location selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					Gross alpha	Gross beta
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	¹³⁷ Cs		
Terrestrial Samples									
Milk	max	2	<4.6	17	<0.24	<0.18	<0.20		
Milk			<5.0		<0.25	<0.20			
Beans		1	<9.0	91	3.4	<0.20	<0.20		
Blackberries		1	<4.0	20	0.30	<0.20	<0.20		
Cabbage / cauliflower		1	<4.0	<3.0	1.3	<0.20	<0.20		
Potatoes		1	<5.0	16	1.3	<0.20	<0.20		
Sea kale		1	<4.0	8.0	1.9	<0.30	0.40		
Wheat		1	<7.0	70	1.2	<0.10	<0.20		
Grass		1				<0.20	<0.20		
Freshwater	Long Pits	2 ^E	<4.0		<1.5	<0.38	<0.32	<0.045	0.31
Freshwater	Pumping station								
	Well number 1	1 ^E	<4.0		<2.0	<0.49	<0.41	<0.040	0.16
Freshwater	Pumping station								
	Well number 2	1 ^E	<4.0		<1.0	<0.39	<0.34	<0.030	0.21
Freshwater	Reservoir	2 ^E	<4.0		<1.5	<0.33	<0.28	<0.025	0.17

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹, and for beans, wheat 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 4.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	2	0.068
Greatstone-on-Sea	Sand	2	0.064
Dungeness East	Sand and shingle	2	0.065
Dungeness South	Shingle	2	0.056
Jury's Gap	Sand and shingle	1	0.059
Jury's Gap	Shingle	1	0.053
Rye Bay	Sand and shingle	2	0.058

Table 4.5 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			Organic ³ H	³ H	¹⁴ C	⁶⁰ Co	⁹⁹ Tc	¹³¹ I
Marine samples								
Plaice	Pipeline	2	<25	<25	24	<0.09		*
Cod	Pipeline	2				<0.08		*
Crabs	Pipeline	2			29	<0.05		*
Winkles	South Gare	2	<25	<25		<0.06		*
Mussels	South Gare	2				<0.05		*
Mussels	Seal Sands	1			150			
Seaweed	Pilot Station	2 ^E				<1.1	19	<15
Sediment	Old Town Basin	2 ^E				<0.63		
Sediment	Seaton Carew	2 ^E				<0.30		
Sediment	Paddy's Hole	2 ^E				<0.62		
Sediment	North Gare	2 ^E				<0.29		
Sediment	Greatham Creek	2 ^E				<0.77		
Sea coal	Old Town Basin	2 ^E				<0.84		
Sea coal	Carr House Sands	2 ^E				<0.75		
Seawater	North Gare	2 ^E		<9.5		<0.34		
Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			¹³⁷ Cs	²¹⁰ Pb	²¹⁰ Po	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	
Marine samples								
Plaice	Pipeline	2	0.26					
Cod	Pipeline	2	0.37					
Crabs	Pipeline	2	<0.07				0.00035	0.0024
Winkles	South Gare	2	0.18	1.3	13		0.011	0.068
Mussels	South Gare	2	<0.06					
Seaweed	Pilot Station	2 ^E	<0.90					
Sediment	Old Town Basin	2 ^E	<0.97					
Sediment	Seaton Carew	2 ^E	<0.25					
Sediment	Paddy's Hole	2 ^E	<1.1					
Sediment	North Gare	2 ^E	<0.26					
Sediment	Greatham Creek	2 ^E	5.3					
Sea coal	Old Town Basin	2 ^E	<0.96					
Sea coal	Carr House Sands	2 ^E	<1.8					
Seawater	North Gare	2 ^E	<0.29					

Table 4.5 (a). continued

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples							
Plaice	Pipeline	2	<0.19				
Cod	Pipeline	2	<0.22				
Crabs	Pipeline	2	0.0021	*	0.0000087		
Winkles	South Gare	2	0.034	*	0.000073		
Mussels	South Gare	2	<0.11				
Seaweed	Pilot Station	2 ^E	<1.0				
Sediment	Old Town Basin	2 ^E	<0.90				
Sediment	Seaton Carew	2 ^E	<0.46				
Sediment	Paddy's Hole	2 ^E	<1.1				
Sediment	North Gare	2 ^E	<0.46				
Sediment	Greatham Creek	2 ^E	<1.2				
Sea coal	Old Town Basin	2 ^E	<0.99				
Sea coal	Carr House Sands	2 ^E	<1.0				
Seawater	North Gare	2 ^E	<0.38			<5.0	18

Material	Location or selection ^b	No. of sampling observ- ations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	¹³⁷ Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk	max	6	<4.3	16	<0.22	<0.17	<0.20		
Milk			<4.5	18	<0.25	<0.20			
Apples		1	<4.0	9.0	<0.20	<0.20	<0.20		
Beetroot		1	<4.0	9.0	<0.20	<0.20	<0.20		
Blackberries		1	<4.0	12	<0.20	<0.20	<0.20		
Cabbage		1	<5.0	11	<0.30	<0.20	<0.10		
Honey		1	<7.0	68	<0.20	<0.20	<0.20		
Potatoes		1	<5.0	20	<0.20	<0.20	<0.20		
Runner beans		1	<5.0	11	0.20	<0.30	<0.20		
Wheat		1	<7.0	84	0.60	<0.30	<0.20		
Freshwater	Public supply	2 ^E	<4.0		<0.75	<0.39	<0.33	<0.15	0.16
Freshwater	Borehole, Dalton Piercy	2 ^E	<4.0		<2.0	<0.29	<0.24	<0.13	<0.19

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹, and for sediment and sea coal where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

^E Measurements labelled "E" are made on behalf of the Environment Agency; all other measurements are made on behalf of the Food Standards Agency

Table 4.5(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2009

Location	Ground type	No. of sampling observations	µGy h ⁻¹
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand and stones	1	0.071
Fish Sands	Rock and sand	1	0.067
Old Town Basin	Sand	1	0.068
Old Town Basin	Sand and coal	1	0.075
Carr House	Sand and coal	2	0.074
Seaton Carew	Pebbles and sand	1	0.068
Seaton Carew	Sand and stones	1	0.071
Seaton Sands	Sand	1	0.068
Seaton Sands	Pebbles and sand	1	0.076
North Gare	Sand	2	0.069
Paddy's Hole	Sand and stones	1	0.19
Paddy's Hole	Grass and stones	1	0.17
Greatham Creek Bird Hide	Mud	1	0.097
Greatham Creek Bird Hide	Mud and salt marsh	1	0.096

Table 4.6 (a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2009

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	¹⁰⁶ Ru
Marine samples									
Flounder	Flookburgh	3			85	<0.10			<0.99
Flounder	Morecambe	4	<25	<25		<0.09	0.038	0.29	<0.93
Plaice	Flookburgh	1				<0.10			<0.84
Whiting	Morecambe	4				<0.11			<1.1
Bass	Morecambe	2				<0.11			<1.1
Whitebait	Sunderland Point	1				<0.09	<0.082		<1.1
Shrimps	Flookburgh	4			80	<0.11		0.80	<1.1
Shrimps	Morecambe	2				<0.07			<0.62
Cockles	Middleton Sands	2				<0.17			<0.56
Cockles ^b	Flookburgh	4			76	0.30	0.37	2.6	<1.2
Winkles	Red Nab Point	4				0.25			<2.1
Mussels	Morecambe	4	48	52	73	<0.10		31	<1.3
Wild fowl	Morecambe	1				<0.05			<0.55
Samphire	Cockerham Marsh	1				<0.10			<1.1
Seaweed	Half Moon Bay	2 ^E				<1.1		300	<7.1
Sediment	Half Moon Bay	2 ^E				<0.86			
Sediment	Pott's Corner	2 ^E				<0.80			
Sediment	Heysham pipelines	1 ^E				<0.38			
Sediment	Morecambe	2 ^E				<0.54			
	Central Pier								
Sediment	Red Nab Point	1 ^E				<1.3			
Sediment	Sunderland Point	4 ^E				<0.92			<6.6
Sediment	Conder Green	4 ^E				<0.76			<6.0
Sediment	Sand Gate Marsh	4 ^E				<0.87			<6.4
Seawater	Heysham Harbour	2 ^E		1300		<0.35			<2.6

Material	Location	No. of sampling observations	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	<0.27	<0.10	12	<0.20	0.00065	0.0040	
Flounder	Morecambe	4	<0.24	<0.10	6.8	<0.18			
Plaice	Flookburgh	1	<0.23	<0.09	7.0	<0.15			
Whiting	Morecambe	4	<0.25	<0.11	6.0	<0.19			
Bass	Morecambe	2	<0.27	<0.10	8.4	<0.24			
Whitebait	Sunderland Point	1	<0.25	<0.10	4.4	<0.22	0.025	0.16	1.4
Shrimps	Flookburgh	4	<0.28	<0.11	5.0	<0.25	0.0037	0.023	0.42
Shrimps	Morecambe	2	<0.16	<0.07	3.3	<0.14			
Cockles	Middleton Sands	2	<0.15	<0.06	1.7	<0.15	0.16	0.96	
Cockles ^b	Flookburgh	4	<0.21	<0.07	3.3	<0.16	0.30	1.8	12
Winkles	Red Nab Point	4	0.45	<0.07	3.9	<0.16	0.33	1.9	
Mussels	Morecambe	4	<0.20	<0.09	1.3	<0.14	0.16	0.92	
Wild fowl	Morecambe	1	<0.14	<0.05	0.81	<0.14			
Samphire	Cockerham Marsh	1	<0.20	<0.10	0.89	<0.13			
Seaweed	Half Moon Bay	2 ^E	<1.9	<0.80	4.5				
Sediment	Half Moon Bay	2 ^E			30		3.1	19	
Sediment	Pott's Corner	2 ^E			21				
Sediment	Heysham pipelines	1 ^E			22				
Sediment	Morecambe	2 ^E			3.3				
	Central Pier								
Sediment	Red Nab Point	1 ^E			19				
Sediment	Sunderland Point	4 ^E	<2.6	<0.78	77	<1.6			
Sediment	Conder Green	4 ^E	<2.4	<0.69	86	<1.5			
Sediment	Sand Gate Marsh	4 ^E	<2.5	<0.76	51	<1.4			
Seawater	Half Moon Bay	1		*	0.12				
Seawater	Heysham Harbour	2 ^E		<0.27	<0.30				

Table 4.6 (a). continued

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples							
Flounder	Flookburgh	3	0.0075	*	*		
Flounder	Morecambe	4	<0.13				
Plaice	Flookburgh	1	<0.09				
Whiting	Morecambe	4	<0.15				
Bass	Morecambe	2	<0.23				
Whitebait	Sunderland Point	1	0.25	*	*		
Shrimps	Flookburgh	4	0.037	*	*		
Shrimps	Morecambe	2	<0.14				
Cockles	Middleton Sands	2	3.1	*	*		
Cockles ^b	Flookburgh	4	5.4	*	0.0063		
Winkles	Red Nab Point	4	3.6	*	0.0042		
Mussels	Morecambe	4	1.8	*	0.0014		
Wild fowl	Morecambe	1	<0.13				
Samphire	Cockerham Marsh	1	0.35				23
Seaweed	Half Moon Bay	2 ^E	<1.0				
Sediment	Half Moon Bay	2 ^E	36				
Sediment	Pott's Corner	2 ^E	11				
Sediment	Heysham pipelines	1 ^E	20				
Sediment	Morecambe	2 ^E	<0.89				
	Central Pier						
Sediment	Red Nab Point	1 ^E	20				
Sediment	Sunderland Point	4 ^E	61			320	700
Sediment	Conder Green	4 ^E	76			290	610
Sediment	Sand Gate Marsh	4 ^E	39			<150	690
Seawater	Heysham Harbour	2 ^E	<0.41			<2.5	20

Material	Location or selection ^c	No. of sampling observations ^d	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					Gross alpha	Gross beta	
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	¹³⁷ Cs			
Terrestrial samples										
Milk	max	7	<4.3	16	<0.28	<0.18	<0.20			
Milk			<4.5	18	0.33	<0.23				
Apples		1	<4.0	8.0	<0.20	<0.20	<0.20			
Blackberries		1	<4.0	16	0.20	<0.20	<0.20			
Cabbage		1	<4.0	4.0	<0.30	<0.20	<0.20			
Honey		1	<6.0	75	<0.20	<0.20	<0.20			
Onions		1	<4.0	13	0.20	<0.20	<0.20			
Potatoes		1	<4.0	12	0.20	<0.20	<0.20			
Sprouts		1	<4.0	15	1.4	<0.20	<0.20			
Wheat		1	<7.0	94	0.90	<0.30	<0.30			
Freshwater	Lancaster	2 ^E	<4.0		<0.75	<0.34	<0.30	<0.030	<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 ²¹⁰Po was 14 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, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass	1	0.084
Sand Gate Marsh	Grass and mud	1	0.085
Sand Gate Marsh	Grass	3	0.085
High Foulshaw	Grass	4	0.081
Arnside 1	Mud	2	0.088
Arnside 1	Mud and sand	1	0.087
Arnside 1	Grass	1	0.090
Arnside 2	Grass	4	0.10
Morecambe Central Pier	Sand	2	0.074
Half Moon Bay	Rock and sand	1	0.083
Half Moon Bay	Rock and shells	1	0.088
Heysham pipelines	Sand	1	0.073
Red Nab Point	Sand and stones	1	0.085
Middleton Sands	Sand	2	0.076
Sunderland	Salt marsh	4	0.098
Sunderland Point	Mud	2	0.10
Sunderland Point	Mud and salt marsh	2	0.10
Colloway Marsh	Salt marsh	2	0.14
Colloway Marsh	Grass	2	0.14
Lancaster	Grass	4	0.084
Aldcliffe Marsh	Grass and mud	2	0.12
Aldcliffe Marsh	Grass	2	0.11
Conder Green	Mud	1	0.095
Conder Green	Salt marsh	1	0.092
Conder Green	Grass and mud	1	0.098
Conder Green	Grass	1	0.088

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2009

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	¹³⁴ Cs
Marine samples										
Cod	Stolford	1	200	200	31	<0.15	<0.13			<0.14
Bass	Stolford	1	89	150	31	<0.11	<0.11			<0.10
Shrimps	Stolford	2	110	110	25	<0.12	<0.12			<0.12
Limpets	Stolford	1		<25	19	<0.16	<0.16			<0.16
Porphyra	Stolford	2				<0.06	<0.06			<0.06
Seaweed	Pipeline	2 ^E					<0.78		9.0	<0.55
Beetroot ^d	Stolford	1			10	<0.14	<0.13			<0.14
Potatoes ^d	Stolford	1			17	<0.04	<0.05			<0.04
Soil ^d	Stolford	1			9.2	<0.62	<0.53			<0.76
Mud	Watchet Harbour	2 ^E					<0.66	<1.0		
Sediment	Pipeline	2 ^E					<1.1	<1.0		
Sediment	Stolford	2 ^E					<1.8	<1.5		
Sediment	Stearl Flats	2 ^E					<0.90	<1.5		
Sediment	River Parrett	2 ^E					<1.5	<1.5		
Sediment	Weston-Super-Mare	2 ^E					<0.72	<2.0		
Sediment	Burnham-On-Sea	2 ^E					<0.58	<1.0		
Sediment	Kilve	2 ^E					<0.65	<1.0		
Sediment	Blue Anchor Bay	2 ^E					<0.63	<1.5		
Seawater	Pipeline	2 ^E					<0.40	<0.035		<0.28

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	Gross alpha	Gross beta
Marine samples										
Cod	Stolford	1	0.66			<0.10				
Bass	Stolford	1	1.1			<0.08				
Shrimps	Stolford	2	0.33	0.00021	0.00091	0.00076	0.00011	*		
Limpets	Stolford	1	<0.16			<0.11				
<i>Porphyra</i>	Stolford	2	0.57			<0.11				
Seaweed	Pipeline	2 ^E	<0.69			<0.79				
Beetroot ^d	Stolford	1	<0.11			<0.09				
Potatoes ^d	Stolford	1	<0.03			<0.03				
Soil ^d	Stolford	1	6.5			<0.59				
Mud	Watchet Harbour	2 ^E	5.4			<1.0				
Sediment	Pipeline	2 ^E	11			<1.2				
Sediment	Stolford	2 ^E	27			<1.8				
Sediment	Stearl Flats	2 ^E	7.7			<1.1				
Sediment	River Parrett	2 ^E	28			<1.8				
Sediment	Weston-Super-Mare	2 ^E	<2.1			<0.92				
Sediment	Burnham-On-Sea	2 ^E	4.0			<0.84				
Sediment	Kilve	2 ^E	5.8			<1.1				
Sediment	Blue Anchor Bay	2 ^E	5.3			<0.85				
Seawater	Pipeline	2 ^E	<0.33			<0.39			<3.5	14

Table 4.7(a). continued

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	¹³⁷ Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk	max	6	<4.5	17	<0.33	<0.17	<0.20		
Milk			<5.3	18	<0.45	<0.20			
Apples		1	<4.0	12	<0.20	<0.20	<0.20		
Blackberries		1	<4.0	18	0.60	<0.20	<0.20		
Carrots		1	<4.0	6.0	<0.10	<0.20	<0.20		
Lettuce		1	<4.0	5.0	0.40	<0.20	<0.20		
Potatoes		1	<5.0	16	0.30	<0.10	<0.20		
Runner beans		1	<4.0	7.0	0.40	<0.30	<0.30		
Spinach		1	<4.0	<3.0	0.80	<0.20	<0.30		
Wheat		1	<8.0	89	1.0	<0.30	<0.20		
Freshwater	Durleigh Reservoir	2 ^E	<4.0		<1.4	<0.45	<0.34	<0.065	0.20
Freshwater	Ashford Reservoir	2 ^E	<4.0		<1.3	<0.32	<0.25	<0.035	<0.11

* Not detected by the method used

^a Except for milk and water where units are Bq l⁻¹ and for sediment and soil where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

^d Used to determine sea to land transfer

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

Table 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2009

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	0.069
Burnham	Mud and sand	2	0.062
Burnham	Sand	2	0.068
River Parrett	Mud	2	0.083
River Parrett	Mud and stones	2	0.075
Stearth Flats	Mud	3	0.080
Stearth Flats	Mud and pebbles	1	0.080
Stolford	Mud	1	0.12
Stolford	Mud and rock	3	0.090
Hinkley Point	Mud	1	0.10
Hinkley Point	Mud and rock	2	0.099
Hinkley Point	Pebbles and rock	1	0.10
Kilve	Mud and sand	1	0.091
Kilve	Mud and rock	2	0.093
Kilve	Rock and sand	1	0.11
Watchet Harbour	Mud	1	0.092
Watchet Harbour	Mud and sand	2	0.090
Watchet Harbour	Pebbles and rock	1	0.090
Blue Anchor Bay	Mud	1	0.089
Blue Anchor Bay	Mud and sand	2	0.083
Blue Anchor Bay	Pebbles and sand	1	0.091

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			³ H	¹⁴ C	¹³⁷ Cs	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu
Marine samples							
Cod	Sizewell	2	<25		0.32		
Sole	Sizewell	1	<25		0.09		
Skates / rays	Sizewell	1	<25		0.27		
Crabs	Sizewell	2		38	<0.09	0.000079	0.00043
Lobsters	Sizewell	1			0.16	0.000031	0.00032
Pacific oysters	Butley Creek	1			<0.04		
Pacific oysters	Blyth Estuary	1			<0.08		
Mussels	River Alde	2	<25		<0.13		
Sediment	Rifle range	2 ^E			<0.56		
Sediment	Aldeburgh	2 ^E			<0.41		
Sediment	Southwold	2 ^E			8.4		
Seawater	Sizewell	2 ^E	<4.0		<0.27		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples							
Cod	Sizewell	2	<0.12				
Sole	Sizewell	1	<0.22				
Skates / rays	Sizewell	1	<0.04				
Crabs	Sizewell	2	0.00085	*	*		
Lobsters	Sizewell	1	0.0011	*	0.000045		
Pacific oysters	Butley Creek	1	<0.04				
Pacific oysters	Blyth Estuary	1	<0.07				
Mussels	River Alde	2	<0.11				
Sediment	Rifle range	2 ^E	<0.69				
Sediment	Aldeburgh	2 ^E	<0.65				
Sediment	Southwold	2 ^E	<1.1				900
Seawater	Sizewell	2 ^E	<0.35			<3.5	18

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	³⁵ S	¹³¹ I	¹³⁷ Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<4.6	16	<0.28		<0.20		
Milk		max	<5.3	19	<0.40				
Milk ^d		2				<0.56			
Milk ^d		max				<0.67			
Milk ^e		2				<0.38			
Milk ^e		max				<0.44			
Apples		1	<4.0	11	<0.20		<0.20		
Blackberries		1	<4.0	14	0.30		<0.20		
Cabbage		1	<4.0	9.0	0.30		<0.20		
Honey		1	6.0	72	<0.20		<0.20		
Onions		1	<4.0	14	0.30		<0.20		
Potatoes		1	<4.0	19	0.50		<0.20		
Runner beans		1	<4.0	5.0	<0.20		<0.20		
Wheat		1	<7.0	88	1.1		<0.30		
Freshwater	Nature Reserve	2 ^E	<4.0		<1.0		<0.29	<0.060	
Freshwater	The Meare	2 ^E	<4.0		<1.0		<0.32	<0.035	
Freshwater	Leisure Park	2 ^E	<4.0		<1.0		<0.28	<0.030	

* Not detected by the method used.

^a Except for milk and water where units are Bq l⁻¹, and for sediment where dry concentrations apply.

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

^d Additional analysis 14 September 2009

^e Additional analysis 21 September 2009

^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, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shale	1	0.055
Sizewell Beach	Sand and shingle	1	0.057
Dunwich	Sand and shingle	2	0.053
Rifle Range	Sand and shingle	2	0.056
Aldeburgh	Sand and shingle	2	0.055
Southwold Harbour	Mud	2	0.072

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	⁶⁰ Co	⁶⁵ Zn	⁹⁰ Sr	⁹⁵ Zr	⁹⁹ Tc
Marine samples									
Flounder	Inner Solway	4		15	<0.10	<0.24	<0.10	<0.35	0.43
Salmon	Inner Solway	1	<5.0		<0.10	<0.15		<0.13	
Trout	Inner Solway	1	<5.0		<0.10	<0.14		<0.11	
Shrimps	Inner Solway	2	<5.5		<0.10	<0.17	<0.10	<0.16	1.5
Cockles	North Solway	1			0.77	<0.26		<0.23	
Mussels	North Solway	4	<5.0	51	0.21	<0.18	0.26	<0.17	58
Winkles	Southernness	4	<5.0		<0.26	<0.27	0.23	<0.27	32
<i>Fucus vesiculosus</i>	Pipeline	4			0.15	<0.16		<0.22	81
<i>Fucus vesiculosus</i>	Brownhouses	4			0.30	<0.21		<0.25	
Sediment	Pipeline	4	<5.0		1.5	<0.45		<0.70	
Sediment	Southernness	1			0.26	<0.22		<0.13	
Seawater	Pipeline	4	3.0		<0.10	<0.13		<0.13	
Seawater	Southernness	4	4.4		<0.10	<0.13		<0.13	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			¹⁰⁶ Ru	^{110m} Ag	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs	¹⁵⁴ Eu
Marine samples								
Flounder	Inner Solway	4	<0.77	<0.13	<0.23	<0.10	13	<0.11
Salmon	Inner Solway	1	<0.42	<0.10	<0.12	<0.10	0.28	<0.10
Trout	Inner Solway	1	<0.43	<0.10	<0.12	<0.10	2.1	<0.10
Shrimps	Inner Solway	2	<0.57	<0.10	<0.15	<0.10	3.9	<0.10
Cockles	North Solway	1	<0.95	<0.15	0.24	<0.12	5.6	<0.14
Mussels	North Solway	4	<0.65	<0.11	<0.23	<0.10	1.7	<0.11
Winkles	Southernness	4	<1.2	<0.14	<0.24	<0.11	1.3	<0.14
<i>Fucus vesiculosus</i>	Pipeline	4	<0.46	<0.10	<0.14	<0.10	6.7	<0.10
<i>Fucus vesiculosus</i>	Brownhouses	4	<0.62	<0.12	<0.14	<0.10	12	<0.11
Sediment	Pipeline	4	2.9	<0.16	1.7	<0.12	240	0.75
Sediment	Southernness	1	<0.60	<0.10	<0.19	<0.10	25	<0.10
Seawater	Pipeline	4	<0.40	<0.10	<0.13	<0.10	<0.11	<0.10
Seawater	Southernness	4	<0.40	<0.10	<0.12	<0.10	0.17	<0.10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	Gross alpha	Gross beta
Marine samples									
Flounder	Inner Solway	4	<0.20	0.0028	0.018		0.030		
Salmon	Inner Solway	1	<0.15				<0.11		
Trout	Inner Solway	1	<0.14				<0.11		
Shrimps	Inner Solway	2	<0.14	0.0027	0.016		0.032		
Cockles	North Solway	1	<0.15	1.4	7.7		23		
Mussels	North Solway	4	<0.17	0.36	2.4	13	5.1		
Winkles	Southernness	4	<0.25	<0.27	0.34	3.5	1.1		
<i>Fucus vesiculosus</i>	Pipeline	4	<0.20	0.55	3.0		5.3	13	340
<i>Fucus vesiculosus</i>	Brownhouses	4	0.38				12	27	330
Sediment	Pipeline	4	1.4	18	91		140		
Sediment	Southernness	1	<0.24	3.2	19		34		
Seawater	Pipeline	4	<0.12				<0.10		
Seawater	Southernness	4	<0.12	<0.026	<0.028		<0.028		

Table 4.9(a). continued

Material	Location or selection ^b	No. of sampling observ- ations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Zr	⁹⁵ Nb
Terrestrial samples									
Milk		12	<6.0	<15	<0.53	<0.05	<0.10	<0.15	<0.18
Milk		max	11	20	<0.68			<0.17	
Apples		2	<5.0	19	<0.50	<0.05	<0.10	<0.06	<0.06
Apples		max		22				<0.07	<0.07
Barley		1	<5.0	53	<0.61	<0.05	0.21	<0.10	<0.08
Beef muscle		1	<5.0	25	<0.50	<0.05	<0.10	<0.08	<0.07
Cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.08	<0.07
Crab Apples		1	<5.0	17	<0.50	<0.05	0.12	<0.08	<0.08
Eggs		1	<5.0	81	<0.50	<0.05	<0.10	<0.10	<0.09
Pears		1	<5.0	16	<0.50	<0.05	0.18	<0.09	<0.06
Potatoes		1	<5.0	<15	<0.50	<0.05	<0.10	<0.07	<0.06
Rhubarb		1	<5.0	<15	<0.93	<0.05	0.23	<0.05	<0.05
Rowan berries		1	<5.0	19	<0.50	<0.05	<0.10	<0.09	<0.07
Turnips		1	<5.0	<15	<0.50	<0.05	0.14	<0.09	<0.08
Grass		4	<8.9	<20	<0.57	<0.06	0.31	<0.31	<0.52
Grass		max	12	37	<0.70	<0.08	0.64	<0.43	<0.71
Soil		4	<5.1	<15	<1.3	<0.10	0.81	<0.50	<0.90
Soil		max	5.5		<1.6	<0.12	0.97	<0.73	<1.5
Surface water		25	63						
Surface water		max	310						
Freshwater	Purdomstone	1	2.0						
Freshwater	Winterhope	1	3.1						
Freshwater	Black Esk	1	<1.1						

Material	Location or selection ^b	No. of sampling observ- ations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			¹⁰⁶ Ru	¹³⁴ Cs	¹³⁷ Cs	¹⁵⁵ Eu	²⁴¹ Am	Gross alpha	Gross beta
Terrestrial samples									
Milk		12	<0.37	<0.05	<0.05		<0.06		
Milk		max	<0.41						
Apples		2	<0.20	<0.05	<0.05		<0.06		
Apples		max	<0.25						
Barley		1	<0.32	<0.05	<0.05		<0.11		
Beef muscle		1	<0.30	<0.05	0.07		<0.09		
Cabbage		1	<0.26	<0.05	<0.05		<0.07		
Crab Apples		1	<0.24	<0.05	<0.05		<0.06		
Eggs		1	<0.31	<0.05	<0.05		<0.09		
Pears		1	<0.35	<0.05	0.05		<0.06		
Potatoes		1	<0.22	<0.05	0.09		<0.06		
Rhubarb		1	<0.23	<0.05	<0.05		<0.06		
Rowan berries		1	<0.36	<0.05	<0.05		<0.10		
Turnips		1	<0.27	<0.05	0.06		<0.07		
Grass		4	<0.54	<0.06	<0.07		<0.08	0.54	430
Grass		max	<0.76	<0.07	0.11		<0.10	0.63	470
Soil		4	<0.94	<0.12	10	0.94	<0.39	200	1100
Soil		max	<1.1	<0.14	12	1.1	<0.45	230	1200
Surface water		25			<0.10				
Freshwater	Purdomstone	1			<0.01			<0.011	0.088
Freshwater	Winterhope	1			<0.01			<0.010	0.046
Freshwater	Black Esk	1			<0.01			<0.010	0.038

^a Except for milk and water where units are Bq l⁻¹, and for sediment and soil where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

Table 4.9(b). Monitoring of radiation dose rates near Chapelcross, 2009

Location	Material or Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Southernness	Winkle bed	4	0.069
Glencaple Harbour	Mud and sand	4	0.079
Priestside Bank	Salt marsh	4	0.063
Powfoot Merse	Mud	4	0.071
Pipeline	Sand	4	0.089
Pipeline	Salt marsh	4	0.087
Battlehill	Sand	4	0.077
Dornoch Brow	Mud and sand	4	0.078
Dornoch Brow	Salt marsh	4	0.081
Browhouses	NA	4	0.092
Redkirk	NA	4	0.067
Mean beta dose rates			$\mu\text{Sv h}^{-1}$
Pipeline 500m east	NA	4	<1.0
Pipeline 500m west	NA	4	<1.0
Pipeline	Stake nets	3	<1.0

NA *Not available*

Table 4.9(c). Radioactivity in air near Chapelcross, 2009

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.010	<0.0066	<0.17
Kirtlebridge	12	<0.010	<0.0080	<0.17
Brydekirk	11	<0.010	<0.0065	<0.16

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	⁵⁴ Mn	⁶⁰ Co	⁹⁹ Tc	^{110m} Ag	¹²⁵ Sb
Marine Samples								
Cod	Millport	2		<0.10	<0.10		<0.10	<0.14
Hake	Millport	1		<0.11	<0.11		<0.14	<0.29
Crabs	Millport	2		<0.11	<0.10	3.9	<0.11	<0.19
<i>Nephrops</i>	Millport	2		<0.10	<0.10		<0.10	<0.15
Lobsters	Largs	1		<0.10	<0.10	29	<0.10	<0.20
Squat lobsters	Largs	4		<0.10	<0.11	21	<0.11	<0.23
Winkles	Pipeline	2		<0.22	<0.23		<0.22	<0.37
Scallops	Largs	2		<0.10	<0.10		<0.10	<0.20
Oysters	Hunterston	1		<0.10	<0.10		<0.10	<0.19
<i>Fucus vesiculosus</i>	N of pipeline	2		<0.20	<0.18		<0.11	<0.18
<i>Fucus vesiculosus</i>	S of pipeline	2		0.35	0.15		<0.11	<0.17
Sediment	Millport	1		<0.10	<0.10		<0.10	<0.14
Sediment	Gull's Walk	1		<0.10	<0.10		<0.10	0.28
Sediment	Ardneil Bay	1		<0.10	<0.10		<0.10	<0.13
Sediment	Fairlie	1		<0.10	<0.10		<0.10	<0.15
Seawater	Pipeline	2	5.0	<0.10	<0.10		<0.10	<0.10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			¹³⁷ Cs	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am
Marine Samples							
Cod	Millport	2	1.6	<0.14			<0.11
Hake	Millport	1	1.7	<0.29			<0.16
Crabs	Millport	2	0.32	<0.17	<0.0091	0.012	0.020
<i>Nephrops</i>	Millport	2	0.57	<0.13			<0.10
Lobsters	Largs	1	0.42	<0.20			<0.13
Squat lobsters	Largs	4	0.44	<0.21	<0.0066	0.021	0.041
Winkles	Pipeline	2	0.23	<0.29	<0.050	0.096	<0.050
Scallops	Largs	2	0.40	<0.19	0.0029	0.017	0.0072
Oysters	Hunterston	1	<0.10	<0.20			<0.11
<i>Fucus vesiculosus</i>	N of pipeline	2	0.73	<0.18			<0.12
<i>Fucus vesiculosus</i>	S of pipeline	2	0.66	<0.17			<0.26
Sediment	Millport	1	3.8	<0.20			0.21
Sediment	Gull's Walk	1	6.0	<0.26			0.65
Sediment	Ardneil Bay	1	2.4	<0.19			<0.18
Sediment	Fairlie	1	6.7	0.32			0.52
Seawater	Pipeline	2	<0.10	<0.10			<0.10

Table 4.10(a). continued

Material	Selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	⁹⁰ Sr	⁹⁵ Nb
Terrestrial Samples								
Milk	max	5	<5.0	<17	<0.56	<0.09	<0.10	<0.39
Milk				<18	<0.58	<0.14		<0.90
Beef muscle		1	<5.0	42	<0.50	<0.05	<0.10	<0.05
Carrots		1	<5.0	<15	<0.81	<0.05	<0.10	<0.07
Cauliflower		1	<5.0	<15	1.7	<0.05	<0.10	<0.07
Crab apples		1	<5.0	20	<0.50	<0.05	0.21	<0.07
Eggs		1	<5.0	22	<0.50	<0.05	<0.10	<0.05
Leeks		1	<5.0	<15	<0.63	<0.07	<0.10	<0.09
Nettles		1	<5.0	22	<0.50	<0.06	2.4	<0.12
Pheasant	max	3	<5.0	<16	<0.50	<0.05	<0.13	<0.06
Pheasant				18			0.18	<0.07
Potatoes		2	<5.0	<19	<0.50	<0.05	<0.10	<0.05
Potatoes	max			23				
Rosehips		1	<5.0	<15	<0.50	<0.05	1.2	<0.07
Rowan berries		1	<5.0	17	<0.50	<0.05	0.59	<0.07
Turnips		1	<5.0	17	<0.50	<0.05	<0.10	<0.05
Grass	max	3	<5.0	<15	<0.50	<0.12	0.57	<1.6
Grass				16		<0.13	0.81	
Soil		3	<5.0	<15	<1.6	<0.06	0.92	<0.86
Soil	max				<2.2	<0.07	1.6	<1.1
Freshwater	Knockenden	1	<1.1					
Freshwater	Loch Ascog	1	<1.3					
Freshwater	Munnoch Reservoir	1	<1.3					
Freshwater	Camphill	1	<1.2					
Freshwater	Outerwards	1	<1.1					

Material	Selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			^{110m} Ag	¹³⁷ Cs	¹⁵⁵ Eu	²⁴¹ Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		5	<0.07	<0.07		<0.08		
Milk		max	<0.16	<0.16		<0.19		
Beef muscle		1	<0.05	0.16		<0.09		
Carrots		1	<0.05	0.10		<0.08		
Cauliflower		1	<0.05	<0.05		<0.10		
Crab apples		1	<0.05	<0.05		<0.12		
Eggs		1	<0.05	<0.05		<0.06		
Leeks		1	<0.06	<0.06		<0.16		
Nettles		1	<0.05	0.08		<0.15		
Pheasant		3	<0.06	0.71		<0.10		
Pheasant		max	<0.08	1.1		<0.13		
Potatoes		2	<0.05	<0.08		<0.07		
Potatoes		max		0.10		<0.08		
Rosehips		1	<0.05	0.08		<0.09		
Rowan berries		1	<0.05	<0.05		<0.11		
Turnips		1	<0.05	<0.05		<0.05		
Grass		3	<0.14	0.74		<0.16	0.63	330
Grass		max	<0.15	1.3		<0.17	0.87	380
Soil		3	<0.10	13	0.49	<0.20	130	640
Soil		max	<0.12	17	0.54	<0.22	150	950
Freshwater	Knockenden	1		<0.01			<0.010	0.022
Freshwater	Loch Ascog	1		<0.01			<0.010	0.12
Freshwater	Munnoch Reservoir	1		<0.01			<0.010	0.053
Freshwater	Camphill	1		<0.01			<0.010	0.019
Freshwater	Outerwards	1		<0.01			<0.010	0.017

^a Except for milk and water where units are Bq l⁻¹ and for sediment and soil where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

Table 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	Stones	2	0.059
Kilchatten Bay	Sand	2	0.053
Millport	Sand	2	0.049
Gulls Walk	Mud	2	0.057
0.5 km north of pipeline	Sand	2	0.065
0.5 km south of pipeline	Sand and stones	2	0.061
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	0.051
Beta dose rates			
Millport	Sand	1	$\mu\text{Sv h}^{-1}$ <1.0
Fairlie	Sand	1	<1.0

NA Not available

Table 4.10(c). Radioactivity in air near Hunterston, 2009

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	9	<0.010	<0.0072	<0.16
West Kilbride	12	<0.010	<0.0066	<0.16
Crosbie Mains	7	<0.012	<0.0051	<0.13
Low Ballees	3	<0.010	<0.0076	<0.20

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			³ H	¹⁴ C	⁵⁴ Mn	⁶⁰ Co	⁹⁹ Tc	^{110m} Ag
Marine Samples								
Cod	White Sands	2			<0.10	<0.10		<0.10
Bass	Pipeline	1			<0.12	<0.12		<0.13
Crabs	Cove	2		20	<0.10	<0.10	0.54	<0.10
Lobsters	Cove	1			<0.10	<0.10	1.6	<0.10
<i>Nephrops</i>	Dunbar	2			<0.10	<0.10		<0.12
Winkles	Pipeline	2			<0.14	0.23		6.2
<i>Fucus vesiculosus</i>	Pipeline	2			0.99	<0.56		<1.4
<i>Fucus vesiculosus</i>	Thornton Loch	2			<0.21	<0.16	78	<0.10
<i>Fucus vesiculosus</i>	White Sands	2			<0.10	<0.10		<0.10
<i>Fucus vesiculosus</i>	Pease Bay	2			<0.11	<0.10		<0.10
<i>Fucus vesiculosus</i>	Coldingham Bay	2			<0.10	<0.10		<0.10
Sediment	Dunbar	1			<0.10	<0.10		<0.14
Sediment	Barns Ness	1			<0.10	<0.10		<0.10
Sediment	Thornton Loch	1			<0.10	<0.10		<0.10
Sediment	Heckies Hole	1			<0.10	<0.10		<0.10
Sediment	Eyemouth	1			<0.10	<0.10		<0.10
Salt marsh	Belhaven Bay	1			<0.10	<0.10		<0.10
Seawater	Pipeline	2	<11		<0.10	<0.10		<0.10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			¹³⁷ Cs	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	Gross alpha	Gross beta
Marine Samples									
Cod	White Sands	2	0.39	<0.17			<0.14		
Bass	Pipeline	1	0.65	<0.25			<0.15		
Crabs	Cove	2	<0.14	<0.15			<0.11		
Lobsters	Cove	1	<0.10	<0.16			<0.10		
<i>Nephrops</i>	Dunbar	2	0.21	<0.21	<0.050	<0.050	0.073		
Winkles	Pipeline	2	<0.20	<0.24			<0.14	<3.5	120
<i>Fucus vesiculosus</i>	Pipeline	2	0.23	<0.19			<0.22		
<i>Fucus vesiculosus</i>	Thornton Loch	2	0.13	<0.10			<0.10		
<i>Fucus vesiculosus</i>	White Sands	2	0.13	<0.18			<0.11		
<i>Fucus vesiculosus</i>	Pease Bay	2	<0.10	<0.19			<0.12		
<i>Fucus vesiculosus</i>	Coldingham Bay	2	<0.10	<0.13			<0.10		
Sediment	Dunbar	1	3.7	<0.37			<0.39		
Sediment	Barns Ness	1	1.2	<0.15			<0.24		
Sediment	Thornton Loch	1	0.94	0.24			<0.16		
Sediment	Heckies Hole	1	6.0	<0.28			<0.30		
Sediment	Eyemouth	1	1.6	<0.15			<0.22		
Salt marsh	Belhaven Bay	1	0.53	0.25			<0.18		
Seawater	Pipeline	2	<0.10	<0.12			<0.10		

Table 4.11(a). continued

Material	Selection ^b	No. of sampling observations ^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	<5.1	<16	<0.50	<0.05	<0.10	<0.18
Goats' milk		1	<5.0	<15	<0.50	<0.05	<0.10	<0.08
Barley		1	<5.0	69	<0.50	<0.05	0.18	<0.14
Broad beans		1	<5.0	17	<0.50	<0.05	<0.10	<0.05
Beetroot		1	<5.0	20	<0.50	<0.07	0.14	<0.09
Broccoli		1	<5.0	<15	<0.50	<0.05	<0.10	<0.06
Celery		1	<5.0	<15	<0.50	<0.05	0.12	<0.05
Crab apples		1	<5.0	19	<0.50	<0.50	<0.10	<0.07
Nettles		1	<5.0	18	<13	<0.05	1.1	<0.20
Potatoes		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Rosehips		1	<5.0	17	<0.50	<0.05	0.39	<0.06
Rowan berries		1	23	36	<0.50	<0.05	0.17	<0.06
Sprouts		1	<5.0	<15	<0.50	<0.05	0.13	<0.05
Swede		1	<5.0	<15	<2.5	<0.05	0.15	<0.23
Wood pigeon		1	<5.0	26	<0.53	<0.05	<0.10	<0.06
Grass		3	<5.0	<20	<0.52	<0.09	0.28	<0.73
Grass	max			23	<0.57	<0.10	0.50	<0.85
Soil		3	<5.0	<18	<2.5	<0.06	1.3	<0.49
Soil	max			<24	<3.1		1.9	<0.60
Freshwater	Boreholes	7	40					
Freshwater	max		180					
Freshwater	Hopes Reservoir	1	<1.2					
Freshwater	Thorters Reservoir	1	<1.2					
Freshwater	Whiteadder	1	<1.2					

Material	Selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹					
			^{110m} Ag	¹³⁷ Cs	¹⁵⁵ Eu	²⁴¹ Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		1	<0.05	<0.05		<0.06		
Goats' milk		1	<0.05	<0.05		<0.06		
Barley		1	<0.05	<0.05		<0.13		
Broad beans		1	<0.05	<0.05		<0.05		
Beetroot		1	<0.06	<0.06		<0.09		
Broccoli		1	<0.05	<0.05		<0.08		
Celery		1	<0.05	0.11		<0.06		
Crab apples		1	<0.05	<0.05		<0.07		
Nettles		1	<0.05	0.09		<0.11		
Potatoes		1	<0.05	<0.05		<0.07		
Rosehips		1	<0.05	0.13		<0.09		
Rowan berries		1	<0.05	<0.05		<0.08		
Sprouts		1	<0.05	<0.05		<0.07		
Swede		1	<0.05	<0.05		<0.12		
Wood pigeon		1	<0.05	0.06		<0.09		
Grass		3	<0.10	<0.08		<0.13	<0.68	480
Grass	max		<0.12	<0.09		<0.15	1.2	570
Soil		3	<0.10	9.2	1.6	<0.26	260	1000
Soil	max		<0.11	17	1.9	<0.29	280	1100
Freshwater	Boreholes	7		<0.10			<0.080	1.7
Freshwater	max						0.15	7.2
Freshwater	Hopes Reservoir	1		<0.01			0.016	0.031
Freshwater	Thorters Reservoir	1		<0.01			<0.010	0.038
Freshwater	Whiteadder	1		<0.01			<0.010	0.042

^a Except for milk and water where units are Bq l⁻¹ and for sediment and soil where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

Table 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Sediment	2	0.056
Dunbar Inner Harbour	Sand	2	0.072
Belhaven Bay	Salt marsh	2	0.053
Barns Ness	Mud, sand and stones	2	0.055
Skateraw	Sand	2	0.051
Thornton Loch	Sand	2	0.056
Pease Bay	Sand	2	0.072
St Abbs Head	Mud	2	0.098
Coldingham Bay	Sand	2	0.058
Eyemouth	Mud	2	0.069
Mean beta dose rates on fishing gear			$\mu\text{Sv h}^{-1}$
Cove	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2009

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	11	<0.010	<0.0067	<0.16
Cockburnspath	10	<0.011	<0.0078	<0.17

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	³⁵ S	⁶⁰ Co	⁹⁰ Sr	¹³⁴ Cs	¹³⁷ Cs	¹⁵⁴ Eu
Freshwater samples									
Brown trout ^b	Trawsfynydd Lake	6			<0.19	1.0	<0.18	43	<0.58
Rainbow trout	Trawsfynydd Lake	6			<0.14		<0.15	6.8	<0.44
Perch	Trawsfynydd Lake	6			<0.31	0.70	<0.30	60	<0.90
Rudd	Trawsfynydd Lake	1			<0.22		<0.21	74	<0.65
Sediment	Lake shore	2 ^E			<1.0	<2.0	<1.0	320	
Sediment	Bailey Bridge	2 ^E			<1.8	6.0	<1.8	1100	
Sediment	Fish farm	2 ^E			<1.5	<1.0	<1.3	480	
Sediment	Footbridge	2 ^E			<0.70	<2.0	<0.72	360	
Sediment	Cae Adda	2 ^E			<0.64	<2.0	<0.59	160	
Freshwater	Public supply	2 ^E	<4.0	<0.90	<0.34		<0.28	<0.28	
Freshwater	Gwylan Stream	2 ^E	<4.5	<0.90	<0.33		<0.26	<0.26	
Freshwater	Hot Lagoon	2 ^E	<4.5	<0.75	<0.32		<0.26	<0.25	
Freshwater	Afon Prysor	2 ^E	<4.0	<0.80	<0.30		<0.24	<0.25	
Freshwater	Trawsfynydd Lake	2 ^E	<4.0	<0.80	<0.13		<0.11	<0.11	
Freshwater	Afon Tafarn-helyg	2 ^E	<4.0	<0.80	<0.32		<0.23	<0.26	

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	Gross alpha	Gross beta
Freshwater samples									
Brown trout ^b	Trawsfynydd Lake	6	0.00010	0.00033	0.00055	*	0.000016		
Rainbow trout	Trawsfynydd Lake	6			<0.24				
Perch	Trawsfynydd Lake	6	0.000054	0.00029	0.00058	*	*		
Rudd	Trawsfynydd Lake	1			<0.19				
Sediment	Lake shore	2 ^E	<1.3	0.91	1.9				
Sediment	Bailey Bridge	2 ^E	2.8	9.4	16				
Sediment	Fish farm	2 ^E	1.6	4.1	7.8				
Sediment	Footbridge	2 ^E	<0.69	0.86	1.9				
Sediment	Cae Adda	2 ^E	<1.3	<1.2	<2.3				
Freshwater	Public supply	2 ^E						<0.030	<0.10
Freshwater	Gwylan Stream	2 ^E						<0.025	<0.10
Freshwater	Hot Lagoon	2 ^E						<0.020	<0.10
Freshwater	Afon Prysor	2 ^E						<0.025	<0.10
Freshwater	Trawsfynydd Lake	2 ^E						<0.045	<0.10
Freshwater	Afon Tafarn-helyg	2 ^E						<0.020	<0.095

Table 4.12(a). continued

Material	Selection ^c	No. of sampling observations ^d	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs
Terrestrial Samples							
Milk	max	3	<4.1	18	<0.21	0.037	
Milk			<4.5	20	<0.23	0.065	
Blackberries		1	<4.0	16	<0.20		0.20
Eggs		1	<6.0	38	<0.20		<0.20
Marrow		1	<4.0	4.0	<0.20		<0.20
Potatoes		1	<4.0	23	<0.20		0.30
Runner beans		1	<4.0	5.0	<0.20		<0.20
Sheep muscle		2	<7.0	26	<0.20	<0.016	
Sheep muscle	max			27		0.023	
Sheep liver		1	<7.0	54	<0.20	0.071	
Sheep offal		1	<8.0	26	<0.20	0.47	
Turnips		1	<4.0	10	<0.10		0.20

Material	Selection ^c	No. of sampling observations ^d	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹			
			Total Cs	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am
Terrestrial Samples						
Milk	max	3	0.13			
Milk			0.15			
Blackberries		1		<0.00020	<0.00020	<0.00040
Eggs		1		<0.00010	<0.00010	0.00080
Marrow		1				
Potatoes		1		<0.00010	0.00030	<0.00030
Runner beans		1		<0.00010	0.00020	<0.00030
Sheep muscle		2	0.48	<0.00015	<0.00015	<0.00040
Sheep muscle	max		0.57	<0.00020	<0.00020	0.00050
Sheep liver		1	0.53	<0.00040	<0.00050	0.00050
Sheep offal		1	0.83	<0.00020	<0.00030	0.00080
Turnips		1		<0.00010	<0.00030	0.00040

* 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 ¹⁴C was 40 Bq kg⁻¹

^c Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

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

Table 4.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2009

Location	Ground type	No. of sampling observations	µGy h ⁻¹
Mean gamma dose rates at 1m over substrate			
Footbridge	Rock and stones	1	0.10
Footbridge	Pebbles	1	0.093
Lake shore	Pebbles	1	0.093
Lake shore	Pebbles and stones	1	0.11
Bailey Bridge	Grass	1	0.065
Bailey Bridge	Grass and stones	1	0.087
Fish Farm	Stones	1	0.097
Fish Farm	Rock and stones	1	0.11
Cae Adda	Mud and sand	1	0.099
Cae Adda	Pebbles	1	0.084

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2009

Material	Location	No. of sampling observations	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	41		<0.20	1.2	
Bass	Outfall	1					<0.17	3.9	
Crabs	Pipeline	2				0.75	<0.12	0.39	0.0028
Lobsters	Pipeline	2				39	<0.18	0.64	
Winkles	Cemaes Bay	2	<32	<25	37		<0.11	0.53	0.036
Seaweed	Cemaes Bay	2 ^E				48	<1.2	<0.61	
Sediment	Cemaes Bay	2 ^E						3.7	
Sediment	Cemlyn Bay	2 ^E						2.7	
	West								
Seawater	Cemaes Bay	2 ^E		<4.0				<0.29	
Seawater	Cemlyn Bay	2 ^E						<0.28	
	West								
Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Marine samples									
Plaice	Pipeline	2			<0.08				
Bass	Outfall	1			<0.07				
Crabs	Pipeline	2	0.018		0.069	*	0.000090		
Lobsters	Pipeline	2			<0.16				140
Winkles	Cemaes Bay	2	0.22	2.1	0.31	*	0.00030		
Seaweed	Cemaes Bay	2 ^E			<0.79				
Sediment	Cemaes Bay	2 ^E			<1.3				
Sediment	Cemlyn Bay	2 ^E			<0.83				
	West								
Seawater	Cemaes Bay	2 ^E			<0.41			<3.5	12
Seawater	Cemlyn Bay	2 ^E			<0.41			<3.5	18
	West								
Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			³ H	¹⁴ C	³⁵ S	¹³⁷ Cs	Gross alpha	Gross beta	
Terrestrial samples									
Milk	max	5	<4.3	18	<0.44	<0.20			
Milk			<4.5	20	0.58				
Apples		1	<4.0	13	<0.10	<0.20			
Barley		1	<7.0	89	1.9	<0.20			
Beetroot		1	<4.0	6.0	<0.10	<0.20			
Blackberries		1	<4.0	17	1.1	<0.20			
Broad beans		1	<4.0	16	1.0	<0.20			
Cabbage		1	<4.0	7.0	0.40	<0.20			
Honey		1	<7.0	95	<0.20	<0.20			
Potatoes		1	<5.0	18	<0.10	<0.20			
Freshwater	Public supply	1 ^E	<4.0		<0.60	<0.29	<0.030	0.20	

* 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

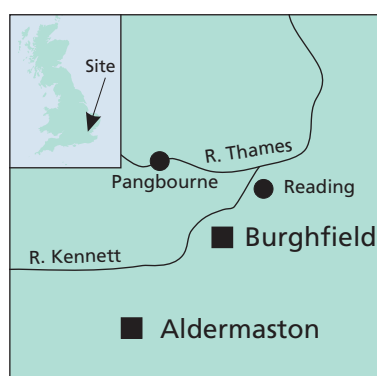
Table 4.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	2	0.065
Cemlyn Bay West	Pebbles and sand	1	0.076
Cemlyn Bay West	Pebbles	1	0.068

5. Defence establishments

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and SEPA undertaken routinely near nine defence-related establishments in the UK. In addition, the MoD makes arrangements for monitoring at other defence sites where contamination may occur. Low level gaseous discharges occur from Burghfield in Berkshire and the operator carries out environmental monitoring at this site. Monitoring at nuclear submarine berths is also conducted by the MoD (DSTL Radiological Protection Services, 2009).

5.1 Aldermaston, Berkshire



The Atomic Weapons Establishment (AWE) at Aldermaston provides and maintains fundamental components of the UK's nuclear deterrent on behalf of the MoD. The site is regulated by the Environment Agency to discharge low

concentrations of radioactive waste to the environment. Aqueous radioactive waste is discharged to the sewage works at Silchester and to Aldermaston Stream, location shown in Figure 3.1, and gaseous radioactive waste is discharged via stacks on the site.

Gaseous discharges and terrestrial monitoring

Gaseous discharges remained low (Table A2.1), though there was an increase in the levels of carbon-14 discharged. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the site. Activity concentrations in milk and foodstuffs (Table 5.2(a)) were generally below the limits of detection, as in 2008. The tritium concentrations in two grass samples show slightly elevated levels, but they are in line with previously observed concentrations. In soil samples, concentrations of caesium-137 increased in 2009 compared with 2008 but are comparable with previous years. Levels of uranium isotopes remained similar to 2008. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Key points

- Environmental concentrations, dose rates and doses in 2009 were broadly similar to those in 2008 at all establishments
- Minor variations were made to the existing operator permit at Devonport

Aldermaston, Berkshire

- Discharges, concentrations and dose rates in 2009 were generally similar to those in 2008
- Radiation doses from all sources were less than 0.5 per cent of the dose limit

Devonport, Devon

- Discharges increased in 2009 due to submarine maintenance work but remained below permitted levels
- A variation to the operator permit was made including increased transfer limits and routes but discharge limits were unchanged
- A spill of active system flush water from HMS *Turbulent* onto the top of the submarine casing occurred in March 2009. There was no spillage into the Tamar Estuary
- Concentrations of radionuclides in the environment were generally below the limits of detection
- Radiation doses from all sources were less than 0.5 per cent of the dose limit

Derby, Derbyshire

- A survey of local consumers' diet and occupancy rates was carried out for the first time and used to improve dose assessments
- *Total dose* from all sources was assessed for the first time and was less than 0.5 per cent of the dose limit

Liquid waste discharges and aquatic monitoring

Alpha, beta/gamma and tritium discharges to Silchester remained at the low levels reported in 2008. The discharge of tritium to Aldermaston Stream decreased compared to 2008. There are two factors behind the longer-term decline in discharges of tritium from Aldermaston (Figure 5.1). These are the closure and decommissioning of the original tritium facility, and historical contamination of groundwater. The original tritium facility was due to be finally demolished during 2010 and the replacement facility uses sophisticated abatement

technology that results in the discharge of significantly less tritium into the environment. The historical contamination has been reduced in 2009 by radioactive decay and diluted by natural processes.

Samples of freshwater, fish and sediments were collected; sampling locations are shown in Figure 3.1. The results of measurements of radionuclide concentrations and dose rates are shown in Tables 5.2(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2008. Concentrations of tritium in freshwater samples were below the LoD. As in 2008, no enhancements of tritium were observed in sediments collected from road gullypots close to the site. Caesium-137 concentrations were again detected in sediment from the River Thames, at similar concentrations to 2008. Currently, routine discharges from AWE do not include significant concentrations of radiocaesium and AWE no longer discharges into the River Thames since the closure of the Pangbourne pipeline in 2005. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. Dose rates recorded on the riverbanks at Pangbourne and Mapledurham were similar to those recorded in 2008. Gross alpha and beta activities in freshwater samples were below the WHO screening levels for drinking water, and this pathway of exposure has been shown to be insignificant (Environment Agency, 2002a).

Doses to the public

The most recent habits survey, in 2002 (Tipple *et al.*, 2003), established that anglers are representative of the people most affected by discharges into the river. Accordingly, their occupancy of the river-bank has been assessed in order to estimate their exposure to external radiation. Although no consumption of freshwater fish was recorded during the survey, the assessment has conservatively included consumption of fish at a low rate of 1 kg per year. No pike were sampled from the outfall in 2009 and estimates of activity concentrations have been based on earlier data. The overall radiological significance of liquid discharges was very low: the radiation dose to anglers was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). Consumption of locally harvested crayfish was also considered as a pathway for radiation exposure. Exposures were much less than 0.005 mSv using consumption data from the habits survey.

The dose from consumption of local foodstuffs and milk, affected by gaseous discharges, was also calculated. The maximum dose from high-rate consumption of local food in 2009, including contributions from the natural and fallout sources, was to the 1-year-old age group (infants). This was less than 0.005 mSv. The dose from non-food pathways arising from discharges to air was also assessed using the methods and data given in Appendix 1. The dose to people most likely to be affected in 2009, including both food and non-food pathways, was less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been less than 0.005 mSv in 2009 (Table 5.1). This is less than 0.5 per cent of the dose limit. As in 2008, the most exposed people in this assessment were adults spending time on the local riverbank.

5.2 Barrow, Cumbria



During 2009, permitted discharges from Barrow continued to be very low or were below the LoD. The Food Standards Agency's monitoring is limited to grass sampling, and in 2009 tritium activity in these samples was below the LoD (Table 5.3(a)).

Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 2) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2009.

5.3 Derby, Derbyshire



Rolls-Royce Marine Power Operations Limited (RRMPOL) carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Megaloughton

Lane Sewage Treatment Works to the River Derwent and very low concentrations of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including the LLWR near Drigg.

Results of the routine monitoring programme at Derby are presented in Table 5.3(a). Analysis of uranium activity in grass and soil samples taken around the site in 2009 found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. Gross alpha and beta activities in water from the River Derwent were less than the WHO screening levels for drinking water, and the dose from using the river as a source of drinking water would be much less than 0.005 mSv per year (Table 5.1).

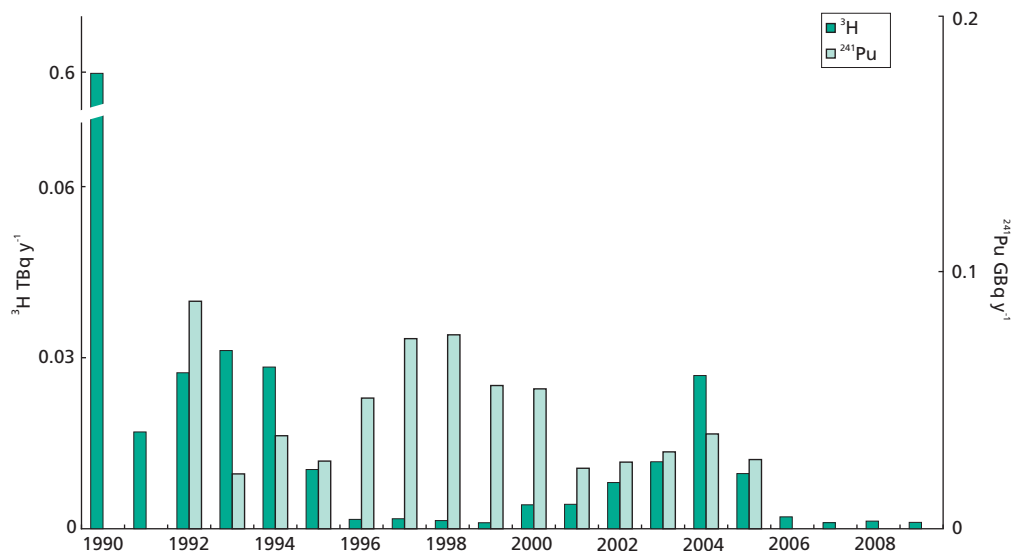


Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2009 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

Table 5.3(a) also includes analysis results from a water sample taken from Fritchley Brook, downstream of Hilts Quarry. RRMPOl formerly used the quarry for the controlled burial of solid low level radioactive waste. Uranium isotopes detected in the sample were at levels similar to those elsewhere in Derbyshire (Table 8.14).

Doses to the public

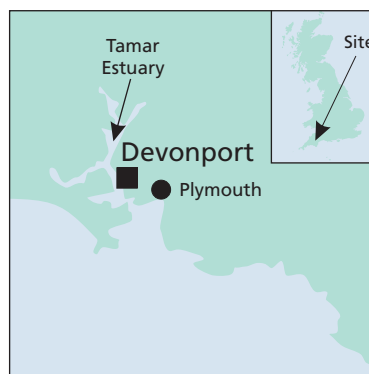
During September 2009, for the first time, a habits survey was conducted to determine the consumption and occupancy rates by members of the public likely to be affected by the operations of the site.

The habits survey established the consumption and occupancy rates of people likely to receive the highest dose (see Appendix 1). In 2009 the estimated dose to people consuming fish and drinking river water was less than 0.005 mSv (Table 5.1) which was less than 0.5 per cent of the dose limit.

Local residents who are exposed to external and inhalation pathways from gaseous discharges also received a dose of less than 0.005 mSv (Table 5.1).

The *total dose* from all sources including direct radiation was assessed at Derby for the first time, using data from the habits survey conducted in 2009. Based on a limited amount of monitoring data with which to perform the assessment, the dose in 2009 was estimated to be less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. The most exposed people were infants consuming water extracted from the river. Although this pathway was not quantified during the habits survey, it has been included in the *total dose* assessment as river water is known to be extracted.

5.4 Devonport, Devon



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

powered submarines and has a permit granted by the Environment Agency to discharge liquid radioactive waste to the Hamoaze, which is part of the Tamar Estuary, and to the local sewer, and gaseous waste to the atmosphere. A variation to the operator permit was made in 2009 which including increased transfer limits and routes, but discharge limits were unchanged. The routine monitoring programme in 2009 consisted of measurements of gamma dose rate and analysis of fruit, vegetables, fish, shellfish and other marine indicator materials (Tables 5.3(a) and (b)).

In March 2009, a few litres of water used to flush an active system on HMS Turbulent were spilt onto the top of the submarine's casing. This water was cleared up by Naval Base operators so that none entered the Tamar Estuary. Samples of materials used to absorb the spill and filter paper wipes were analysed by the site and by the Environment Agency for gamma emitting radionuclides and tritium. A small amount of tritium was detected in the paper used to absorb the spillage and trace amounts of cobalt-60 were detected in the paper and one of the filter paper wipes. There was no significant hazard to people or the environment.

Gaseous discharges and terrestrial monitoring

Particulate beta/gamma, tritium, carbon-14 and argon-41 are permitted to be discharged to the atmosphere. The amount of carbon-14 discharged increased in 2009 due to the Primary Circuit Decontamination of the Vanguard class submarine currently being re-fitted at Devonport. Almost all of Devonport's gaseous carbon-14 discharge results from this process. Samples of fruit and vegetables were analysed for a number of radionuclides, including carbon-14. Concentrations of carbon-14 were slightly enhanced above expected natural concentrations in lettuce and courgettes (Table 5.3(a)), although there is uncertainty over natural background levels in particular foods. The results remain of low radiological significance, and concentrations of other radionuclides were below the limits of detection in all terrestrial foods.

Liquid waste discharges and marine monitoring

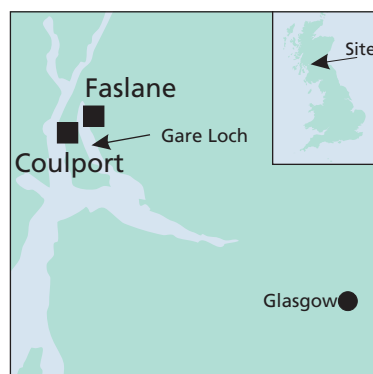
The amount of tritium and carbon-14 discharged to the Hamoaze increased compared to 2008 due to the submarine refit and other maintenance work taking place. Figure 5.2 shows the discharge history of tritium and cobalt-60 since 1990. Vanguard class submarines have a higher tritium inventory in their primary circuit as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. Concentrations of these nuclides and others were below limits of detection for the vast majority of marine samples. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapons test fallout, were measured in fish samples. An increased concentration of americium-241 was measured in sediment, and the technetium-99 level in seaweed had also increased compared to 2008. These isolated results are unlikely to be related to activities or discharges from Devonport. Gamma dose rates in the vicinity of Devonport were similar to 2008.

Doses to the public

The most recent habits survey in 2004 (Tipple *et al.*, 2005) established that people who are likely to be the most exposed to radiation from the site are fish and shellfish consumers and occupants of houseboats. Taking account of relevant consumption of marine foods and occupancy times, doses from both pathways were estimated to be less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). Trends in doses in the area of the south coast (and the Severn Estuary) are shown in Figure 6.5. The dose from consumption of locally-grown fruit and vegetables, affected by gaseous discharges, was less than 0.005 mSv. The dose from non-food pathways arising from discharges to air was also assessed, using the methods and data given in Appendix 1. The dose received by prenatal children in 2009, including food and non-food pathways, was much less than 0.005 mSv which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). In 2009, the *total dose* from all sources was assessed to be less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent

of the dose limit. Adults spending a long time over riverside sediments were the most exposed people but the radiological significance of this site continued to be low.

5.5 Faslane and Coulport, Argyll and Bute



The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Marine, a subsidiary of Babcock International Group plc, operates HMNB Clyde in partnership with the MoD. However, the MoD

remains in control of the undertaking, through the Naval Base Commander, Clyde, in relation to radioactive waste disposal.

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD. The discharges released during 2009 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 2009.

In 2009 MOD made a number of significant improvements to the radioactive waste handling arrangements at HMNB Clyde. The refurbishment of the effluent treatment plant was completed during the year and the new plant was successfully commissioned in September. Works will be carried out in 2010 to decommission some of the redundant plant within the effluent treatment facility. In addition the introduction of new sorting facilities for solid waste has significantly reduced the amount of solid low level radioactive waste generated on the site.

The routine monitoring programme consisted of the analysis of seawater, seaweed and sediment samples, and gamma dose rate measurements. Samples of fish and shellfish species were again not available in 2009. Analysis results are given in Tables 5.3(a) and (b). These show that radionuclide concentrations were generally below the limits of detection, with caesium-137 concentrations in sediment and seaweed consistent with the distant effects of discharges from Sellafield, and with weapons testing and Chernobyl fallout. Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2006 (Sherlock *et al.*, 2009). Taking into account the occupancy and consumption rate data from this survey, and using seafood concentrations based on earlier data, the dose to people who consume fish and shellfish and from

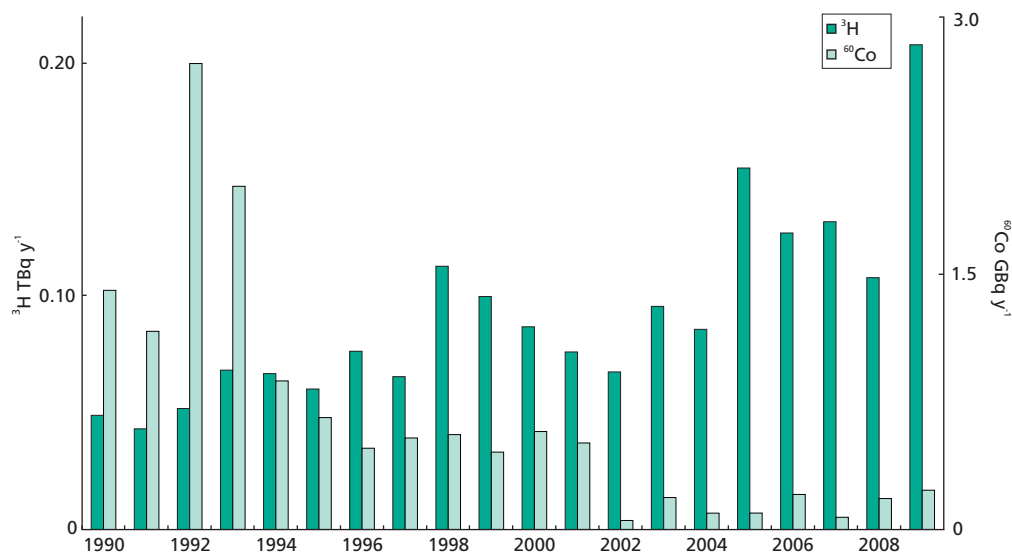


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2009

external radiation was less than 0.005 mSv, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The *total dose* from all sources was assessed to be less than 0.005 mSv in 2009 (Table 5.1). The most exposed people were adults spending time on the shores of the loch, but as in 2008 the dose was less than 0.5 per cent of the dose limit for members of the public.

5.6 Holy Loch, Argyll and Bute



A small programme of monitoring at Holy Loch continued during 2009 in order to determine the effects of past discharges from the US submarine support facilities which closed in 1992. Radionuclide concentrations were below detection

limits (Table 5.3(a)). Gamma dose rate measurements from intertidal areas (Table 5.3(b)) showed similar levels with previous years. The external radiation dose to people spending time on the loch shore was less than 0.005 mSv in 2009, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

5.7 Rosyth, Fife



The site is operated by Babcock Marine, a division of Babcock International Group, who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning

started in April 2006, and is expected to continue until 2013. To date, more than 99 per cent of the waste arising as a result of site decommissioning is being recycled.

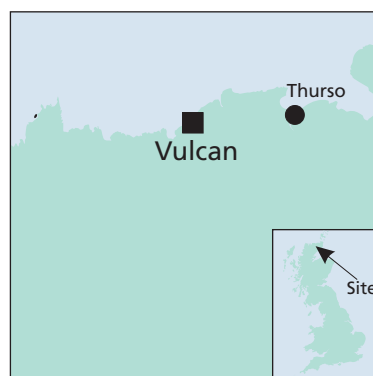
Radioactive waste produced during decommissioning will be disposed of under the conditions of an authorisation granted to Rosyth Royal Dockyard Limited (RRDL) in November 2004. Operational wastes continue to be discharged under separate, continuing, authorisations for such wastes. RRDL has applied for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

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

In 2009, authorised gaseous discharges from Rosyth were below the LoD. Liquid wastes are discharged via pipeline to the Firth of Forth. Tritium releases during 2009 were typical of the low levels discharged since 2000, and cobalt-60 discharges continued to decline. In all cases the activity in the liquid discharged was below authorised limits.

SEPA's routine monitoring programme included analysis of crabs and whelks, as well as environmental indicator materials, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 5.3(a) and (b). The radioactivity levels detected were at similar low levels to 2009, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2005 (Tipple *et al.*, 2006b). In 2009, the doses to local fishermen and beach users were assessed to be less than 0.005 mSv, which is less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The *total dose* from all sources was assessed to be less than 0.005 mSv in 2009 (Table 5.1), which is less than 0.5 per cent of the dose limit. The most exposed people were adults spending time on shoreline sediments.

5.8 Vulcan NRTE, Highland



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

3. SEPA has reviewed the application from the MoD to dispose of radioactive waste from the Vulcan NRTE. A letter of approval (Vulcan decision document) was issued for the disposal of radioactive waste from the premises (Scottish Environment Protection Agency, 2009a).

Table 5.1. Individual radiation exposures defence sites, 2009

Site	Exposed population ^a	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment and water	Gaseous plume related pathways
Aldermaston	Anglers ^b	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally harvested crayfish ^b	<0.005	<0.005	-	-	-	-
	Consumers of locally grown food ^e	<0.005	-	<0.005	-	-	<0.005
	All sources ^d	<0.005	-	-	-	-	-
Derby	Anglers consuming fish and drinking water ^c	<0.005	-	-	-	<0.005	-
	Local residents	<0.005	-	-	-	-	<0.005
	All sources ^d	<0.005	-	-	-	-	-
Devonport	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-
	Prenatal children of consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005
	All sources ^d	<0.005	-	-	-	-	-
Faslane	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	All sources ^d	<0.005	-	-	-	-	-
Holy Loch	Anglers	<0.005	-	-	<0.005	-	-
Rosyth	Fishermen	<0.005	<0.005	-	-	-	-
	Beach users	<0.005	<0.005	-	<0.005	-	-
	All sources ^d	<0.005	-	-	-	-	-

^a Adults are the most exposed age group unless stated otherwise

^b Includes a component due to natural sources of radionuclides

^c Water is from rivers and streams and not tap water

^d The total dose due to discharges and direct radiation. See Appendix 4

^e Children aged 1y

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹						
			Organic ³ H	³ H	¹³¹ I	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U
Freshwater samples									
Pike	Newbridge	1	<25	<25	*	<0.04			
Flounder	Beckton	1		<25	*	0.09			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	*	<0.08	0.040	0.0010	0.027
Sediment	Pangbourne	4 ^E				<1.9	12	<1.0	14
Sediment	Mapledurham	4 ^E				7.4	11	<0.83	10
Sediment	Aldermaston	4 ^E				<1.6	12	<1.1	11
Sediment	Spring Lane	4 ^E				<1.8	11	<0.80	11
Sediment	Stream draining south	4 ^E				<2.3	14	<0.98	15
Sediment	Reading (Kennet)	4 ^E				5.4	15	<0.72	15
Gulypot sediment	Falcon Gate	1 ^E		<25		<1.9	11	<0.80	11
Gulypot sediment	Main Gate	1 ^E		<10		<1.2	13	<2.0	14
Gulypot sediment	Tadley Entrance	1 ^E		<10		3.5	17	<0.90	16
Gulypot sediment	Burghfield Gate	1 ^E		<10		<1.6	16	<2.0	16
Freshwater	Pangbourne	4 ^E		<4.0		<0.32	0.012	<0.0050	<0.0095
Freshwater	Mapledurham	4 ^E		<4.0		<0.26	0.011	<0.0050	0.0088
Freshwater	Aldermaston	4 ^E		<5.3		<0.25	<0.0095	<0.0050	<0.011
Freshwater	Spring Lane	4 ^E		<4.5		<0.28	<0.0055	<0.0050	<0.0055
Freshwater	Reading (Kennet)	4 ^E		<4.0		<0.29	<0.0078	<0.0050	<0.0065
Crude liquid effluent	Silchester treatment works	4 ^E		<16		<0.26	<0.0011	<0.0053	<0.0083
Final Liquid effluent	Silchester treatment works	4 ^E		<27		<0.29	<0.0080	<0.0053	<0.0078
Sewage sludge	Silchester treatment works	4 ^E		<23		<0.43	0.54	<0.040	0.56

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	Gross alpha	Gross beta
Freshwater samples									
Pike	Newbridge	1	0.000049	0.00030	0.00047	*	*		
Flounder	Beckton	1			<0.18				
Signal crayfish	Ufton Bridge - Theale	1	0.000097	0.00012	0.00018	*	*		
Sediment	Pangbourne	4 ^E	<1.4	<0.59	<2.2			250	390
Sediment	Mapledurham	4 ^E	<0.48	<0.57	<2.3			100	<270
Sediment	Aldermaston	4 ^E	<0.50	<0.57	2.0			220	330
Sediment	Spring Lane	4 ^E	<0.45	<0.63	2.3			<150	490
Sediment	Stream draining south	4 ^E	<0.58	<0.59	<1.6			320	650
Sediment	Reading (Kennet)	4 ^E	<0.97	<2.2	3.1			150	440
Gulypot sediment	Falcon Gate	1 ^E	<0.40	0.51	<1.8			300	630
Gulypot sediment	Main Gate	1 ^E	<0.80	<0.30	<1.4			410	520
Gulypot sediment	Tadley Entrance	1 ^E	<0.40	<0.40	<1.5			330	690
Gulypot sediment	Burghfield Gate	1 ^E	0.37	0.42	<1.6			250	520
Freshwater	Pangbourne	4 ^E	<0.0065	<0.0053	<0.0083			<0.048	0.28
Freshwater	Mapledurham	4 ^E	<0.0073	<0.0050	<0.0088			<0.040	0.28
Freshwater	Aldermaston	4 ^E	<0.0050	<0.0050	<0.0095			<0.035	0.22
Freshwater	Spring Lane	4 ^E	<0.0053	<0.0050	<0.0088			<0.033	0.16
Freshwater	Reading (Kennet)	4 ^E	<0.0053	<0.0050	<0.0011			<0.035	<0.12
Crude liquid effluent	Silchester treatment works	4 ^E	<0.013	<0.0058	<0.38			<0.14	0.74
Final Liquid effluent	Silchester treatment works	4 ^E	<0.0093	<0.0053	<0.40			<0.083	0.80
Sewage sludge	Silchester treatment works	4 ^E	<0.16	<0.15	<0.59			<6.1	16

Table 5.2(a). continued

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			³ H	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U
Terrestrial samples							
Milk	Opposite gate 26A Location 7 Location 8 Opposite gate 36	5	<4.4	<0.20	0.0010	<0.00084	<0.00098
Milk		max	<5.3		0.0018	<0.0011	<0.0011
Beans		1	<5.0	<0.30	0.0028	0.00070	0.0028
Blackberries		1	<4.0	<0.20	0.0021	0.0015	0.0032
Honey		1	<7.0	<0.20	0.00090	<0.00070	<0.00090
Potatoes		1	<5.0	<0.20	0.0042	<0.00090	0.0051
Rabbit		1	<5.0	<0.20	0.0044	<0.00070	0.0012
Root vegetables		1	<4.0	<0.20	0.0032	<0.00050	0.0054
Sprouts		1	<4.0	<0.20	0.0067	<0.00040	0.0068
Wheat		1	<7.0	<0.20	<0.0010	<0.00080	<0.0013
Grass		1 ^E	<10	<1.1	<0.50	<0.30	<0.30
Grass		1 ^E	<10	<2.0	<0.30	<0.20	<0.30
Grass		1 ^E	72	<1.9	<0.50	<0.40	<0.50
Grass		1 ^E	49	<1.7	<0.40	<0.20	<0.40
Soil		1 [#]			4.2	0.17	4.1
Soil	1 ^E	<10	32	11	<0.80	12	
Soil	1 ^E	<10	6.9	22	0.96	25	
Soil	1 ^E	13	13	11	<2.0	11	
Soil	1 ^E	21	17	10	<1.0	13	

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹				
			²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	Gross alpha	Gross beta
Terrestrial samples							
Milk	Opposite gate 26A Location 7 Location 8 Opposite gate 36	5	<0.00010	<0.00012	<0.00012		
Milk		max		<0.00013	<0.00015		
Beans		1	<0.00010	0.00010	<0.00030		
Blackberries		1	<0.00010	<0.00010	<0.00030		
Honey		1	<0.00010	0.00010	0.00030		
Potatoes		1	<0.00010	0.00010	<0.00030		
Rabbit		1	<0.00020	<0.00040	<0.00030		
Root vegetables		1	<0.00010	0.00020	<0.00030		
Sprouts		1	<0.00010	0.00020	<0.00020		
Wheat		1	<0.00020	<0.00010	<0.00030		
Grass		1 ^E	<0.30	<0.080		4.4	340
Grass		1 ^E	<0.10	<0.050		25	370
Grass		1 ^E	<0.10	0.19		2.3	160
Grass		1 ^E	<0.20	<0.20		4.1	140
Soil		1 ^E	<0.30	0.91		160	420
Soil	1 ^E	<0.30	0.48		280	600	
Soil	1 ^E	<0.50	1.0		150	570	
Soil	1 ^E	<0.60	0.85		250	660	

* Not detected by the method used

^a Except for milk, sewage effluent and water where units are Bq l⁻¹, and for sediment and soil where dry concentrations apply (except for those marked with a # which are fresh concentrations)

^b Data are arithmetic means unless stated as 'max'. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

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

Table 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2009

Location	Ground type	No. of sampling observations	µGy h ⁻¹
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	4	0.072
Mapledurham, riverbank	Grass and mud	3	0.068
Mapledurham, riverbank	Grass	1	0.071

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2009

Material	Location or selection ^a	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹									
			Organic ³ H	³ H	¹⁴ C	⁵⁴ Mn	⁵⁸ Co	⁶⁰ Co	⁶⁵ Zn	¹⁰⁶ Ru	^{110m} Ag	¹²⁵ Sb
Barrow												
Grass	Barrow	2 ^F		<5.0								
Derby												
Sediment	River Derwent, upstream	1						<1.6				
Sediment	Station Road Bridge	4						<1.0				
Sediment	Fritchley Brook	1						<1.4				
Water	River Derwent, upstream	1						<0.40				
Water	Station Road Bridge	4						<0.32				
Water ^c	Fritchley Brook	1		<4.0				<0.47				
Devonport												
Ballan wrasse	Plymouth Sound	2 ^F				<0.06	<0.18	<0.06	<0.18	<0.56	<0.12	<0.13
Crabs	Plymouth Sound	2 ^F			20	<0.05	<0.10	<0.05	<0.13	<0.41	<0.09	<0.09
Shrimps	Lynher Estuary	1 ^F			26	<0.06	<0.17	<0.05	<0.14	<0.55	<0.11	<0.12
Cockles	Southdown	1 ^F				<0.11	<0.22	<0.12	<0.27	<1.2	<0.20	<0.23
Pacific oysters	Southdown	1 ^F				<0.04	<0.12	<0.03	<0.12	<0.37	<0.07	<0.08
Mussels	River Lynher	2 ^F	<27	<29		<0.13	<0.25	<0.13	<0.32	<1.4	<0.24	<0.30
Seaweed ^d	Kinterbury	2						<1.1				
Sediment ^e	Kinterbury	2		<29				<1.5				
Sediment	Torpoint (South)	2		<32				<0.80				
Sediment	Lopwell	2		<20				<1.7				
Seawater	Torpoint (South)	2		<4.5	<3.5			<0.50				
Seawater	Millbrook Lake	2		<4.0	<4.5			<0.34				
Beetroot		1 ^F		<4.0	8.0			<0.20		<1.5	<0.20	
Blackberries		1 ^F		<4.0	11			<0.20		<1.1	<0.20	
Carrots		1 ^F		<4.0	9.0			<0.20		<1.3	<0.20	
Courgettes		1 ^F		<4.0	17			<0.20		<1.0	<0.10	
Lettuce		1 ^F		<4.0	19			<0.20		<2.1	<0.20	
Faslane												
<i>Fucus vesiculosus</i>	Rhu	1				<0.10	<0.11	<0.10	<0.15	<0.42	<0.10	<0.12
Sediment	Carnban boatyard	1				<0.10	<0.20	<0.10	<0.34	<0.83	<0.13	0.52
Seawater	Carnban boatyard	2		<1.1		<0.10	<0.11	<0.10	<0.13	<0.46	<0.10	<0.14
Freshwater	Helensburgh Reservoir	1		<1.3								
Freshwater	Loch Finlas	1		<1.3								
Freshwater	Auchengaich	1		<1.3								
Freshwater	Loch Eck	1		<1.3								
Freshwater	Loch Lomond	1		<1.1								
Holy Loch												
Sediment	Mid Loch	1				<0.10	<0.29	<0.10	<0.39	<0.81	<0.14	<0.23
Rosyth												
Crabs	East of dockyard	1				<0.15	<0.29	<0.14	<0.41	<1.3	<0.15	<0.34
Whelks	East of dockyard	1				<0.10	<0.20	<0.10	<0.27	<0.86	<0.11	<0.24
<i>Fucus vesiculosus</i>	East of dockyard	1				<0.10	<0.14	<0.10	<0.20	<0.57	<0.10	<0.14
Sediment	East of dockyard	1				<0.10	<0.16	<0.10	<0.25	<0.58	<0.10	<0.17
Sediment	Port Edgar	1				<0.10	<0.25	<0.10	<0.38	<0.85	<0.15	<0.23
Sediment	West of dockyard	1				<0.10	<0.11	<0.10	<0.20	<0.47	<0.10	<0.14
Sediment	East Ness Pier	1				<0.10	<0.14	<0.10	<0.22	<0.53	<0.10	<0.17
Sediment	Blackness Castle	1				<0.10	<0.14	<0.10	<0.23	<0.54	<0.10	<0.17
Sediment	Charlestown Pier	1				<0.10	<0.18	<0.10	<0.31	<0.75	<0.12	<0.21
Seawater	East of dockyard	2		<1.1		<0.10	<0.10	<0.10	<0.14	<0.42	<0.10	<0.14
Freshwater	Castlehill	1		<1.3								
Freshwater	Holl Reservoir	1		<1.3								
Freshwater	Gartmorn	1		<1.3								
Freshwater	Morton No.2	1		<1.2								

Table 5.3(a). continued

Material	Location or selection ^a	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹									Gross alpha	Gross beta
			¹³¹ I	¹³⁴ Cs	¹³⁷ Cs	¹⁵⁵ Eu	²³⁴ U	²³⁵ U	²³⁸ U	²⁴¹ Am			
Derby													
Sediment	River Derwent, upstream	1					18	<0.80	17		150	520	
Sediment	Station Road Bridge	4					16	<0.84	17		<260	890	
Sediment	Fritchley Brook	1					17	<2.0	14		150	390	
Grass		4 ^F					0.056	<0.0027	0.051				
Grass	max						0.098	0.0046	0.095				
Soil		4 ^F					17	0.64	16				
Soil	max						18	0.71	17				
Water	River Derwent, upstream	1									<0.090	0.19	
Water	Station Road Bridge	4									<0.068	0.32	
Water ^c	Fritchley Brook	1			<0.40		0.021	<0.0050	0.017		<0.060	0.17	
Devonport													
Ballan wrasse	Plymouth Sound	2 ^F	*	<0.05	0.18	<0.11				<0.09			
Crabs	Plymouth Sound	2 ^F	*	<0.05	<0.04	<0.07				<0.04			
Shrimps	Lynher Estuary	1 ^F	*	<0.05	<0.04	<0.13				<0.11			
Cockles	Southdown	1 ^F	*	<0.10	<0.10	<0.17				<0.09			
Pacific oysters	Southdown	1 ^F	*	<0.04	<0.03	<0.09				<0.10			
Mussels	River Lynher	2 ^F	*	<0.13	<0.12	<0.24				<0.17			
Seaweed ^d	Kinterbury	2											
Sediment ^e	Kinterbury	2								2.3			
Beetroot		1 ^F		<0.20	<0.20								
Blackberries		1 ^F		<0.20	<0.20								
Carrots		1 ^F		<0.20	<0.20								
Courgettes		1 ^F		<0.20	<0.20								
Lettuce		1 ^F		<0.30	<0.30								
Faslane													
<i>Fucus vesiculosus</i>	Rhu	1		<0.10	0.42	<0.12				<0.10			
Sediment	Carnban boatyard	1		<0.11	13	1.2				0.98			
Seawater	Carnban boatyard	2		<0.10	<0.10	<0.14				<0.10			
Freshwater	Helensburgh Reservoir	1			<0.01						<0.010	0.024	
Freshwater	Loch Finlas	1			<0.01						<0.010	0.038	
Freshwater	Auchengaich	1			<0.01						<0.010	0.065	
Freshwater	Loch Eck	1			<0.01						<0.010	0.021	
Freshwater	Loch Lomond	1			<0.01						<0.010	0.019	
Holy Loch													
Sediment	Mid Loch	1		<0.11	<0.11	0.97				<0.35			
Rosyth													
Crabs	East of dockyard	1		<0.14	<0.13	<0.30				<0.18			
Whelks	East of dockyard	1		<0.10	<0.10	<0.21				<0.14			
<i>Fucus vesiculosus</i>	East of dockyard	1		<0.10	0.12	<0.14				<0.10			
Sediment	East of dockyard	1		<0.10	3.1	<0.20				<0.21			
Sediment	Port Edgar	1		<0.11	4.9	0.53				<0.30			
Sediment	West of dockyard	1		<0.10	0.72	<0.22				<0.19			
Sediment	East Ness Pier	1		<0.10	5.5	<0.25				<0.22			
Sediment	Blackness Castle	1		<0.10	2.6	0.43				<0.20			
Sediment	Charlestown Pier	1		<0.10	3.5	<0.49				<0.27			
Seawater	East of dockyard	2		<0.10	<0.10	<0.13				<0.10			
Freshwater	Castlehill	1			<0.01						<0.010	0.069	
Freshwater	Holl Reservoir	1			<0.01						<0.010	0.038	
Freshwater	Gartmorn	1			<0.01						<0.010	0.078	
Freshwater	Morton No.2	1			<0.01						<0.010	0.037	

* Not detected by the method used

^a Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

^b Except for sediment where dry concentrations apply, and for water where units are Bq l⁻¹

^c The concentrations of ²²⁸Th, ²³⁰Th and ²³²Th were <0.0050, 0.0060 and <0.0050 Bq l⁻¹

^d The concentration of ⁹⁹Tc was 14 Bq kg⁻¹

^e The concentrations of ²³⁸Pu and ²³⁹⁺²⁴⁰Pu were <0.80 and <0.98 Bq kg⁻¹

^f Measurements labelled "F" are made on behalf of the Food Standards Agency, all other measurements are made on behalf of the environment agencies

Table 5.3(b). Monitoring of radiation dose rates near defence establishments, 2009

Establishment	Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate				
Devonport	Torpoint South	Mud and rock	1	0.085
Devonport	Torpoint South	Mud and pebbles	1	0.11
Devonport	Kinterbury Access Gate	Mud and stones	1	0.082
Devonport	Kinterbury Access Gate	Stones	1	0.089
Devonport	Lopwell	Mud	2	0.093
Faslane	Gareloch Head	Mud, sand and stones	2	0.065
Faslane	Gulley Bridge Pier	Sand and stones	2	0.073
Faslane	Rhu	Gravel	2	0.056
Faslane	Helensburgh	Sand	2	0.066
Faslane	Carnban boatyard	Gravel	2	0.080
Holy Loch	North Sandbank	Mud and sand	1	<0.047
Holy Loch	Kilmun Pier	Sand and stones	1	0.058
Holy Loch	Mid-Loch	Sand	1	0.050
Rosyth	Blackness Castle	Mud and sand	2	0.061
Rosyth	Charlestown Pier	Sand	2	0.058
Rosyth	East Ness Pier	Sand	2	0.056
Rosyth	East of Dockyard	Sand	2	0.067
Rosyth	Port Edgar	Mud	2	0.064
Rosyth	West of Dockyard	Mud and rock	2	0.056

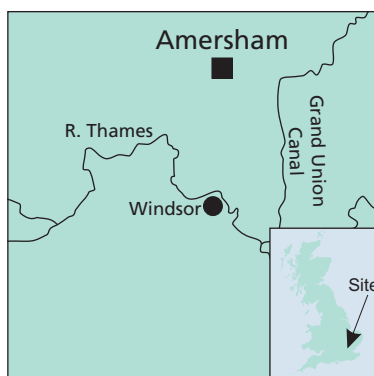
6. Radiochemical production

This section focuses on the discharges and monitoring programme at two sites associated with the radiopharmaceutical industry. The sites, at Amersham and Cardiff, are operated by GE Healthcare. This is a health science company functioning in world-wide commercial healthcare and life science markets. GE Healthcare also administers an additional facility on the Harwell campus, and the environmental effects of these operations are covered by general monitoring of the Harwell site (Section 3).

Permits have been issued by the Environment Agency to each of the sites allowing the discharge of gaseous and liquid radioactive wastes (Appendix 2). Independent monitoring of the environment around the Amersham and Cardiff sites is conducted by the Food Standards Agency and the Environment Agency. The medium-term trends in discharges, environmental concentrations and dose at Amersham and Cardiff were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010).

In June 2009, GE Healthcare reached an agreement to sell part of their Cardiff-based radiochemical manufacturing business to Quotient Bioresearch. This follows the announcement in late 2008 that GE Healthcare would be ceasing radiochemical manufacturing operations and progressively decommissioning associated areas of the site. Radiochemical manufacturing continued at the Maynard Centre until April 2010. Quotient Bioresearch was issued with a permit by the Environment Agency to discharge radioactive wastes, effective from 16 April 2010. Quotient Bioresearch is in the process of moving the acquired divisions to a purpose-built laboratory at Trident Park, Cardiff.

6.1 Grove Centre, Amersham, Buckinghamshire



GE Healthcare's principal establishment is located in Amersham, Buckinghamshire. It consists of a wide range of plants for manufacturing diagnostic imaging products, using short half-life radionuclides such as fluorine-18

and technetium-99m, for use in medicine and research. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials, and

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- Discharges of radon-222 to the atmosphere decreased by approximately 15 per cent
- Concentrations of radioactivity in terrestrial and aquatic samples, and gamma dose rates, were low and similar to those in 2008
- Radiation doses from discharges were less than 2 per cent of the dose limit, and the *total dose* from all sources, including direct radiation, was approximately 22 per cent of the dose limit

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- GE Healthcare ceased the majority of their radiochemical production operations in Cardiff in preparation for decommissioning and delicensing of the site
- A variation to the site's discharge permit was granted, allowing increased volumes of waste to be transferred to other locations for treatment and disposal. The implementation of a tritium recycling project was also cancelled as part of the variation
- Overall tritium concentrations in fish and shellfish continued their long-term decline; carbon-14 levels also decreased
- Radiation doses from all sources were less than 1 per cent of the dose limit

measurements of gamma dose rates. The monitoring locations are shown in Figure 3.1. A consumption and occupancy habits survey in the vicinity of the site was conducted in August 2009. This found increased rates of riverbank occupancy alongside the River Colne and the Grand Union Canal.

Gaseous discharges and terrestrial monitoring

The Amersham facility is permitted to discharge gaseous radioactive wastes via stacks on the site. In 2009, discharges of radon-222 to the atmosphere were around 15 per cent lower than in 2008; other gaseous discharges were very similar to those made the previous year. Sulphur-35 was positively detected in a wider range of foodstuffs than in 2008, although at low concentrations, and tritium was detected in one sample (Table 6.2). The activity concentrations in most other terrestrial samples were below limits of detection. Caesium-137 activity,

which was again detected in soil near the site, is likely to be due to global fallout from testing of weapons or from the Chernobyl accident.

Liquid waste discharges and aquatic monitoring

Radioactive liquid wastes are discharged to sewers serving the Maple Lodge sewage treatment works (STW); treated effluent subsequently enters the Grand Union Canal and the River Colne. The results of the aquatic monitoring programme are presented in Table 6.2. Activity concentrations in freshwater, and effluent and sludge from Maple Lodge STW, were below the limits of detection. The caesium-137 detected in sediments upstream of the sewage treatment works outfall is likely to be derived from weapons test fallout or the Chernobyl accident. Gross alpha and beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates (see footnote, Table 6.2) above the banks of the canal remained low, and are very similar to levels expected due to background radiation.

Doses to the public

In 2009, the maximum dose due to consumption of local terrestrial foodstuffs at high-rates was to the 1-year-old age group. This dose was assessed to be less than 0.005 mSv. The largest contribution was from caesium-137 in milk, although this pathway was assessed using concentrations at the limit of detection. The contribution from non-food pathways was also calculated, in order to assess members of the public's combined exposure to plume-related pathways and locally grown foodstuffs. The dose from this assessment method, which was again to 1-year-old infants, was 0.016 mSv, or less than 2 per cent of the dose limit to members of the public of 1 mSv (Table 6.1). The decrease in dose, from 0.019 mSv in 2008, is primarily due to the reduction in atmospheric discharges of radon-222, although this nuclide remains the dominant contributor. It should be noted that the current assessment methodology uses a conservative dose factor based on this nuclide being in equilibrium with its daughter products. The removal of selenium-75 from the list of nuclides permitted for discharge also led to a decrease in the assessed dose, as this nuclide was consequently excluded from dose calculations.

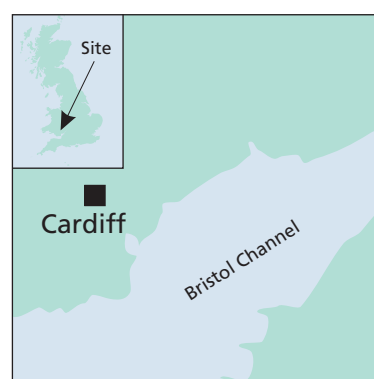
Exposure to aquatic pathways downstream of the release point for discharges of liquid effluents has also been considered. The 2009 habits survey at Amersham did not directly identify any consumers of fish, shellfish or freshwater plants. As in previous surveys, however, there was anecdotal evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg per year for fish has been included in the dose assessment. The dose in 2009 from fish consumption and external radiation was much less than 0.005 mSv, which was less than 0.5 per cent of the dose limit of 1 mSv (Table 6.1).

The Grove Centre discharges liquid waste to Maple Lodge sewage treatment works, and the prolonged proximity to

raw sewage and sludge experienced by sewage treatment workers is a common exposure pathway (National Dose Assessment Working Group, 2004). The dose received by these workers in 2009 was modelled using the methods described in Appendix 1. The dose from a combination of external exposure to contaminated raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides was less than 0.005 mSv.

The *total dose* from all sources, which uses integrated habits survey data to combine relevant contributions from all discharges and emissions (Appendix 4), was assessed to have been 0.22 mSv or 22 per cent of the dose limit. This dose was primarily due to the relatively high level of direct radiation at the site perimeter (Table A4.1). Given the variation in this quantity around the boundary of the Grove Centre, this should be considered as a cautious upper bound.

6.2 Maynard Centre, Cardiff



GE Healthcare operates a second establishment, on the Forest Farm industrial estate near Whitchurch, Cardiff, which until 2009 manufactured a range of radiolabelled products containing tritium and carbon-14. The company announced in late

2008 that they intended to cease production of radiochemicals at the Maynard Centre, a process which is underway and should be completed in 2010. Following this, the site will be decommissioned and the bulk of the site will be delicensed, leaving a small licensed area for storage of historic radioactive wastes. GE Healthcare's custom radiolabelling division has been acquired by Quotient Bioresearch, who will operate from different premises in Cardiff.

With a view to the cessation of their Cardiff operations, GE Healthcare submitted an application for a variation to their existing discharge permit. This variation would allow the transfer of greater volumes of radioactive waste to other sites for treatment and storage, and would remove the requirement for GE Healthcare to implement the planned tritium recycling plant, Project Paragon. Following a public consultation, the Environment Agency issued a notice in December 2009 granting GE Healthcare the desired variation (Environment Agency, 2009c).

The Food Standards Agency and the Environment Agency conduct a routine monitoring programme on behalf of the Welsh Assembly Government. This includes sampling of locally produced food, fish and shellfish, and external dose rate measurements over muddy, intertidal areas (Figure 6.1). These are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, seaweed, soil and

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

The Environment Agency also analysed samples of sewage products from the Cardiff East Waste Water Treatment Works (WWTW) for tritium and carbon-14. This enabled an assessment of exposure from eating crops grown on land fertilised with sludge pellets to be undertaken. The constraints of the Sludge (Use in Agriculture) Regulations (United Kingdom – Parliament, 1989) (commonly referred to as the Safe Sludge Matrix) require that crops cannot be harvested within 10 months of the application of sludge pellets. A recent Food Standards Agency research project (Ham *et al.*, 2007) investigated the transfer of tritium from treated soil to crops, under the Safe Sludge Matrix conditions, and concluded that the transfer of tritium to each of the crops considered was small.

Hunt *et al.* (2010) reviewed past monitoring data from Cardiff in order to compare the apparent enhancement of tritium concentrations on uptake by marine biota with bioaccumulation at other UK sites. The observed enhancement factor at Cardiff remains at least an order of magnitude greater than at the

other sites studied, although the organically bound fractions were uniformly high. Various earlier monitoring and research efforts have targeted organically bound tritium (OBT) in foodstuffs (Food Standards Agency, 2001b; Swift, 2001; Williams *et al.*, 2001; Leonard *et al.*, 2001 and McCubbin *et al.*, 2001).

Gaseous discharges and terrestrial monitoring

The Maynard Centre discharges radioactivity to the atmosphere via stacks on the site. This is predominantly tritium and carbon-14, with smaller levels of phosphorus-32/33 and iodine-125 also released. The amount of tritium discharged in 2009 represented a significant decrease on that of 2008 (by almost a factor of two) as a result of reduced commercial operations in advance of the site's planned shutdown. Carbon-14 discharges were also lower than in 2008, although the reduction was less pronounced. Enhanced tritium activities continue to be detected in terrestrial food samples (Table 6.3(a)), with no clear trend apparent in spite of the lower discharges in 2009. Carbon-14 activities were also enhanced in some foodstuffs, and levels of both nuclides increased in non-food samples. This may be a result of grass and silage

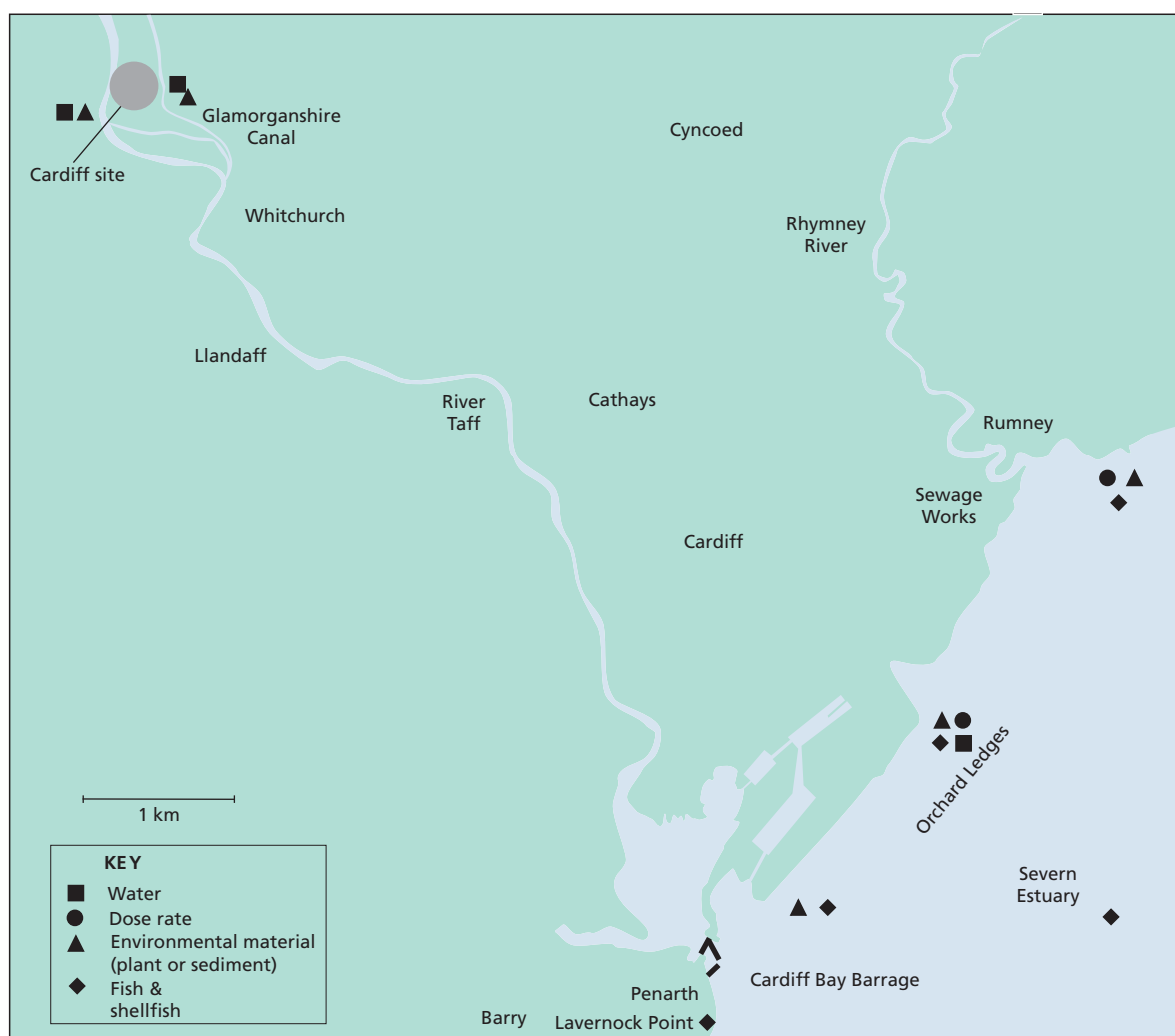


Figure 6.1. Monitoring locations at Cardiff, 2009 (not including farms)

samples being collected soon after a gaseous release, given the apparent anomaly. Low levels of sulphur-35 were detected in foods, at concentrations similar to those found in 2008, and caesium-137 was detected in one fruit sample. These nuclides are not discharged by the site. Phosphorus-32 and iodine-125 were below the limits of detection in all terrestrial samples.

Liquid waste discharges and aquatic monitoring

The Maynard Centre discharges liquid wastes into the Ystradfydwg and Pontypridd public sewer (YP). This joins the Cardiff East sewer, which after passing through a waste water treatment works discharges into the Severn estuary near Orchard Ledges. During periods of high rainfall, effluent from the YP sewer has been known to overflow into the River Taff. In addition, there is run-off from the site into the river via surface water drains.

The bulk of the radioactivity discharged to the YP sewer is tritium and carbon-14. The amount of tritium released to the sewer in 2009 was increased compared with 2008 levels, but over the longer term the discharge rate of this nuclide has decreased substantially (Figure 6.2). Carbon-14 discharges decreased in 2009, continuing its recent and long-term downward trend. Small amounts of iodine-125 were also released via this route.

The results of routine monitoring in 2009 are presented in Tables 6.3(a) and (b). The effects of liquid discharges remain evident in enhanced tritium and carbon-14 concentrations in fish samples. Further analysis of these samples shows that a high proportion of the tritium was associated with organic matter, a situation that has been observed since the late 1990s (McCubbin *et al.*, 2001; Leonard *et al.*, 2001; Williams *et al.*, 2001). The tritium is strongly bound to organic matter and has the potential to transfer through the marine food chain from small organisms to accumulate in fish. The overall mean concentration of tritium in fish decreased in 2009 (Figure 6.2), although concentrations in some species (flounder and grey mullet) showed an increase on their 2008 levels. Tritium levels in cod, sole and skates/rays showed a significant decrease over 2008 concentrations. The intra-species variability was less pronounced than in 2008, with only the two lesser spotted dogfish samples exhibiting considerable variation. There was around a ten fold difference in these two samples; other species varied by less than a factor of two. The continued overall decline in tritium concentrations in fish from the Cardiff area is likely to be a direct response to the decreasing inputs from the Maynard Centre, as well as a shift in the composition of this discharge away from organically bound compounds. However, the annual uncertainty and variation in certain species suggests that complex indirect uptake mechanisms continue to affect tritium concentrations in the region.

No mussel samples were collected from Cardiff in 2009, leaving limpets as the only mollusc sample. Figure 6.2 suggests that the overall mollusc concentrations of tritium decreased significantly in 2009, but this comparison is spurious given

that levels of tritium in these species differed so significantly in 2008 (when mussel concentrations averaged over 1000 Bq kg⁻¹ and limpet concentrations were below the limit of detection). Tritium was also detected in marine sediment samples at comparable levels to 2008.

The mean concentration of carbon-14 in both fish and molluscs showed a decrease consistent with the reduction in discharges in 2009. The longer term trend in concentrations and the relationship to discharges is shown in Figure 6.3.

Concentrations of caesium-137 in marine samples remain low and can largely be explained by other sources such as Chernobyl, weapon test fallout and discharges from other establishments such as the Hinkley Point, Berkeley and Oldbury nuclear sites. Where directly comparable, gamma dose rates over sediment were slightly lower than 2008 levels, and are not in the main attributable to discharges from the Maynard Centre.

Samples of raw and treated sewage and associated products from Cardiff East WWTW were analysed for tritium and carbon-14 in 2009. This monitoring was conducted by the Environment Agency in order to enable assessment of exposure from the transfer of tritium in sludge pellets, which are used as fertiliser, to crops grown in treated soil. The results (Table 6.3(a)) show enhanced concentrations of tritium in sludge pellets.

Relatively low levels of tritium continue to be detected in sediment and freshwater from the Glamorganshire Canal; however, this is not used as a source of water for the public water supply. The recent trend in sediment concentrations from the marine and freshwater environments are shown in Figure 6.4. The overall decline echoes that of tritium discharges, although the decline in marine levels (east/west of the pipeline) is less pronounced than in the canal sediments. In 2009, tritium was also detected in water run-off from the site into the River Taff. Carbon-14 was not detected in sediment or freshwater samples.

Doses to the public

The people most exposed to atmospheric discharges, via local terrestrial food consumption and exposure to the plume, were the 1-year-old age group (infants). In 2009 they were estimated to receive 0.008 mSv (Table 6.1), which is less than 1 per cent of the dose limit for members of the public, down from 0.010 mSv in 2008. Their exposure to the food pathway alone was 0.007 mSv. The decrease can be attributed to lower radionuclide levels in milk. Phosphorus-32 was the largest contributor to dose, albeit that this was below the limit of detection.

An assessment of the dose from the transfer of tritium in sludge pellets to crops grown in treated soil was also made, using the method described in Appendix 1. Prenatal children were found to be the most exposed people, and their dose due to tritium transferred from sludge pellets to fruit and vegetable crops was estimated to be much less than 0.005 mSv.

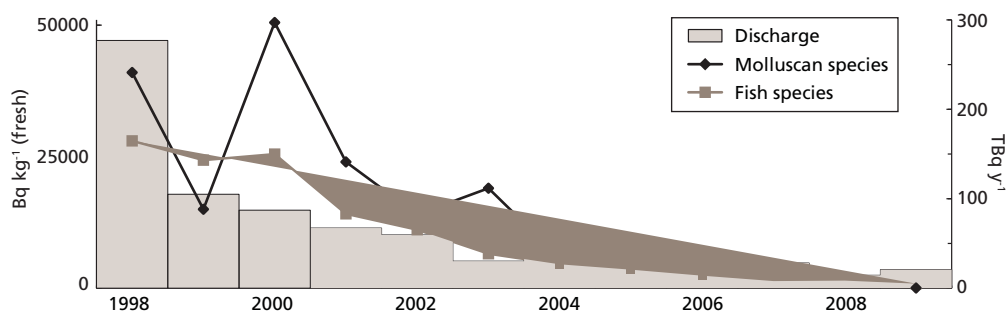


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

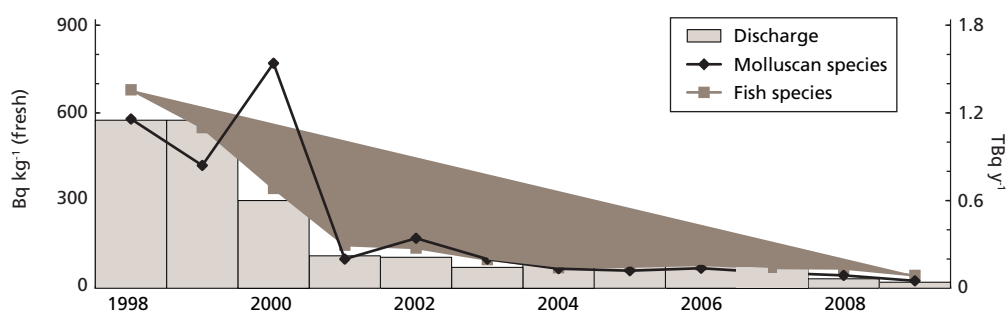


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff (species include all those reported in RIFE for the given year)

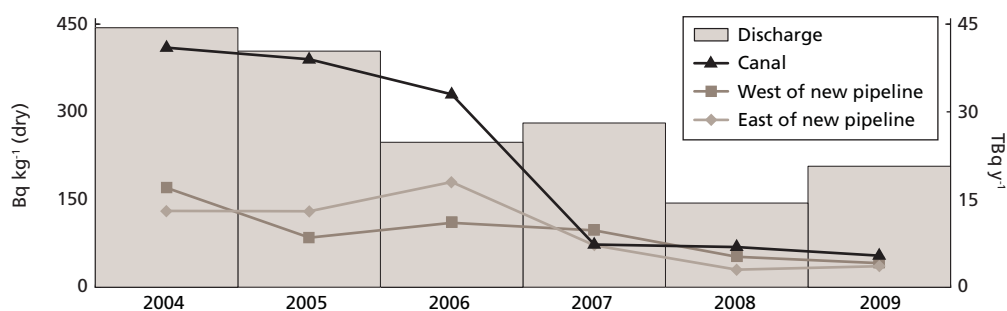


Figure 6.4. Tritium liquid discharge from Cardiff and mean concentrations in sediment near Cardiff, 2004-2009

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

In 2009 the dose to people who consume high rates of fish and shellfish was 0.009 mSv (Table 6.1). This was to prenatal children, with the associated adult age group receiving 0.008 mSv. These doses were calculated using an increased dose

coefficient for tritium specifically derived for the OBT discharged from this site, and are less than 1 per cent of the dose limit to members of the public. For comparison, the respective doses to these age groups in 2008 were 0.012 and 0.010 mSv and the reduction is primarily due to lower tritium concentrations in fish and shellfish, although the lack of mussel samples in 2009 may have exacerbated this decrease. Dose from carbon-14 in seafood was also lower than in 2008. The 2009 dose estimates include a 0.006 mSv component due to external radiation (Table 6.1), the same contribution as in 2008.

Exposures representative of anglers on the banks of the River Taff were well below 0.005 mSv. This is composed of the internal dose from inadvertently ingesting sediment and river water and an external component from occupancy of the river-bank. As in previous years, the largest contribution was from

the inadvertent ingestion of iodine-131 in river water, with small contributions from tritium and other radionuclides discharged by the site. The concentration of iodine-131, which is not discharged from the Maynard Centre, was below the limit of detection.

The Maynard Centre 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). The dose received by workers in 2009 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 assessed to have been much less than 0.005 mSv.

Exposures from aquatic pathways to people representative of the area surrounding the Severn Estuary have been kept under review (Figure 6.5). All doses from Cardiff, Hinkley Point and Berkeley/Oldbury were well within the annual dose

limit for members of the public of 1 mSv. These dose estimates take into account the increased dose coefficients for OBT derived for discharges from the Maynard Centre and include consideration of prenatal children. The continued reduction in the doses for Cardiff, in recent years, is largely due to the reductions in concentrations of tritium and carbon-14 in seafood (Figures 6.2 and 6.3). As in recent years, the impact from Cardiff on doses for Hinkley Point and Berkeley/Oldbury was very low.

The *total dose*, which includes contributions from all relevant sources based on data obtained from habits surveys (see Appendix 4), was assessed to have been 0.006 mSv in 2009 (Table 6.1), or less than 1 per cent of the dose limit. The prenatal children of adults who spend time over intertidal sediments were the most exposed people. The dominant contribution to this exposure was the low levels of external radiation emitted from radionuclides in the sediment, which are mainly due to variations in natural radioactivity or radioactive sources other than the Maynard Centre. Tritium in fish and molluscs contributed less than 0.002 mSv to the *total dose*.

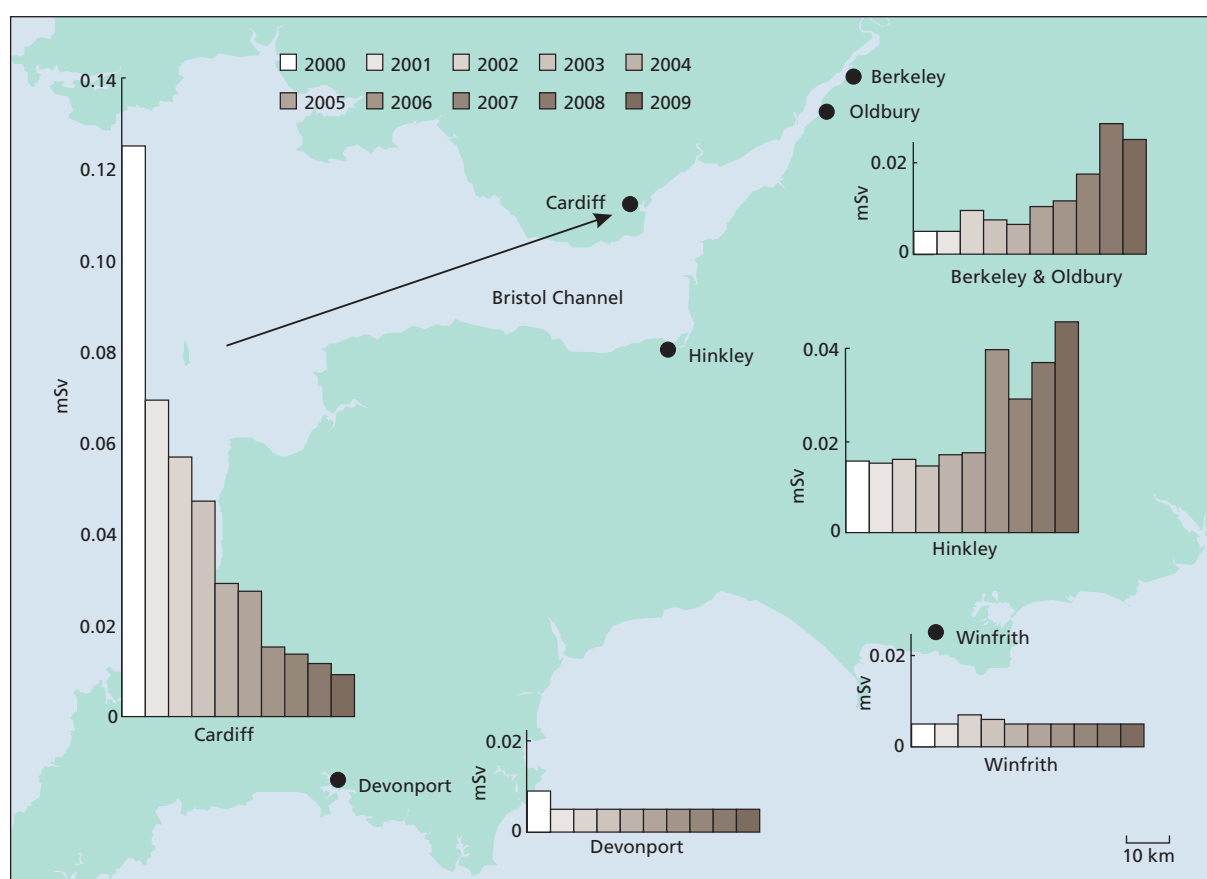


Figure 6.5. Individual radiation exposures by marine pathways from artificial radionuclides in the Severn Estuary and south coast, 2000-2009

Table 6.1. Individual radiation exposures radiochemical sites, 2009

Site	Exposed population ^a	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment and water	Gaseous plume related pathways
Amersham	Anglers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food ^b	0.016	-	<0.005	-	-	0.013
	Workers at Maple Lodge STW	<0.005	-	-	<0.005 ^d	<0.005 ^e	-
	All sources ^c	0.22	-	-	-	-	-
Cardiff	Prenatal children of seafood consumers	0.009	<0.005	-	0.006	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-
	Consumers of locally grown food ^b	0.008	-	0.007	-	-	<0.005
	Workers at Cardiff East WWTW	<0.005	-	-	<0.005 ^d	<0.005 ^e	-
	Prenatal children of consumers of crops grown in soil treated with sludge pellets	<0.005	-	<0.005	-	-	-
	All sources ^{c,f}	0.006	-	-	-	-	-

^a Adults are the most exposed group unless stated otherwise

^b Children aged 1y

^c The total dose due to discharges and direct radiation. See Appendix 4

^d External radiation from raw sewage and sludge

^e Intakes of resuspended raw sewage and sludge

^f Prenatal children

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2009^g

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							
			Organic ³ H	³ H	³² P	³⁵ S	⁵⁷ Co	⁶⁵ Zn	¹²⁵ I	¹³¹ I
Freshwater samples										
Pike	Newbridge	1	<25	<25			<0.02	<0.12		*
Flounder	Beckton	1		<25			<0.04	<0.17		*
Sediment	Outfall (Grand Union Canal)	2 ^E					<0.48	<3.0	<10	<4.4
Sediment	Upstream of outfall (Grand Union Canal)	2 ^E					<0.63	<5.0	<12	<6.6
Freshwater	Maple Cross	2 ^E		<4.0			<0.15	<0.69	<1.8	<0.70
Freshwater	Upstream of outfall (Grand Union Canal)	2 ^E		<4.0			<0.14	<0.78	<2.2	<0.68
Freshwater	River Chess	1 ^E		<4.0			<0.14	<0.64	<0.26	<0.42
Freshwater	River Misbourne – upstream	1 ^E		<4.0			<0.17	<0.79	<0.33	<2.4
Freshwater	River Misbourne – downstream	1 ^E		<4.0			<0.13	<0.64	<0.27	<0.44
Crude effluent ^d	Maple Lodge Sewage Treatment Works	4 ^E		<14	<3.0	<0.83	<0.15	<0.78	<1.0	
Digested sludge ^e	Maple Lodge Sewage Treatment Works	4 ^E		<15	<3.2	<1.0	<0.13	<0.67	<1.3	
Final effluent ^f	Maple Lodge Sewage Treatment Works	4 ^E		<15	<3.6	<0.83	<0.14	<0.73	<1.1	

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	Gross alpha	Gross beta
Freshwater samples										
Pike	Newbridge	1	<0.04	0.0000490	0.00030	0.00047	*	*		
Flounder	Beckton	1	0.09			<0.18				
Sediment	Outfall (Grand Union Canal)	2 ^E	<1.9						110	380
Sediment	Upstream of outfall (Grand Union Canal)	2 ^E	7.0						140	370
Freshwater	Maple Cross	2 ^E	<0.29						<0.055	0.55
Freshwater	Upstream of outfall (Grand Union Canal)	2 ^E	<0.29						<0.065	<0.13
Freshwater	River Chess	1 ^E	<0.24						<0.050	<0.10
Freshwater	River Misbourne – upstream	1 ^E	<0.32						<0.030	0.19
Freshwater	River Misbourne – downstream	1 ^E	<0.24						<0.020	0.10
Crude effluent ^d	Maple Lodge Sewage Treatment Works	4 ^E	<0.30			<0.39			<0.12	0.53
Digested sludge ^e	Maple Lodge Sewage Treatment Works	4 ^E	<0.27			<0.36			<1.1	6.1
Final effluent ^f	Maple Lodge Sewage Treatment Works	4 ^E	<0.28			<0.37			<0.17	0.78

Table 6.2. continued

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹								Gross alpha	Gross beta
			³ H	³⁵ S	⁵⁷ Co	⁶⁵ Zn	¹²⁵ I	¹³¹ I	¹³⁷ Cs			
Terrestrial samples												
Milk	max	2	<4.6	<0.33			<0.017	<0.0036	<0.20			
Milk			<4.8	<0.35			<0.018					
Apples		1	<4.0	<0.20			<0.025		<0.20			
Beetroot		1	<4.0	<0.20			<0.056		<0.20			
Blackberries		1	<4.0	0.20			<0.074		<0.20			
Broad beans		1	6.0	1.0			<0.051		<0.20			
Carrots		1	<5.0	0.20			<0.055		<0.30			
Peas		1	<4.0	0.30			<0.052		<0.20			
Spinach		1	<4.0	0.40			<0.027		<0.20			
Wheat		1	<9.0	1.2			<0.065		<0.20			
Grass	Next to site	1 ^E		<4.2	<0.65	<3.6	<1.4	<1.6	<1.3	<3.0	240	
Grass	Orchard next to site	1 ^E		<8.4	<0.52	<3.1	<0.89	<1.4	<1.2	<2.0	310	
Grass	Water Meadows (River Chess)	1 ^E		<6.5	<0.49	<2.4	<1.0	<1.3	<0.95	<2.0	200	
Soil	Next to site	1 ^E			<0.48	<2.2	<2.3	<1.4	9.6	280	510	
Soil	Orchard next to site	1 ^E			<0.55	<4.1	<1.3	<1.7	9.1	300	760	
Soil	Water Meadows (River Chess)	1 ^E			<0.18	<0.89	<0.39	<0.45	9.5	140	260	

* Not detected by the method used

^a Except for milk, water and effluent where units are Bq l⁻¹ and for sediment and soil where dry concentrations apply

^b Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

^d The concentration of ³H as tritiated water was <4.7 Bq l⁻¹

^e The concentration of ³H as tritiated water was <5.0 Bq l⁻¹

^f The concentration of ³H as tritiated water was <4.8 Bq l⁻¹

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

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

Table 6.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2009

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹								
			Organic ³ H ^e	³ H	³ H ^f	¹⁴ C	¹²⁵ I	¹³¹ I	¹³⁴ Cs	¹³⁷ Cs	²⁴¹ Am
Marine samples											
Cod	East of new pipeline	1		110		30		*	<0.08	0.69	<0.20
Flounder	East of new pipeline	4	2000	2200		63		*	<0.12	0.47	<0.09
Sole	East of new pipeline	2		1300		61		*	<0.04	0.22	<0.04
Mullet	East of new pipeline	1		280		42		*	<0.07	0.71	<0.07
Lesser spotted dogfish	Off Orchard Ledges	2	700	720		35		*	<0.15	0.58	<0.11
Skates/Rays	Off Orchard Ledges	2	550	550		35		*	<0.07	0.73	<0.19
Limpets	Lavernock Point	2	36	31		26		*	<0.19	0.65	<0.14
Seaweed ^d	Orchard Ledges	2 ^E		<21	8.3	<25	<0.72			<0.97	
Sediment	East of new pipeline	2 ^E		36		<25	<13			26	
Sediment	West of new pipeline	2 ^E		41	<4.5	<25	<14			27	
Seawater	Orchard Ledges	2 ^E		<14	<4.0	<4.0	<0.35			<0.29	

Material	Location or selection ^b	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹									
			Organic ³ H ^e	³ H	³ H ^f	¹⁴ C	³⁵ S	¹²⁵ I	¹³¹ I	¹³⁷ Cs	Gross alpha	Gross beta
Terrestrial samples												
Milk ^g		6	<5.0	<6.2		18	<0.34	<0.016		<0.19		
Milk ^g		max	<7.8	<14		19	<0.50	<0.019		<0.20		
Barley		1		<8.0		81	1.9	<0.037		<0.20		
Cabbage		1	5.0	21		13	1.7	<0.056		<0.20		
Honey		1		<7.0		68	<0.20	<0.020		<0.20		
Leeks		1	<17	17		13	0.90	<0.037		<0.10		
Onions		1	<5.0	<5.0		14	0.40	<0.054		<0.20		
Potatoes		1	<9.0	7.0		19	0.30	<0.043		<0.20		
Rape oil		1		<8.0		100	4.5	<0.050		<0.20		
Raspberries		1	<3.0	69		23	0.30	<0.061		<0.20		
Strawberries		1	<64	59		12	0.10	<0.030		0.60		
Swede		1	<19	15		12	0.50	<0.041		<0.20		
Grass		5	65	84		110				<0.17		
Grass	max		200	230		140				<0.20		
Silage		2	<25	34		63						
Silage	max		43	62		70						
Soil		3								7.0		
Soil	max									10		
Sediment	Canal	2 ^E		54		<29		<16		5.8		
Freshwater	Run off into River Taff	1 ^E		37	18	<4.0		<0.23	<0.68	<0.31	<0.040	<0.10
Freshwater	Canal	2 ^E		<25	26	<4.0		<0.27	<0.91	<0.35	<0.075	<0.18
Freshwater	River Taff	2 ^E		<14	<5.5	<4.0		<0.26	<0.90	<0.36	<0.040	0.22
Crude effluent	Cardiff East WWTW	3 ^E	<28	<36	19	<9.5						
Final effluent	Cardiff East WWTW	3 ^E	<30	64	53	<8.3						
Sludge pellets	Cardiff East WWTW	3 ^E		45000		330						

* 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 ⁹⁹Tc was 3.8 Bq kg⁻¹

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

^f As tritiated water

^g The concentration of ³²P was <0.32 (max <0.35) 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, 2009

Location	Ground type	No. of sampling observations	$\mu\text{Gy h}^{-1}$
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	2	0.074
West of Pipeline	Mud and pebbles	1	0.10
West of Pipeline	Pebbles and rock	1	0.096
Peterstone Wentlooge	Salt marsh	2	0.086

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, at LLWR near Drigg in Cumbria, as well as other landfill sites which have received small quantities of solid wastes and (ii) other sites where industries or incidents may have introduced radioactivity into the environment.

7.1 Low Level Waste Repository near Drigg, Cumbria



The Low Level Waste Repository (LLWR) is the UK's national low level waste disposal facility and is located on the West Cumbrian coast, approximately 7 km south east of Sellafield. The main function of LLWR is to receive low-level solid radioactive

wastes from all UK nuclear sites (except Dounreay) and many non-nuclear sites. Where possible the waste is compacted, and then all waste is grouted within containers before disposal. Wastes are now disposed of in engineered concrete vaults on land. The site is operated by LLW Repository Limited on behalf of the NDA. From 1 April 2008, a consortium, UK Nuclear Waste Management Ltd (UKNWM), took over as the Parent Body Organisation for LLW Repository Limited.

In 2009, a new solid waste transfer route to the Metals Recycling Facility (MRF) at Lillyhall was brought into operation. The facility helps to ensure that the amount of low level waste that is sent for disposal is kept to a minimum, whilst also recovering metal for recycling.

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

The disposal permit allows for the discharge of leachate from the site through a marine pipeline. These discharges are small compared with those discharged from the nearby Sellafield site (Appendix 2). Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme, described in Section 2. The contribution to exposures due to LLWR discharges is negligible compared with that attributable to

Key points

LLWR, near Drigg

- Disposals of solid radioactive waste at the LLWR site near Drigg were similar to 2008
- Concentrations and dose rates at LLWR were similar to those in 2008
- Doses near Drigg were dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven (Table 7.1)

Other sites

- Tritium found in leachate from other landfill sites. Probably due to disposal of Gaseous Tritium Light Devices. Doses were less than 0.5 per cent of dose limit
- Enhancement in natural radionuclides at Whitehaven from phosphate processing now very difficult to detect, however the radiation dose from the enhancement was estimated to be 18 per cent of the dose limit
- Radium-226 contamination requires further investigation near Dalgety Bay, Fife
- A survey of a shipwreck in North East England showed no enhanced radioactivity
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in regulations

Sellafield and any effects of LLWR discharges in the marine environment could not, in 2009, be distinguished from those due to Sellafield. In 2009, disposals of solid radioactive waste (Appendix 2) were generally similar to 2008.

Although the permit for disposal to the Drigg Stream has been revoked, reassurance monitoring of samples of water and sediment has continued. The results are given in Table 7.2. The gross alpha and beta concentrations were below or close to the WHO screening levels for drinking water from the Drigg stream. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use could occur, for example by campers. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2008. 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. The previous operators of the site (BNFL) took steps in the early 1990s to reduce ingress of water from the trenches by building a "cut-off wall" to reduce lateral migration of leachate. The results of monitoring in the drain show that activity concentrations are now very low and have reduced significantly since the "cut-off wall" was constructed. Both gross alpha and gross beta concentrations were below or close to the relevant WHO screening limit. Concentrations of tritium were below the limit of detection.

The monitoring programme of terrestrial foodstuffs at the site is primarily directed at the potential migration of radionuclides from the waste burial site via groundwater. Results for 2009 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 from terrestrial pathways to high rate consumers, including a component due to Chernobyl and weapon test fallout, was 0.013 mSv which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). The *total dose* from all sources including direct radiation was assessed using methods in Appendix 4 to have been 0.28 mSv or 28 per cent of the dose limit. This is dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven, which are near to the LLWR site. If these effects were to be excluded, the *total dose* at the LLWR site near Drigg would have been 0.036 mSv, mostly due to direct radiation.

7.2 Other landfill sites

Some organisations are granted authorisations or permits by SEPA in Scotland or the Environment Agency in England and Wales respectively 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 2009 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4. The programme in England and Wales reduced significantly in 2007 because the data from the previous, larger programme, collected over many years, showed that any enhancements in concentrations were predictable and gave rise to doses of very low significance. The remaining programme in England and Wales constitutes continued monitoring in relation to sites near Springfields where solid LLW has been disposed of, and at a few other landfill sites where disposals of radioactive waste are ongoing.

The results, in common with previous years, show very low concentrations of caesium-137 in leachate and evidence for migration of tritium from some of the discharge sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is

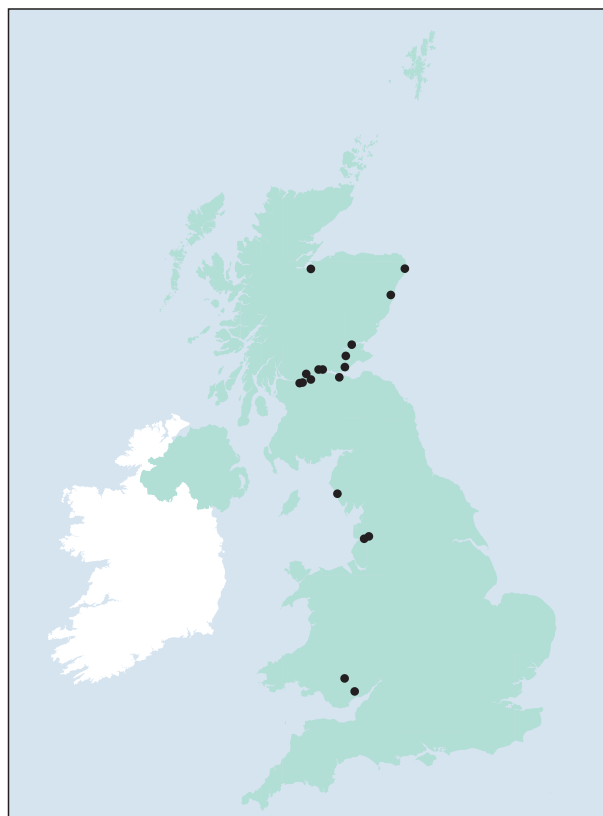


Figure 7.1. Landfill sites monitored in 2009

thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al.*, 1998). Inadvertent ingestion of leachate (2.5 l per year) from the site with the highest observed concentration of tritium would result in a dose of less than 0.005 mSv or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 7.1).

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 permit to discharge radioactive wastes revoked by the Environment Agency.

The results of routine monitoring for naturally-occurring radioactivity near the site in 2009 are shown in Table 7.5. Analytical effort has focused on lead-210 and polonium-210, which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally-occurring radionuclides are slightly enhanced near Whitehaven but

quickly reduce to background levels further away. Figures 7.2 and 7.3 show how concentrations of polonium-210 in winkles and crabs have decreased since 1998. Concentrations in the early 1990s were in excess of 100 Bq kg⁻¹ (fresh weight). There were small decreases in concentrations of polonium-210 in these samples in 2009 compared with 2008. However, the changes were small and taking into account the ranges of values observed, it is now difficult to distinguish between the total naturally-occurring radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. These are shown in Figures 7.2 and 7.3 and in Appendix 1 (Annex 4). There were small enhancements for some samples above the expected natural background median levels for marine species, but the majority were within

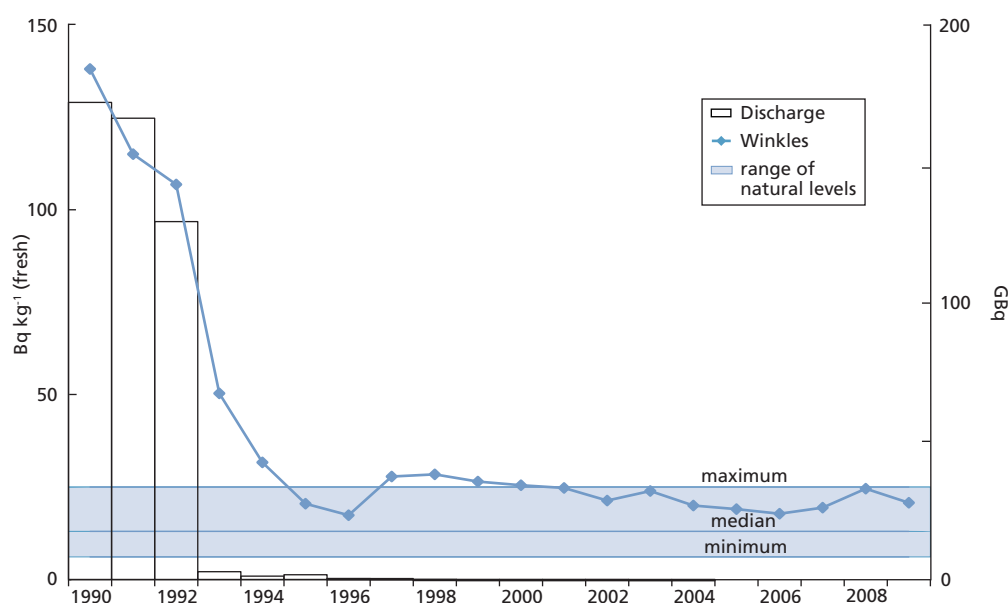


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2009

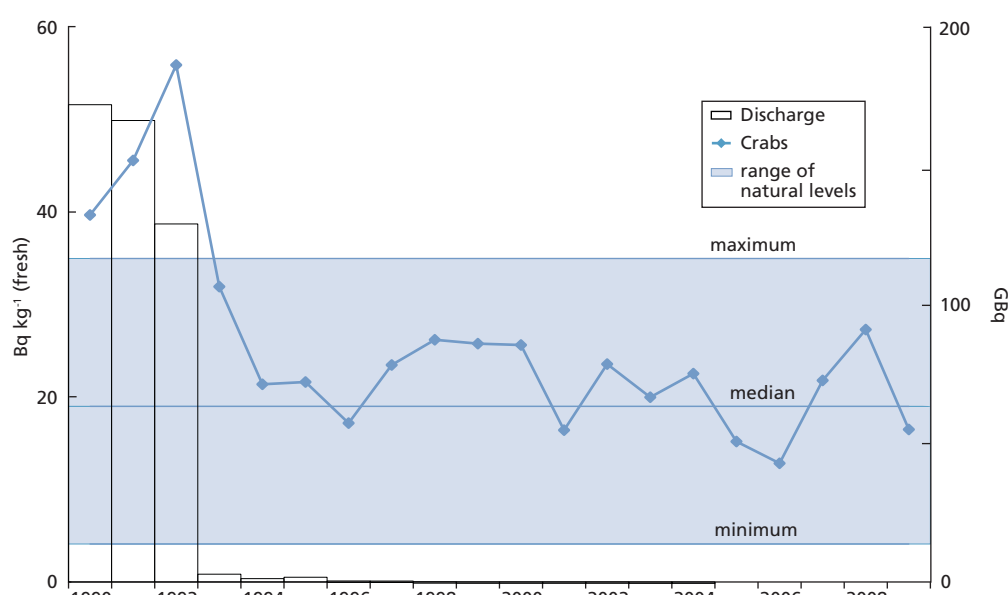


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2009

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.

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 people who eat at high-rates were reviewed and revised in 2009. The assessment is based on averaging the consumption rates over a five-year period from 2005 – 2009. The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

The dose to high rate consumers of seafood from enhanced naturally-occurring radionuclides from non-nuclear industrial activity (i.e. TNORM) was 0.18 mSv in 2009 (Table 7.1), a decrease from the estimate for 2008 of 0.39 mSv. The decrease is largely due to small decreases in concentrations of polonium-210. A time trend plot of doses since 1998 is shown in Figure 7.4. The changes in dose reflect changes in both concentrations and consumption rates, primarily of lobsters and molluscs. The fish and shellfish consumed also contained artificial radionuclides due to Sellafield discharges. The additional exposure due to artificial radionuclides has been calculated using data from Section 2. In 2009, these exposures added a further 0.20 mSv to the doses above resulting in a total dose to this group of 0.38 mSv. The estimated doses in 2009 are

therefore below the dose limit for members of the public of 1 mSv.

7.4 Aberdeen

Enhancement of naturally-occurring radionuclides in the marine environment may also result from operations conducted by Scotoil in Aberdeen. The company operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. Prior to these operations, a fertiliser manufacturing process was operated on the site, which made discharges to sea. Scotoil is authorised by SEPA to discharge small amounts of radioactive waste to the sea near Aberdeen Harbour. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring. The primary discharge is of radium-226 and radium-228, with lead-210 and polonium-210 in smaller quantities. Following a review of the authorisation held by Scotoil, SEPA issued a variation notice requiring a range of improvements. The variation notice which required use of the discharge pipeline to cease by December 2008 was appealed by Scotoil in 2007.

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

7.5 Dalgety Bay, Fife

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

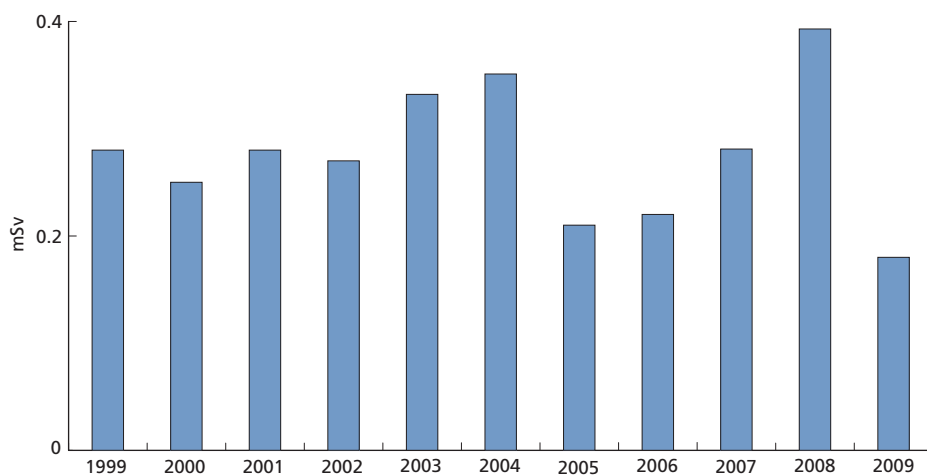


Figure 7.4. Trend in dose to seafood consumers from naturally-occurring radionuclides near Whitehaven, 1999 - 2009

is now exposed and adjacent to the foreshore. Some of the incinerated material contained items which had been painted with luminous paint containing radium-226.

In June 1990, environmental monitoring showed elevated radiation levels in the Dalgety Bay area. The monitoring was undertaken as part of the routine environmental monitoring programme for Rosyth Royal Dockyard conducted in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material was removed for analysis, which indicated the presence of radium-226. Further investigation confirmed that the contamination could not have originated from the dockyard and was most likely to be associated with past practices related to the nearby former RNAS Donibristle/HMS Merlin military airfield. Since this initial discovery, there have been several monitoring exercises to determine the extent of this contamination.

The data from a monitoring exercise, conducted during March 2006, was used to undertake a screening risk assessment. The monitoring survey report and screening risk assessment have been published (RWE Nukem, 2006; Scottish Environment Protection Agency, 2006). The screening risk assessment considered the range of activities of radium-226 in samples removed from the beach, the likelihood of encountering such items and various modes of exposure – ingestion, inhalation and external exposure.

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

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

In 2009, SEPA concluded that while some of the dose estimates were above the criteria set out in the Guidance, there remained sufficient uncertainty, especially in the assessment of skin dose, such that a determination could not be made. In addition, it was also noted at that time that the wording of the Regulations (which have since been amended) excluded radon and its daughters from the scope of the assessment and so contributions from polonium-210 and lead-210 could not be included. However, following the issue of the report by Dale

(2009), Defence Estates has set out a plan to manage the contamination on the foreshore. This plan has included improving the warning notices, and the regular monitoring and removal of contamination. This work was welcomed by SEPA and is ongoing, and SEPA awaits the results of this monitoring and removal programme before deciding on the next steps.

7.6 Other non-nuclear sites

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

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

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

Discharges may also occur without an authorisation or permit when the quantities are considered to be below the need for specific regulatory control. For example discharges of natural radionuclides are made from coal-fired power stations because of the presence of trace quantities of uranium and thorium and their decay products in coal.

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

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

In 2009, SEPA undertook a small-scale survey (as part of the annual programme) of the effects of discharges from non-nuclear operators by taking and analysing samples of mussels and other materials in the River Clyde. The results in marine samples show the expected effects of Sellafield discharges at this distance (Table 7.8). The results were similar to those in 2008. An assessment of the dose to a hypothetical group of high-rate mollusc consumers was undertaken. The dose was less than 0.005 mSv or less than 0.5 per cent of the dose limit.

SEPA undertakes to monitor WWTW to assess the impacts of selected areas across Scotland. The results of previous monitoring exercises are being assessed and will be reported upon completion.

7.7 The wreck of the cargo ship SS Somali

The SS Somali was bombed and sank in water off the North East coast of England in 1941, 1800m offshore of the village of Beadnell. In August 2008, there was a story in the media that the cargo had contained technetium. It is highly unlikely that the cargo ship contained any technetium; however as a precaution some measurements in the area surrounding the

wreck were made. One of the best environmental indicators for technetium is seaweed. Seaweed samples from nearby were therefore taken and analysed for technetium-99, the most likely radioisotope. Results in seaweed samples from around the wreck ranged from 38 to 102 Bq kg⁻¹ (fresh weight). These values can be compared with levels seen in seaweed near the Hartlepool Nuclear Power Station. Between 1998 — 2008, values ranged up to 180 Bq kg⁻¹ (fresh weight) with an average of 39 Bq kg⁻¹ (fresh weight) in 2008. The results seen for the monitoring in the vicinity of the wreck are in the normal range found near Hartlepool due to the dispersion of technetium-99 from the Sellafield reprocessing plant. No further action is planned.

Table 7.1. Individual radiation exposures industrial and landfill sites, 2009

Site	Exposed population ^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
LLWR near Drigg	Consumers of locally grown food ^b	0.013	-	-	0.013	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
	All sources ^d	0.28	-	-	-	-	-
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers ^b	<0.005	-	-	-	-	<0.005
Whitehaven (habits averaged 2005-09)	Seafood consumers ^c	0.38	0.17	0.18	-	0.033	-

^a Adults are the most exposed group unless stated otherwise

^b Children aged 1y

^c Includes the effects of discharges from the adjacent Sellafield site

^d The total dose due to discharges and direct radiation. See Appendix 4. The doses from man-made and naturally occurring radionuclides were 0.15 and 0.14 mSv respectively. The source of man-made radionuclides was Sellafield; naturally occurring ones were from the phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR site into the same area

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2009

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	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹²⁵ Sb
Milk		1	<4.3	15	<0.21	0.10	<0.33	<0.24	<0.0060	<1.3	<0.38
Blackberries		1	<4.0	17	<0.20	0.18	<0.30	<0.30		<1.3	<0.50
Cabbage		1	<4.0	9.0	<0.20	0.28	<0.30	<0.20	<0.020	<1.0	<0.30
Carrots		1	<4.0	5.0	<0.20	0.39	<0.20	<0.20		<1.6	<0.50
Deer muscle		1	<6.0	27	<0.20	0.020	<0.20	<0.20	<0.025	<1.2	<0.40
Eggs		1	<6.0	33	<0.20	<0.0070	<0.30	<0.20		<0.70	<0.50
Potatoes		1	7.0	13	<0.20	0.067	<0.20	<0.20	<0.022	<1.1	<0.40
Rabbit		1	<5.0	24	<0.10	0.022	<0.20	<0.20	<0.019	<0.50	<0.30
Sheep muscle		1	<5.0	29	<0.10	0.024	<0.20	<0.20	<0.022	<1.1	<0.40
Sheep offal		1	<8.0	31	<0.20	0.49	<0.30	<0.20	<0.024	<1.2	<0.30
Grass		2							<0.053		
Grass max									0.077		
Sediment	Drigg Stream	4 ^E			<1.2	<4.5	<2.4	<0.92		<9.4	<3.8
Freshwater	Drigg Stream	4 ^E	<7.2		<0.33	<0.16					
Freshwater	Railway Drain	1 ^E	<5.0		<0.30	0.26					

Material	Location or selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹								
			¹²⁹ I	¹³⁴ Cs	¹³⁷ Cs	Total Cs	¹⁴⁴ Ce	²¹⁰ Po	²²⁸ Th	²³⁰ Th	²³² Th
Milk		1	<0.0085	<0.19	<0.25		<0.81				
Blackberries		1	<0.026			0.090	<1.0				
Cabbage		1	<0.029			0.18	<0.60				
Carrots		1	<0.025			0.18	<0.80				
Deer muscle		1	<0.049			0.92	<0.50				
Eggs		1	<0.027			0.097	<0.80				
Potatoes		1	<0.027			0.13	<0.80				
Rabbit		1	<0.029			0.59	<0.60				
Sheep muscle		1	<0.023			1.7	<0.60				
Sheep offal		1	<0.041			1.4	<0.80				
Sediment	Drigg Stream	4 ^E		<1.0	230		<4.3	16	18	15	12
Freshwater	Drigg Stream	4 ^E		<0.28	<0.28			<0.0052	<0.012	<0.0062	<0.0052
Freshwater	Railway Drain	1 ^E		<0.22	<0.27			<0.0050	<0.0090	<0.0050	<0.0050

Material	Location or selection ^a	No. of sampling observations ^c	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹								
			²³⁴ U	²³⁵ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	Gross alpha	Gross beta
Milk		1				<0.00013	<0.00013	<0.035	<0.00020		
Blackberries		1				<0.00020	0.00030	<0.062	0.00080		
Cabbage		1				0.00020	0.00030	<0.062	0.00030		
Carrots		1				0.00010	0.00040	<0.062	0.00050		
Deer muscle		1				0.00020	0.00070	<0.097	<0.00040		
Eggs		1				<0.00010	<0.00010	<0.052	0.00060		
Potatoes		1				<0.00010	<0.00020	<0.059	<0.00030		
Rabbit		1				0.00020	0.00030	<0.094	0.0010		
Sheep muscle		1				0.00030	0.00090	<0.086	0.0024		
Sheep offal		1				0.027	0.15	0.69	0.20		
Grass		2	0.012	<0.00065		0.012					
Grass max			0.013	<0.00070	0.013						
Soil		1	9.4	0.37	9.3						
Sediment	Drigg Stream	4 ^E	38	<2.4	32	13	77	340	110	820	1400
Freshwater	Drigg Stream	4 ^E	0.011	<0.0050	0.0088	<0.0052	<0.0052	<0.80	<0.018	<0.055	0.57
Freshwater	Railway Drain	1 ^E	0.0060	<0.0050	0.0060	<0.0050	<0.0050	<0.10	<0.010	<0.050	1.3

^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 and freshwater where units are Bq l⁻¹, and for sediment where dry concentrations apply

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

^E Measurements are made on behalf of the Food Standards Agency unless labelled "E".

In that case they are made on behalf of the Environment Agency

Table 7.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2009

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹			
			³ H	¹⁴ C	¹³⁷ Cs	²⁴¹ Am
Aberdeen City	Ness Tip	1	140	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	240	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	330	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	16	<15	<0.05	<0.05
Dunbartonshire	Birdstone	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	8.5	<15	<0.05	<0.05
Edinburgh	Braehead	1	5.0	<15	<0.05	<0.05
Fife	Balbarton	1	84	<15	<0.05	<0.05
Fife	Melville Wood	1	130	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	160	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	330	<15	0.10	<0.05

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2009

Location	Sample source	No. of sampling observations	Mean radioactivity concentration, Bq kg ⁻¹						
			³ H	³ H ^a	¹⁴ C	⁴⁰ K	⁶⁰ Co	¹³⁷ Cs	²²⁸ Th
Glamorgan									
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	1200	1300	<4.5				
Trecatti Landfill, Merthyr Tydfil	Treated leachate	2	1100	1000	<4.0				
Lancashire									
Clifton Marsh	Borehole 6	2		14		<6.7	<0.35	<0.31	<0.0085
Clifton Marsh	Borehole 19	2		<5.5		<9.3	<0.41	<0.34	0.0070
Clifton Marsh	Borehole 40	2		<5.5		<6.5	<0.29	<0.26	<0.013
Clifton Marsh	Borehole 59	2		15		<6.6	<0.30	<0.26	<0.0070
Ulnes Walton	Pond	1		<4.0		<6.5	<0.32	<0.27	<0.0080
South Glamorgan									
Lamby Way Tip ^b	Borehole 1A	2		<11	<4.0	<7.3	<0.31	<0.27	

Location	Sample source	No. of sampling observations	Mean radioactivity concentration, Bq kg ⁻¹						
			²³⁰ Th	²³² Th	²³⁴ U	²³⁵ U	²³⁸ U	Gross alpha	Gross beta
Lancashire									
Clifton Marsh	Borehole 6	2	<0.0090	<0.0050	<0.012	<0.0050	0.011	<0.25	5.1
Clifton Marsh	Borehole 19	2	<0.0055	<0.0040	0.019	<0.0050	0.016	<0.45	3.3
Clifton Marsh	Borehole 40	2	<0.0055	<0.0075	<0.0070	<0.0050	<0.0070	<0.15	1.5
Clifton Marsh	Borehole 59	2	<0.0055	<0.0050	<0.0060	<0.0060	<0.0055	<0.20	2.8
Ulnes Walton	Pond	1	0.0090	<0.0050	0.11	<0.0080	0.10	0.12	0.51
South Glamorgan									
Lamby Way Tip ^b	Borehole 1A	2						<0.20	1.1

^a As tritiated water^b The concentrations of ¹²⁵I and ¹³¹I were <0.26 and <0.60 Bq l⁻¹ respectively

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2009

Material	Location	No. of sampling observations	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	Salton Bay	4	13	2.1						
Winkles	Parton	4	21	1.9	0.61	0.81	0.42	1.2	0.036	1.0
Winkles	North Harrington	1	16							
Winkles	Nethertown	4	17							
Winkles	Drigg	1			0.75	0.82	0.63			
Winkles	Tarn Bay	1	13							
Mussels	Parton	4	36	1.5						
Mussels	Nethertown	4	39	2.7						
Limpets	St Bees	2	14							
Cockles	Ravenglass	2	23							
Crabs	Parton	4	16	<0.0018	0.089	0.011	0.0063	0.056	0.0024	0.048
Crabs	Sellafield coastal area	4	16	0.15						
Lobsters	Parton	4	13	0.11	0.030	0.0046	0.0017	0.038	0.0014	0.031
Lobsters	Sellafield coastal area	4	16	<0.00081						
Cod	Parton	2	1.1	0.038	0.033	0.0045	0.0031	0.014	<0.0011	0.012
Plaice	Whitehaven	1	1.5							
Other samples										
Winkles	South Gare (Hartlepool)	2	13	1.3						
Winkles	Kirkcudbright	1	4.2							
Mussels	Ribble Estuary	2			0.16	0.17	0.075			
Cockles	Southern North Sea	1			0.37	0.22	0.28			
Cockles	Flookburgh	2	14							
Crabs	Kirkcudbright	1	4.4							
Lobsters	Kirkcudbright	1	2.0							
Shrimps	Ribble Estuary	2			0.0052	0.0023	0.0017			
Wild fowl	Ribble Estuary	1			0.0047	0.0084	0.0020			
Seaweed	Isle of Man	1						2.5	<0.18	2.0
Sediment	Kirkcudbright	1						12	0.41	11
Sediment	Rascarrel Bay	1						6.3	<0.12	5.7

^a Except for sediment where dry concentrations apply

Table 7.6. Discharges of gaseous radioactive wastes from non nuclear establishments in the United Kingdom, 2008^a

	Discharges during 2008, GBq								
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)		
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland
³ H	2.1E-01						7.9E+02		
¹⁴ C	1.8E-04			3.7E-05			1.9E+03	2.3E-02	5.0E+00
¹⁸ F	2.2E+02						1.7E+02		
³⁵ S	2.6E-01						8.4E-01		
⁴¹ Ar									
⁸⁵ Kr							2.1E-01		
^{99m} Tc				1.3E+00			9.1E-01		
¹²⁵ I	3.5E-04			5.5E-02			2.0E-01		
¹³¹ I				5.3E-01			1.8E-01		
¹³⁷ Cs							1.0E-05		
²²² Rn							2.0E+00		
Plutonium Alpha							1.6E-07		
Uranium Alpha									
²⁴¹ Am							3.6E-07		
Other Alpha particulate							1.9E+02		
Other Beta/Gamma				2.7E+02					
Other Beta/Gamma Particulate	9.2E+02			3.1E-01		1.0E+00	2.2E+04		

^a Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland discharge data refers to 2009

Table 7.7. Discharges of liquid radioactive waste from non nuclear establishments in the United Kingdom, 2008^a

	Discharges during 2008, TBq										
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)			Oil and gas (onshore)	Oil and gas (offshore)
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Scotland	Northern Ireland	Scotland	United Kingdom
³ H	2.1E-02	2.8E-05		1.0E-03			5.7E-01				
¹⁴ C	6.0E-03	9.1E-06	8.0E-04	1.2E-03		8.1E-04	9.1E-01	9.1E-03	3.4E-02		
¹⁸ F	5.0E-01			1.3E+00	2.2E-01	4.6E-02	1.2E+00				
²² Na	7.9E-06										
³² P	2.4E-02	1.2E-04	4.9E-03	1.0E-02	7.3E-05	9.7E-04	1.3E-02	5.4E-03			
³³ P	1.7E-03	5.3E-07	4.6E-04				6.1E-03	4.2E-02			
³⁵ S	3.7E-02	2.7E-04	2.6E-03	3.7E-03			7.4E-03	9.5E-04			
⁵¹ Cr	8.4E-01		1.0E-04	4.7E-02	2.2E-04	3.5E-03	1.4E-03				
⁵⁷ Co	2.3E-06	1.5E-07		1.1E-04	7.0E-08		2.6E-09				
⁵⁸ Co				4.8E-06							
⁶⁰ Co	3.9E-05	3.1E-06			3.1E-06		4.9E-08				
⁶⁷ Ga				2.5E-02	1.5E-04	5.9E-04	1.5E-04				
⁷⁵ Se	3.2E-05			1.0E-03		1.2E-05	6.0E-06				
⁸⁹ Sr			3.0E-03	2.2E-02		5.4E-03	1.8E-04				
⁹⁰ Sr	2.6E-07			1.1E-03			1.4E-09				
⁹⁰ Y				3.5E-01							
⁹⁹ Tc	1.5E-04					5.8E-04	4.3E-03				
^{99m} Tc	2.7E-02		5.1E-01	5.3E+01	1.6E+00	5.1E+00	1.1E+00				
¹¹¹ In	1.6E-03		5.8E-04	2.8E-01	7.6E-03	5.2E-01	2.1E-03				
¹²³ I	3.8E-05		1.9E-02	8.7E-01	5.1E-02	1.2E-01	8.7E-03				
¹²⁵ Sb											
¹²⁵ I	4.5E-03	4.6E-05	1.3E-03	2.0E-03	2.9E-05	1.2E-03	6.5E-02		1.4E-04		
¹²⁹ I	7.2E-10										
¹³¹ I			1.0E-02	9.0E+00	1.5E-02	8.6E-01	1.6E-01				
¹³⁴ Cs	1.1E-09										
¹³⁷ Cs	2.6E-04						5.4E-08				
¹⁴⁴ Ce											
¹⁵³ Sm				7.5E-02							
¹⁸⁶ Re					4.9E-03						
²¹⁰ Pb											5.11E-03
²⁰¹ Tl				1.5E-01		3.6E-02	2.1E-04				
²²⁶ Ra											2.16E-01
²²⁸ Ra											1.53E-01
²³⁰ Th	7.5E-11										
²³² Th							4.8E-03				
Plutonium Alpha							6.2E-10				
Uranium Alpha	5.2E-08						8.9E-03				
²³⁷ Np											
²⁴¹ Am	1.1E-07						4.5E-08				
²⁴¹ Pu							5.0E-09				
Total Alpha	4.1E-06			3.5E-05			3.3E-02	1.1E-06		4.9E-03	
Total Beta/Gamma (Excl Tritium)	6.1E-01		5.5E-01	5.5E+01		5.4E+00	1.5E+00	2.9E-02		2.7E-03	
Other Alpha particulate	2.8E-07			3.0E-05			2.2E-04				
Other Beta/Gamma ^b	6.6E-03		1.1E-03	1.8E-01		8.0E-05	5.6E-02	1.5E-05			
Other Beta/ Gamma particulate							1.0E-02				

^a Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland discharge data refers to 2009

^b Excluding specific radionuclides

Table 7.8. Monitoring in the River Clyde, 2009^a

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹					
			³ H	¹⁴ C	³² P	⁹⁰ Sr	⁹⁹ Tc	¹²⁵ Sb
Between Finlaystone and Woodhall	Mussels	1		15	<1.2		5.6	<0.25
Between Finlaystone and Woodhall	<i>Fucus vesiculosus</i>	1			<1.1		160	<0.10
14 km downstream of Dalmuir	Sediment	1		<15	<1.1			0.76
Downstream of Dalmuir	Freshwater	4			<0.40			<0.11
River Clyde	Freshwater	4	<1.2			<0.0051		
Daldowie	Sludge pellets	4			<30			<0.89

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹				
			¹³⁷ Cs	¹⁵⁵ Eu	²⁴¹ Am	Gross alpha	Gross beta
Between Finlaystone and Woodhall	Mussels	1	0.72	<0.23	<0.17		
Between Finlaystone and Woodhall	<i>Fucus vesiculosus</i>	1	0.45	<0.10	<0.10		
14 km downstream of Dalmuir	Sediment	1	47	1.7	2.3		
Downstream of Dalmuir	Freshwater	4	<0.10	<0.10	<0.10		
River Clyde	Freshwater	4	<0.10			<0.073	0.64
Daldowie	Sludge pellets	4	4.4	<0.96	<0.51		

^a Results are available for other radionuclides detected by gamma spectrometry.

All such results are less than the limit of detection

^b Except for water where units are Bq l⁻¹, and sludge pellets and sediment where dry concentrations apply

8. Chernobyl and regional monitoring

8.1 Chernobyl

The Chernobyl accident occurred in April 1986, in the former USSR (now Ukraine). After the accident, radiocaesium was detected in sheep grazing certain upland areas in the UK, which were subjected to heavy rainfall in the days following the accident. Restrictions were put in place on the movement, sale and slaughter of sheep from the affected areas, in order to prevent animals from entering the food chain above the action level of 1,000 Bq kg⁻¹ of radiocaesium, a level based on the recommendations of an EU expert committee in 1986.

A programme of monitoring live animals, known as the Mark and Release Scheme, ensures that food safety is protected, whilst allowing established sheep farming practices to continue. A farmer wishing to move sheep out of a restricted area must have them tested using an external monitor held against the sheep. Any sheep which is assessed to have levels of contamination exceeding the limit of 1,000 Bq kg⁻¹ is marked on the back of the head with coloured paint. Painted sheep may be moved off restricted areas, but cannot be sold to slaughter nor returned to the restricted areas for a minimum of three months, which allows time for the radiocaesium to pass out of the body. It is planned to review this policy during 2010. Results of the Mark and Release monitoring programme for 2009 are given in Table 8.1.

In the summer of 2009, whole flock monitoring surveys of sheep on selected farms in the post-Chernobyl restricted areas of England, Scotland and Wales were conducted with the aim of removing restrictions where controls are no longer necessary. As a result of the 2008 and 2009 surveys, more farms in Wales have had their controls lifted.

There remain a total of 343 farms or part farms (eight in England, five in Scotland and 330 in Wales) subject to restrictions. There are approximately 190,000 sheep within these restricted areas. This represents a reduction of over 95 per cent since 1986, when approximately 9,700 farms and 4,225,000 sheep were under restriction across the UK. All remaining restrictions in Northern Ireland were lifted in 2000. In Scotland, restrictions for all the five remaining farms were lifted in 2010.

Sampling locations for freshwater fish affected by Chernobyl are now limited to Cumbria in England, which had areas of relatively high deposition of fallout from the accident. Samples from areas of low deposition in England were also obtained for comparison. Table 8.2 presents concentrations of caesium-134 and caesium-137 in fish. Other artificial radionuclides from the Chernobyl accident are no longer detectable. In 2009 the highest concentration of caesium-137 was 87 Bq kg⁻¹ in perch from Devoke Water, down from 110 Bq kg⁻¹ in 2008.

Key points

- Contamination of sheep and fish with caesium-137 from Chernobyl remains evident but is decreasing. Concentrations in fish are now less than 10 per cent of those observed in the immediate aftermath of the accident
- Sampling of marine biota from the Channel Islands continued to monitor possible effects from French nuclear facilities discharging radioactivity into the English Channel. Doses were less than 0.5 per cent of the limit
- Monitoring in Northern Ireland and the Isle of Man showed low concentrations of man-made radionuclides from Sellafield and other UK nuclear facilities. Doses were approximately 1 per cent of the dose limit
- Samples from the UK food supply, air, rain and drinking water were analysed. Natural radionuclides dominated the doses due to consumption of general diet and drinking water
- SEPA undertook additional monitoring of residues from the Icelandic volcano Eyjafjallajökull. The radiological significance was low, and air monitors stationed at Scottish nuclear sites indicated no unusual levels of radioactivity
- Surveys of seas around the UK supported international assessments for the OSPAR Treaty. In the Irish Sea, caesium-137 concentrations showed a decrease over 2007 levels and tritium was below the limit of detection away from Sellafield. The concentration of both nuclides was very low in the western English Channel

Levels in fish from other locations were generally similar to those in recent years and substantially less than the 1,000 Bq kg⁻¹ level reached shortly after the accident. Caesium-134 concentrations were below detection limits in all samples. 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 six and 30 years.

A cautious assessment has been made of the dose from consuming fish contaminated with radiocaesium following the Chernobyl accident. A consumption rate of 37 kg per year, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures

are likely to be much lower, not only because this consumption rate is higher than expected (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have a much lower radiocaesium concentration. In 2009, estimated doses were less than 0.1 mSv.

8.2 Channel Islands

Samples of marine environmental materials provided by the Channel Island States have been analysed for levels of radioactivity. The programme monitors the effects of radioactive discharges from the French reprocessing plant at Cap de la Hague and the power station at Flamanville; it also serves to monitor any effects of historical disposals of radioactive waste in the Hurd Deep, a natural trough in the western English Channel. Fish and shellfish are monitored in order to determine exposure from the internal irradiation pathway; sediment is analysed with relevance to external exposures. Seawater and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers.

Analysis results for 2009 are given in Table 8.3. There was evidence of routine releases from the nuclear industry in some samples (cobalt-60 and technetium-99); however, activity concentrations 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 dose to people who consume high-rates of fish and shellfish was undertaken, and in 2009 they were estimated to receive less than 0.005 mSv, which is less than 0.5 per cent of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources, therefore, continued to be of negligible radiological significance.

Milk and crop samples from the Channel Islands were also analysed. The results are included in Tables 8.9 and 8.10, respectively, and form part of the programmes considered in Sections 8.6 and 8.7.

8.3 Isle of Man

The Food Standards Agency carries out an on-going programme of radioactivity monitoring on behalf of the Department of Local Government and the Environment on the Isle of Man for a range of terrestrial foodstuffs (Table 8.4). The results complement the Isle of Man Government's own independent radiation monitoring programme (www.gov.im/dlge/enviro/govlabs) and provide a comprehensive assessment of environmental radioactivity levels on the Isle of Man. Results of aquatic monitoring are presented in Section 2 because of their significance in relation to Sellafield, but are also included here for completeness (Table 8.4).

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

Many of the analyses conducted showed that levels of radionuclides were below the limit of detection of the method used. Carbon-14 concentrations were similar to those expected from natural background, and concentrations of sulphur-35, 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. Strontium-90 was present in one sample at a slightly elevated level, compared to recent years, and technetium-99 was positively detected in milk and food samples, albeit at very low concentrations. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2009.

Radiation doses to people on the Isle of Man from different exposure pathways are given in Table 2.18. The dose to local people from high-rate consumption of the terrestrial foodstuffs monitored in 2009 was 0.008 mSv (0.009 mSv in 2008), which is less than 1 per cent of the dose limit for members of the public of 1 mSv. The effects of liquid discharges from Sellafield into the Irish Sea are discussed fully in Section 2. The dose to people consuming large quantities of Manx fish and shellfish was 0.007 mSv in 2009, which is unchanged from the 2008 dose, and residents spending a typical amount of time on sandy beaches were assessed to receive 0.011 mSv from external exposure to radionuclides entrained on the sand.

8.4 Northern Ireland

The Northern Ireland Environment Agency undertakes monitoring of the far field effects of liquid discharges into the Irish Sea from Sellafield (Environment and Heritage Service, 2004). The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 8.1). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 8.5(a) and (b).

In 2009, the main effect of discharges from Sellafield was evident as concentrations of technetium-99 in shellfish and seaweed samples. These were somewhat lower than in 2008, reflecting the considerably decreased inputs to the Irish Sea in recent years. Caesium-137 concentrations were low and showed a slight decline over 2008 levels, and trace amounts of transuranic nuclides were detected. Observed concentrations were less than those found nearer to Sellafield and were generally lower than those in 2008, although with the exception of technetium-99 the decrease was sufficiently



Figure 8.1. Monitoring locations in Northern Ireland, 2009

small to be attributable to natural variability. The radiation dose rates over intertidal areas were slightly lower than those in previous years.

Habits representative of high-rate fish and shellfish consumers have been established by a survey of consumption and occupancy in coastal regions of Northern Ireland (Smith *et al.*, 2002). The dose to the most exposed people on the basis of monitoring results from the marine environment in 2009 was 0.012 mSv, which is approximately 1 per cent of the dose limit for members of the public.

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

8.5 General diet

As part of the Government's general responsibility for food safety, concentrations of radioactivity are determined in diets of the regions. These data (and those on other dietary components in Sections 8.6 and 8.7) form the basis of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with those from other EU Member States (e.g. Joint Research Centre, 2009). Diet data are reported to

the EC by the Food Standards Agency (for England, Northern Ireland and Wales), and by SEPA (for Scotland) under a sampling programme run by the Food Standards Agency. Most data are derived from the Food Standards Agency's Total Diet Study (TDS). In 2009, this sampling did not include any Total Diet samples in Scotland. The design of the UK TDS has been described in detail elsewhere, but basically involves 119 categories of food combined into 20 groups of similar foods for analysis (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). The relative importance of each food category within a group reflects its importance in the diet (Ministry of Agriculture, Fisheries and Food, 1998). Foods are grouped so that commodities known to be susceptible to contamination (e.g. offals, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk) (Ministry of Agriculture, Fisheries and Food, 1994; Peattie *et al.*, 1983). These samples are analysed for radioactivity. The system of sampling mixed diet, rather than individual foodstuffs from specific locations, provides more 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 2009 and the mixed diet results for England, Northern Ireland and Wales

are provided in Table 8.6. Data for mixed diet concentrations for Scotland are given within Table 8.10.

There was little evidence of the effects of radioactive waste disposal into the environment reaching the general diet and all of the results for man-made radionuclides were low. Results of all tritium and sulphur-35 analyses were below the limits of detection, and the overall mean concentration of caesium-137 decreased compared with 2008. Whilst there was some variability from region to region, in general it was no more than is usual for the programme, and there were no discernible trends in concentrations.

Exposures as a result of consuming diet at average rates containing the activity concentrations given in Table 8.6 have been assessed for intakes by adults and summarised in Table 8.7. The nationwide mean dose for all man-made radionuclides was low at 0.001 mSv. The most important man-made radionuclide was strontium-90 derived from weapons test fallout, which contributed over half of this dose.

The mean dose due to consumption of naturally-occurring radionuclides (excluding potassium-40*) was considerably higher than that from anthropogenic nuclides at 0.022 mSv, although this represents a decrease from the value of 0.039 mSv in 2008. Lower overall polonium-210 concentrations are partially responsible for this decline, along with a reduced monitoring programme in areas that have previously contributed to this portion of the dose. The most important radionuclides were polonium-210 and radium-226. The results demonstrate that radionuclides from natural sources are by far the most important source of exposure in the average diet of consumers. Man-made radionuclides only contributed about 4 per cent of the mean dose.

The maximum exposures from diet in each region are also provided in Table 8.7. The highest exposure in the UK was estimated to be 0.035 mSv based on sampling at Norbury in England, with almost 70 per cent of the dose being derived from polonium-210. In 2008, the highest exposure in the UK was 0.062 mSv.

The concentrations found in a survey of radioactivity in canteen meals collected across the UK (Table 8.8) were similar to the mean concentrations found in UK diet with some higher potassium-40 levels apparent, particularly in Northern Ireland.

8.6 Milk

The programme of milk sampling across dairies in the UK continued in 2009. The aim is to collect and analyse samples for their radionuclide content on a monthly basis. 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 that may enhance concentrations above background levels. Milk data are reported by the Food Standards Agency (for England, Northern Ireland and Wales) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (e.g. Joint Research Centre, 2009).

The results are summarised in Table 8.9. The majority of measurements, where comparable, are similar to those in previous years. Carbon-14 concentrations from dairies in Northern Ireland showed a slight increase over 2008, but these are still very close to the expected background concentration in milk (see Appendix 1, Annex 4). Tritium results were again below their limits of detection. The mean concentration of strontium-90 was about 0.02 Bq l⁻¹. In the past, the concentrations of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. However, the concentrations are now very low and it is less easy to distinguish this trend. The highest concentrations of caesium-137 were found in Northern Ireland.

Radiation dose from the consumption of milk at average rates was assessed for various age groups. In 2009 the maximum dose was to one-year-old infants. For the range of radionuclides analysed, the dose was less than 0.005 mSv. Previous surveys (e.g. Food Standards Agency and Scottish Environment Protection Agency, 2002) have shown that if a full range of nuclides are analysed and assessed the dose is dominated by naturally-occurring lead-210 and polonium-210 whereas man-made radionuclides contribute less than 10 per cent.

8.7 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2009 (Table 8.10). Tritium activity was below the LoD in most samples. Carbon-14 was generally detected at levels close to those expected to occur through natural processes. Levels of other naturally-occurring radionuclides varied from region to region, and where directly comparable were slightly lower than in 2008. Plutonium isotopes and americium-241 were detected at trace levels in some samples. However, within the variability observed, the concentrations of all radionuclides in crops were similar to those observed in 2008.

In 2009, 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. Two samples were analysed and the results are given in Table 8.11. The activity concentrations ranged from 140 – 520 Bq kg⁻¹. This was below the maximum level permissible under EC regulations, which is 600 Bq kg⁻¹, and so no action on food restrictions was necessary.

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

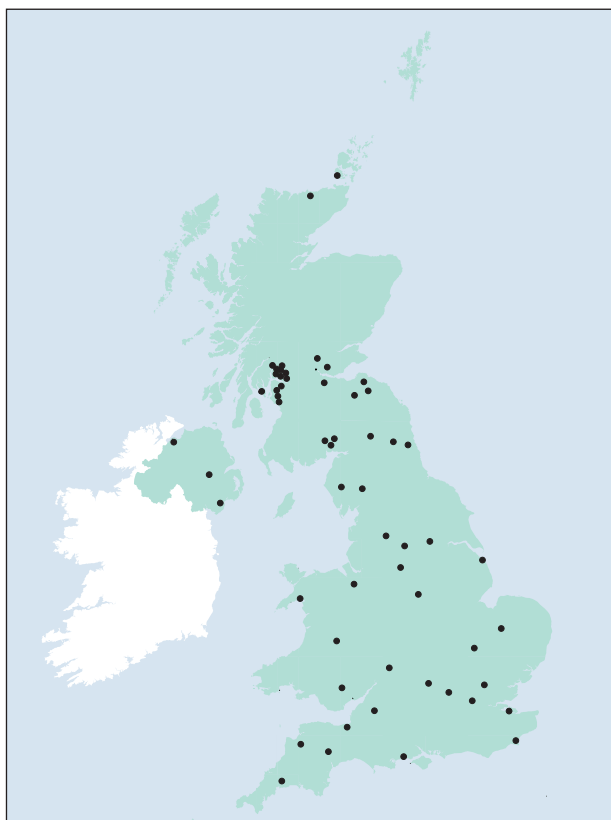


Figure 8.2. Drinking water sampling locations, 2009

8.8 Airborne particulate, rain, freshwater, groundwater and sediments

Monitoring of radioactivity in rainwater and air took place at several UK locations as part of a monitoring programme of background sampling. These data are reported by HPA (for England, Northern Ireland and Wales) and SEPA (for Scotland) on behalf of DECC, NIEA and the Scottish Government, as part of the UK submission to the EC under Article 36 of the Euratom Treaty (e.g. Joint Research Centre, 2009). The results are given in Table 8.12. The routine programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an *ad hoc* basis by gamma-ray spectrometry. Caesium-137 concentrations were all below the limits of detection. These levels in air, typical of recent years, remain less than 0.01 per cent of those observed in 1986, the year of the Chernobyl reactor accident.

Concentrations of beryllium-7, a naturally-occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in

rainwater were similar to those in 2007. Concentrations in air and rainwater are very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2009 (Figure 8.2). These water data are reported by the Environment Agency (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (e.g. Joint Research Centre, 2009). 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 8.13, 8.14 and 8.15 show that concentrations of tritium are all substantially below the EU indicator limit for tritium of 100 Bq l⁻¹. Concentrations of gross alpha and gross beta were all below the WHO screening levels for drinking water of 0.5 and 1.0 Bq l⁻¹, respectively.

The mean annual dose from consumption of drinking water in the UK was assessed as 0.027 mSv in 2009 (Table 8.16). 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 0.029 mSv due to radionuclides in a source of drinking water from Matlock in Derbyshire.

Separately, in 2009, SEPA took a series of groundwater samples from across Scotland with the aim of determining natural variability. Samples were taken in summer and winter to assess seasonal effects which may be caused by changes in ground water flow. The mean results are displayed in Table 8.17. All samples contained levels of tritium and caesium-137 below the limit of detection, and so in this respect the seasonal and geographical variability was low.

In 2009 SEPA also continued a programme of sampling and analysis of marine and freshwater sediments to determine natural variability across Scotland. The results are shown in Table 8.18. Levels of caesium-137 were elevated in two samples, suggesting that accretion and/or erosion can expose sediments contaminated by the Chernobyl accident.

During the period when Scotland was being impacted by the ash cloud from the Icelandic volcano Eyjafjallajökull, SEPA sought to establish by all readily available means the concentration of ash in the atmosphere and whether there was any risk to the environment and human health. Air monitoring stations used by SEPA for environmental radioactivity monitoring around Scotland's nuclear sites were used as a source of information to determine the non-radioactive properties of the ash. Information on the potential radioactive consequence of the ash was obtained by SEPA using the RIMNET* system which indicated that the effect of the

* The Radioactive Incident Monitoring Network (RIMNET) was implemented after the Chernobyl incident in 1986. It comprises of a network of detectors across the British Isles.

ash was negligible. The RIMNET system also allowed SEPA to make predictions of the movement of the plume and its deposition over Scotland.

At each of the nuclear sites where the SEPA air monitoring stations were located, additional air samplers operated by the nuclear sites themselves, continued to operate normally. SEPA has been informed that the results of these samplers indicate no unusual levels of radioactivity. However, as a result of the use of SEPA's air monitors for Eyjafjallajökull monitoring, there was a short disruption to the RIFE monitoring programme.

8.9 Seawater surveys

The UK Government is committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally-occurring radioactive substances, and close to zero for artificial radioactive substances (Department of Energy and Climate Change, Department of the Environment, Northern Ireland, The Scottish Government and Welsh Assembly Government, 2009). 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, 2009b). In 2006 OSPAR adopted the Periodic Evaluation of the Progress in Implementing the OSPAR Radioactive Substances Strategy (concerning progressive and substantial reductions in discharges of radioactive substances, as compared with the agreed baseline) (OSPAR, 2007). The programme of radiological surveillance work provides the source data and therefore the means to monitor and make an assessment of progress in line with the UK's commitments towards OSPAR's 1998 Strategy for Radioactive Substances target for 2020. The surveys also provide information that can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al.*, 1998; Kershaw *et al.*, 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Evidence to help gauge progress towards achievement of the Government's vision for radionuclides and other hazardous substances is set out in a recent report (Department for Environment, Food and Rural Affairs, 2010).

The research vessel programme on radionuclide distribution currently comprises annual surveys of the Bristol Channel/western English Channel and biennial surveys of the Irish Sea and the North Sea. The results of the 2009 cruises are presented in Figures 8.3 – 8.7. Shoreline sampling is also conducted around the UK, and the data are given in Table 8.19. Much of the shoreline sampling is directed at establishing whether the impacts of discharges from individual sites are

detectable. Where appropriate, commentary is found in the relevant site section.

A survey of the Irish Sea was conducted in July 2009. The caesium-137 data from this survey (Figure 8.3) show a band of higher concentrations along the coast to the north and south of Sellafield, with levels decreasing with distance from the coast. Slightly raised levels are evident to the south-east of the Isle of Man, possibly an indication of redissolution of caesium-137 from the eastern Irish Sea mud patch (McCubbin *et al.*, 2002). Overall concentrations have decreased since the last Irish Sea survey in 2007 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Protection Agency, 2008), when levels above 0.1 Bq l⁻¹ were observed, and are a fraction of their 1970s peak of up to 30 Bq l⁻¹ (Baxter *et al.*, 1992). Given the relative mobility of caesium in seawater, the higher levels observed close to the Sellafield outfall may be due to insufficient mixing following a discharge.

The predominant source of caesium-137 to the Irish Sea is now considered to be remobilisation into the water column from activity associated with seabed sediment. Discharges from Sellafield have decreased substantially since the commissioning of the SIXEP waste treatment process in the mid 1980s, and this has been reflected in a near exponential decrease in shoreline seawater concentrations at St Bees (Figure 8.8). Longer time series showing peak concentrations in the Irish Sea and, with an associated time-lag, the North Sea are also shown in Figure 8.8.

In 2008, very low activities of caesium-137 (<0.01 Bq l⁻¹) were found throughout the majority of the North Sea survey area (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2009), and these were only slightly above the global fallout levels in North Atlantic surface waters (~0.0012 Bq l⁻¹ in 2002, Bailly du Bois pers. comm.). Relatively high activities were observed at two stations close to the Norwegian Coast, characteristic of the input of Chernobyl-derived caesium-137 from the Baltic, via the Skaggeak. The 2008 survey also indicated a few anomalous results of slightly elevated caesium-137 in the southern North Sea. These are likely to have been outliers, or the outcome of complex water circulation from an unknown source (possibly Chernobyl-derived).

Concentrations of caesium-137 in the western English Channel (Figure 8.4) were slightly higher in 2009 (average activity 0.003 Bq l⁻¹) than in 2008. However, these are considerably lower than in both the Irish and North Seas, and to within experimental error are similar to the background level resulting from global fallout.

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

The concentrations of tritium observed in the Irish Sea during the July 2009 survey are shown in Figure 8.5. As expected, these are higher than those observed in the North Sea in 2008 (Environment Agency, Food Standards Agency, Northern

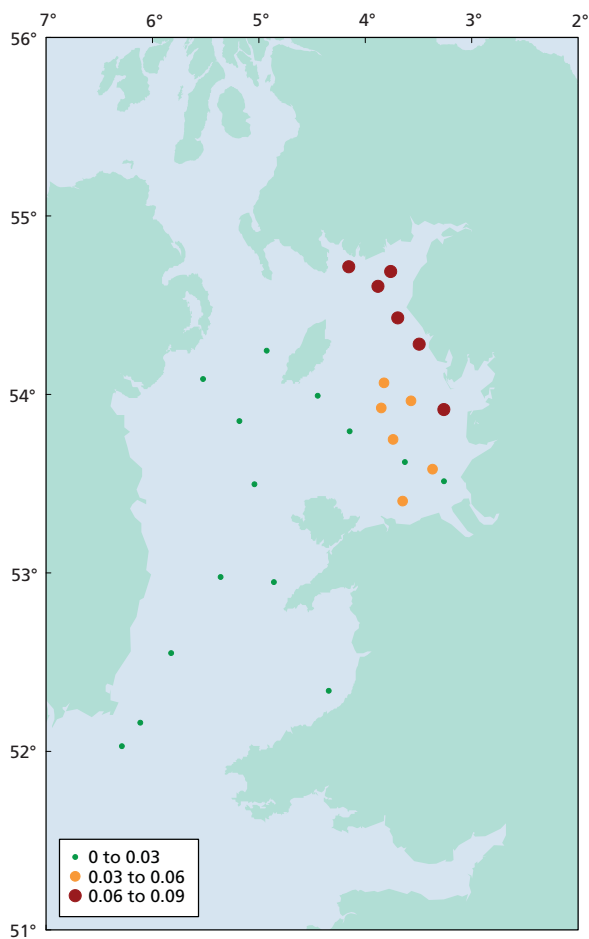


Figure 8.3. Concentrations (Bq l⁻¹) of caesium-137 in filtered surface water from the Irish Sea, July 2009

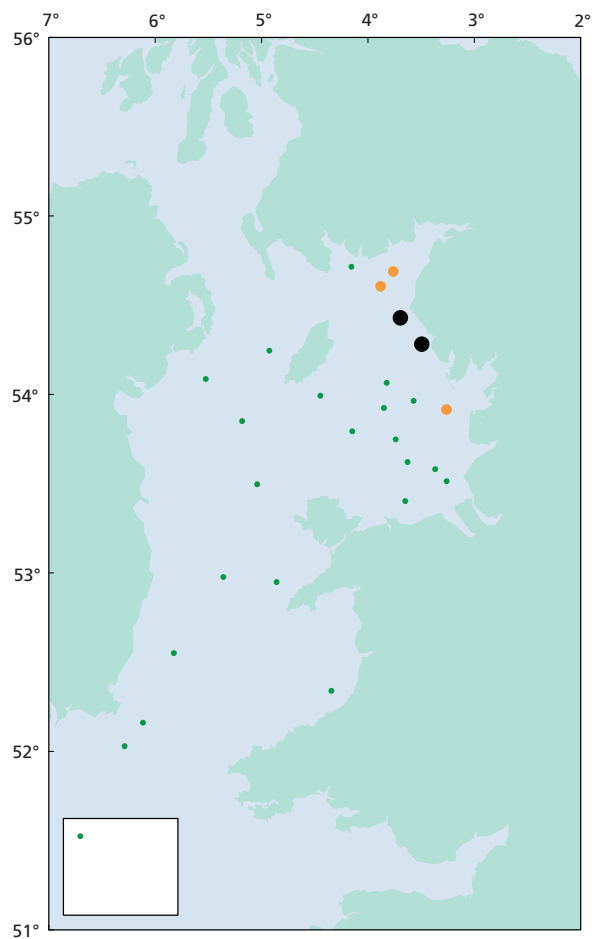


Figure 8.5. Concentrations (Bq l⁻¹) of tritium, in surface water, from the Irish Sea, July 2009

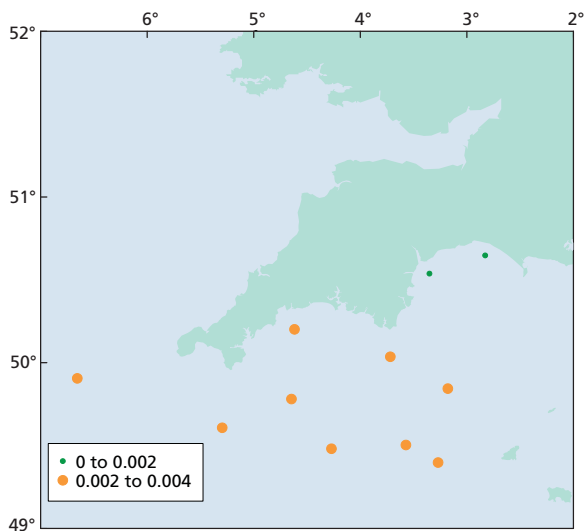


Figure 8.4. Concentrations (Bq l⁻¹) of caesium-137 in filtered surface water from the western English Channel, March 2009

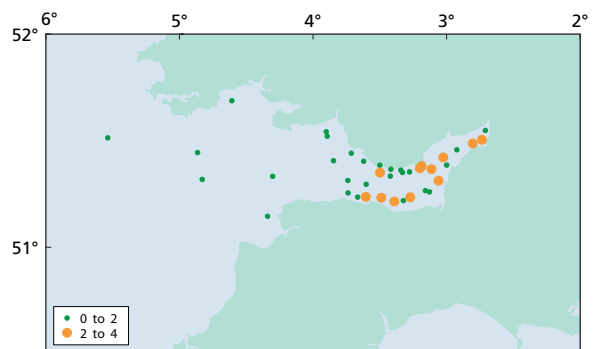


Figure 8.6. Concentrations (Bq l⁻¹) of tritium in surface water from the Bristol Channel, September 2009

Ireland Environment Agency and Scottish Environment Protection Agency, 2009) due to the influence of discharges from Sellafield and other nuclear sites. The majority of samples to the south and west of the Isle of Man contained tritium levels below the limit of detection.

In the Bristol Channel, the combined effect of tritium discharges from Cardiff, Berkeley, Oldbury and Hinkley Point remains evident in samples from points close to these installations (Figure 8.6). However, the general level is low and many samples were below the limits of detection. Tritium concentrations in the western English Channel were very low (Figure 8.7).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed from 1994 to their most recent peak in 2003. The results of research cruises to study this radionuclide have been published by Leonard *et al.*, (1997a, b; 2004) and McCubbin *et al.*, (2002, 2008). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al.* (1999). A full review of the quality status of the north Atlantic and a periodic evaluation of progress towards internationally agreed targets have been published by OSPAR (2000b; 2009b).

Samples of seawater were also collected as part of routine site and regional monitoring programmes. These are reported in the relevant sections of this report, and the analysis results are collated in Table 8.19. Most radionuclides are below limits

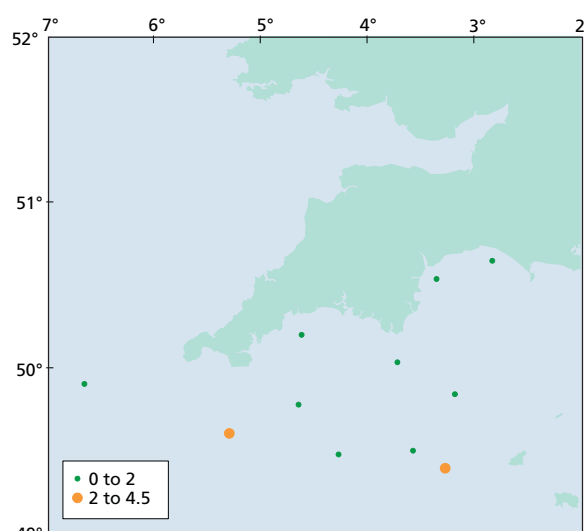


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water from the western English Channel, March 2009

of detection, and tritium and caesium-137 levels are consistent with those in Figures 8.3 – 8.7. An elevated tritium concentration was measured in a seawater sample collected during 2009 from the vicinity of the Heysham Harbour inlet. This sample was most likely collected shortly after a permitted discharge of tritiated effluent was made from one of the Heysham stations.

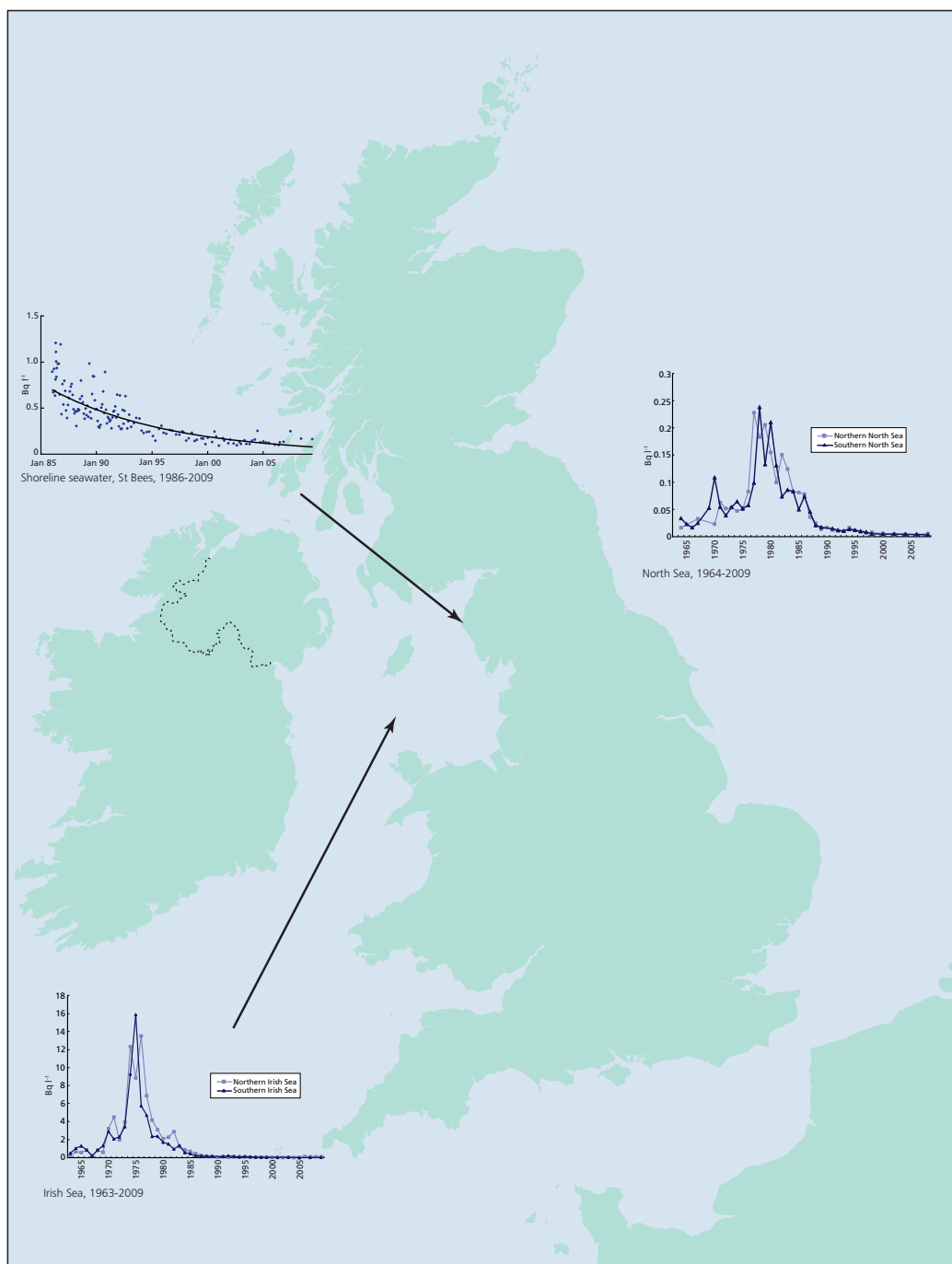


Figure 8.8. Concentration of caesium-137 in the Irish sea, North sea and in shoreline seawater close to Sellafield (at St. Bees)

Table 8.1. Mark and release monitoring of sheep in England, Wales and Scotland, 2009

	England	Wales	Scotland	United Kingdom
Number of sheep monitored	4404	76729	2095	83228
Number of sheep above action level	0	204	0	204
Percentage of sheep above action level	0	0.27	0	0.25
Number of farms under restriction	8	330	5	343
Approximate number of sheep	6000	180000	3000	189000
Approximate land area (ha)	12000	53000	7000	72000

Table 8.2. Concentrations of radiocaesium in the freshwater environment, 2009

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹	
			¹³⁴ Cs	¹³⁷ Cs
England				
Borrowdale	Rainbow trout	1	<0.08	0.28
Cogra Moss	Rainbow trout	2	<0.07	0.27
Narborough ^a	Rainbow trout	1	<0.09	0.15
Low Wath	Rainbow trout	1	<0.06	0.32
Devoke Water	Brown trout	1	<0.08	32
Devoke Water	Perch	1	<0.22	87
Gilcrux	Rainbow trout	1	<0.05	<0.04

^a The concentrations of ¹⁴C, ²³⁸Pu, ²³⁹⁺²⁴⁰Pu and ²⁴¹Am were 39, 0.000088, 0.00049 and 0.00087 Bq kg⁻¹ respectively

Table 8.3. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2009

Location	Material	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	¹⁰⁶ Ru	¹²⁹ I	¹³⁷ Cs
Guernsey											
	Mackerel	1				<0.06			<0.62		0.15
	Bass	1				<0.04			<0.38		0.34
	Crabs	1				0.04			<0.41		<0.04
	Lobsters	1				<0.08			<0.66		<0.06
	Limpets	1				<0.10			<1.1		<0.08
	Scallops	1				<0.07			<0.63		<0.06
	Ormers	1				<0.07			<0.73		<0.06
Fermain Bay	<i>Porphyra</i>	2				<0.12			<1.4		<0.11
Fermain Bay	<i>Fucus serratus</i>	2				<0.11	0.049	2.8	<1.2		<0.09
St. Sampson's Harbour	Mud	1				<0.27			<2.6		1.2
	Seawater	4									0.001
Jersey											
	Mackerel	1				<0.06			<0.56		0.13
	Pollack	2				<0.13			<1.3		<0.17
	Bass	1				<0.08			<0.85		0.27
	Crabs	1				<0.07			<0.80		<0.07
	Spiny spider crabs	1				0.33			<1.3		<0.11
	Lobsters	1				<0.06		0.52	<0.53		<0.05
La Rocque	Oysters	1				<0.04			<0.34		<0.03
La Rozel	Limpets	1				<0.07			<0.63		<0.05
	Scallops	2				<0.08			<0.47		<0.05
Plemont Bay	<i>Porphyra</i>	2				<0.16			<1.7		<0.13
La Rozel	<i>Fucus vesiculosus</i>	4				<0.10	0.10	5.4	<0.74		<0.08
Verclut	<i>Laminaria digitata</i>	4				<0.06			<0.57		<0.05
St Helier	Mud	1				2.5			<3.5		1.7
St Catherine's Bay	Seawater	1									0.001
Alderney											
	Crabs	2	<29	<25	49	<0.10		0.19	<0.73		<0.07
	Spiny spider crabs	1				0.34			<0.45		<0.04
	Lobsters	1				<0.08			<0.70		<0.07
	Toothed winkles	1	<25	<25	26	<0.16	<0.23		<1.7		<0.14
	<i>Fucus vesiculosus</i>	2								<0.45	
Quenard Point	<i>Fucus serratus</i>	4				<0.12	<0.056	3.8	<0.72		<0.06
Quenard Point	<i>Laminaria digitata</i>	4				<0.07			<0.67		<0.06
Little Crabbe Harbour	Sand	1				<0.25			<2.2		1.3
	Seawater	4		<4.4							<0.001

Table 8.3. continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^a , Bq kg ⁻¹							Gross beta
			¹⁴⁴ Ce	¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu + ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	
Guernsey										
	Mackerel	1	<0.25	<0.11	<0.000036	0.00010	0.00012	*	*	140
	Bass	1	<0.18	<0.08	0.000055	0.00011	0.00026	*	*	160
	Crabs	1	<0.20	<0.08	0.00025	0.00064	0.0020	*	0.00023	89
	Lobsters	1	<0.29	<0.12			<0.07			100
	Limpets	1	<0.42	<0.15			<0.08			59
	Scallops	1	<0.34	<0.16	0.00028	0.0013	0.0012	*	0.000085	140
	Ormers	1	<0.38	<0.17			<0.20			110
Fermain Bay	<i>Porphyra</i>	2	<0.50	<0.20	0.0012	0.0043	0.0061	0.000079	0.00058	190
Fermain Bay	<i>Fucus serratus</i>	2	<0.44	<0.17	0.0040	0.019	0.0067	*	0.00064	150
St. Sampson's Harbour	Mud	1	<1.4	<0.53	0.062	0.19	0.14	*	0.011	560
Jersey										
	Mackerel	1	<0.25	<0.10	0.000021	0.00017	0.00019	*	*	
	Pollack	2	<0.45	<0.17			<0.09			160
	Bass	1	<0.44	<0.19			<0.23			170
	Crabs	1	<0.38	<0.14	0.00025	0.00090	0.0032	*	0.00035	150
	Spiny spider crabs	1	<0.61	<0.24			<0.13			300
	Lobsters	1	<0.23	<0.09	0.00017	0.00052	0.0041	*	0.00040	91
La Rocque	Oysters	1	<0.15	<0.06	0.0011	0.0033	0.0030	*	0.00039	51
La Rozel	Limpets	1	<0.33	<0.15	0.0020	0.0055	0.0080	*	0.00067	84
	Scallops	2	<0.23	<0.10	0.0018	0.0053	0.0059	*	0.00056	160
Plemont Bay	<i>Porphyra</i>	2	<0.71	<0.27			<0.20			190
La Rozel	<i>Fucus vesiculosus</i>	4	<0.38	<0.19	0.0079	0.023	0.010	0.000057	0.00095	180
Verclut	<i>Laminaria digitata</i>	4	<0.31	<0.14			<0.17			150
St Helier	Mud	1	<2.2	<1.0	0.39	1.1	2.1	0.0052	0.20	680
Alderney										
	Crabs	2	<0.34	<0.16	0.00021	0.00071	0.0022	*	0.00067	100
	Spiny spider crabs	1	<0.20	<0.08	0.0011	0.0029	0.0044	*	0.00056	69
	Lobsters	1	<0.39	<0.18	0.00023	0.00079	0.0083	0.000032	0.0010	110
	Toothed winkles	1	<0.59	<0.21	0.0079	0.026	0.041	0.00031	0.0039	58
	<i>Fucus vesiculosus</i>	2								
Quenard Point	<i>Fucus serratus</i>	4	<0.36	<0.17	0.0022	0.0073	0.0026	<0.0000090	0.00031	230
Quenard Point	<i>Laminaria digitata</i>	4	<0.29	<0.15			<0.10			330
Little Crabbe Harbour	Sand	1	<1.4	<0.57			1.0			820

* Not detected by the method used

^a Except for seawater where units are Bq l⁻¹, and for sediment where dry concentrations apply

Table 8.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2009^a

Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
		⁶⁰ Co	⁹⁵ Zr	⁹⁵ Nb	⁹⁹ Tc	¹⁰⁶ Ru	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs
Aquatic samples									
Cod	4	<0.07	<0.29	<0.44		<0.63	<0.15	<0.07	3.1
Mackerel	4	<0.12	<0.62	<1.1		<1.2	<0.26	<0.12	1.4
Lobsters	4	<0.06	<0.25	<0.37	47	<0.55	<0.14	<0.06	0.35
Scallops	4	<0.07	<0.26	<0.36		<0.62	<0.15	<0.07	0.33
Seaweed ^c	4 ^E	<1.0	<1.6	<0.74	240	<6.5	<2.1	<0.73	<0.87
Sediment	1 ^E	<0.98	<2.6	<0.79		<7.3	<4.0	<0.93	6.1
Material	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
		¹⁴⁴ Ce	²³⁸ Pu	²³⁹ Pu + ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm	Gross alpha	Gross beta
Aquatic samples									
Cod	4	<0.32	0.00012	0.0010	0.0017	*	*		
Mackerel	4	<0.50	0.000093	0.00064	0.0012	*	0.000031		
Lobsters	4	<0.29			<0.13				150
Scallops	4	<0.32	0.017	0.10	0.026	*	*		
Seaweed ^c	4 ^E	<2.8			<1.0				
Sediment	1 ^E	<3.8			<1.3			<100	730
Material or selection ^d	No. of sampling observations ^e	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
		³ H	¹⁴ C	³⁵ S	⁶⁰ Co	⁹⁰ Sr	⁹⁹ Tc	¹⁰⁶ Ru	
Terrestrial samples									
Milk	2	<4.5	15	<0.40	<0.20	0.031	0.0070	<1.2	
Milk max		<4.8	16	<0.45		0.035		<1.4	
Cabbage	1	<4.0	<3.0	1.1	<0.20	0.053	<0.020	<1.0	
Potatoes	1	<5.0	16	<0.20	<0.20	0.026	0.037	<1.6	
Rhubarb	1	<5.0	9.0	<0.20	<0.20	0.51		<0.70	
Material or selection ^d	No. of sampling observations ^e	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹							
		¹²⁵ Sb	¹²⁹ I	Total Cs	²³⁸ Pu	²³⁹ Pu + ²⁴⁰ Pu	²⁴¹ Pu	²⁴¹ Am	
Terrestrial samples									
Milk	2	<0.35	<0.0080	0.077	<0.00010	<0.00020	<0.052	<0.00010	
Milk max				0.089					
Cabbage	1	<0.40	<0.025	0.021	<0.00020	0.00020	<0.047	<0.00020	
Potatoes	1	<0.50	<0.032	0.044	<0.00020	0.00010	<0.051	<0.00020	
Rhubarb	1	<0.20		0.072					

* Not detected by the method used

^a The gamma dose rate in air at 1m over sand and stones at Ramsey^F was 0.095 µGy h⁻¹

^b Except for milk where units are Bq l⁻¹, and sediment where dry concentrations apply

^c The concentrations of ²³⁴U, ²³⁵U and ²³⁸U were 2.5, <0.18 and 2.0 Bq kg⁻¹ respectively

^d Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.

If no 'max' value is given the mean value is the most appropriate for dose assessments

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

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

Table 8.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2009^a

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹					
			¹⁴ C	⁶⁰ Co	⁹⁹ Tc	¹²⁵ Sb	¹³⁴ Cs	¹³⁷ Cs
Cod	Kilkeel	4	40	<0.06		<0.15	<0.06	1.2
Plaice	Kilkeel	4		<0.06		<0.14	<0.06	0.51
Haddock	Kilkeel	4		<0.07		<0.17	<0.07	0.88
Herring	Ardglass	2		<0.10		<0.25	<0.11	1.0
Spurdog	North coast	4		<0.08		<0.18	<0.08	1.8
Spurdog	Kilkeel	4		<0.13		<0.28	<0.13	1.6
Crabs	Kilkeel	4		<0.10		<0.21	<0.10	0.28
Lobsters	Ballycastle	2		<0.03	30	<0.08	<0.03	0.21
Lobsters	Kilkeel	4		<0.05	14	<0.11	<0.05	0.24
<i>Nephrops</i>	Kilkeel	4		<0.12	12	<0.24	<0.12	0.82
Winkles	Minerstown	4		<0.14		<0.31	<0.14	0.31
Mussels	Carlingford Lough	2		<0.10	6.2	<0.23	<0.11	0.50
Scallops	Co. Down	2		<0.08		<0.17	<0.08	0.30
<i>Ascophyllum nodosum</i>	Ardglass	1		<0.16		<0.37	<0.17	0.45
<i>Ascophyllum nodosum</i>	Carlingford Lough	1		<0.10		<0.23	<0.11	0.26
<i>Fucus</i> spp.	Carlingford Lough	3		<0.07	57	<0.13	<0.07	0.58
<i>Fucus</i> spp.	Portrush	3		<0.08		<0.15	<0.08	0.15
<i>Fucus vesiculosus</i>	Ardglass	3		<0.10	220	<0.20	<0.10	0.52
<i>Rhodomenia</i> spp.	Strangford Lough	4		<0.16	4.9	<0.28	<0.15	0.82
Mud	Carlingford Lough	2		<0.72		<2.2	<0.96	45
Mud	Dundrum Bay	2		<0.65		<1.7	<0.88	5.5
Mud	Oldmill Bay	2		<0.78		<2.3	<0.95	38
Mud	Strangford Lough-Nicky's point	2		<0.60		<1.9	<0.88	25
Mud	Ballymacormick	2		<0.58		<1.6	<0.76	14
Mud	Carrichue	1		<0.39		<1.0	<0.47	0.71
Mud and sand	Carrichue	1		<0.42		<1.2	<0.60	2.4
Sand	Portrush	2		<0.34		<0.90	<0.46	0.78
Seawater	North of Larne	12			0.0035		*	0.02

Table 8.5(a). continued

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh) ^b , Bq kg ⁻¹					
			¹⁵⁵ Eu	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am	²⁴² Cm	²⁴³ Cm+ ²⁴⁴ Cm
Cod	Kilkeel	4	<0.14			<0.16		
Plaice	Kilkeel	4	<0.13			<0.10		
Haddock	Kilkeel	4	<0.17			<0.20		
Herring	Ardglass	2	<0.26			<0.27		
Spurdog	North coast	4	<0.17			<0.14		
Spurdog	Kilkeel	4	<0.21			<0.13		
Crabs	Kilkeel	4	<0.15			<0.08		
Lobsters	Ballycastle	2	<0.06			0.12		
Lobsters	Kilkeel	4	<0.09			<0.07		
<i>Nephrops</i>	Kilkeel	4	<0.17	0.0032	0.020	0.059	0.000093	0.000056
Winkles	Minerstown	4	<0.20	0.025	0.14	0.18	*	0.00025
Mussels	Carlingford Lough	2	<0.18			<0.17		
Scallops	Co. Down	2	<0.15			<0.14		
<i>Ascophyllum nodosum</i>	Ardglass	1	<0.37			<0.47		
<i>Ascophyllum nodosum</i>	Carlingford Lough	1	<0.26			<0.28		
<i>Fucus</i> spp.	Carlingford Lough	3	<0.11			<0.08		
<i>Fucus</i> spp.	Portrush	3	<0.13			<0.12		
<i>Fucus vesiculosus</i>	Ardglass	3	<0.15			<0.11		
<i>Rhodomenia</i> spp.	Strangford Lough	4	<0.21	0.042	0.24	0.38	0.00077	0.00062
Mud	Carlingford Lough	2	<2.3	1.7	11	6.9	*	0.0056
Mud	Dundrum Bay	2	<1.7			2.5		
Mud	Oldmill Bay	2	<1.9			26		
Mud	Strangford Lough-Nicky's point	2	<1.6			9.2		
Mud	Ballymacormick	2	<1.5			12		
Mud	Carrichue	1	<1.5	0.069	0.47	0.76	*	0.00087
Mud and sand	Carrichue	1	<1.3			1.9		
Sand	Portrush	2	<0.93			<0.90		

* Not detected by the method used

^a All measurements are made on behalf of the Northern Ireland Environment Agency^b Except for seawater where units are Bq l⁻¹, and for sediment where dry concentrations apply

Table 8.5(b). Monitoring of radiation dose rates in Northern Ireland, 2009^a

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu\text{Gy h}^{-1}$
Lishally	Mud	1	0.061
Eglinton	Shingle	1	0.053
Carrichue	Mud	1	0.057
Bellerena	Mud	1	0.061
Benone	Sand	1	0.062
Castlerock	Sand	1	0.061
Portstewart	Sand	1	0.062
Portrush, Blue Pool	Sand	1	0.059
Portrush, White Rocks	Sand	1	0.061
Portballintrae	Sand	1	0.057
Giant's Causeway	Sand	1	0.058
Ballycastle	Sand	1	0.057
Cushendun	Sand	1	0.062
Cushendall	Sand and stones	1	0.071
Red Bay	Sand	1	0.064
Carnlough	Sand	1	0.063
Glenarm	Sand	1	0.056
Half Way House	Sand	1	0.057
Ballygally	Sand	1	0.058
Drains Bay	Sand	1	0.059
Larne	Sand	1	0.062
Whitehead	Sand	1	0.059
Carrickfergus	Sand	1	0.061
Jordanstown	Sand	1	0.058
Helen's Bay	Sand	1	0.059
Groomspoint	Sand	1	0.070
Millisle	Sand	1	0.076
Ballywalter	Sand	1	0.068
Ballyhalbert	Sand	1	0.067
Cloghy	Sand	1	0.075
Portaferry	Shingle and stones	1	0.090
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.090
Ards Maltings	Mud	1	0.083
Island Hill	Mud	1	0.070
Nicky's Point	Mud	1	0.093
Strangford	Shingle and stones	1	0.10
Kilclief	Sand	1	0.072
Ardglass	Mud	1	0.089
Killough	Mud	1	0.084
Rocky Beach	Sand	1	0.084
Tyrella	Sand	1	0.078
Dundrum	Sand	1	0.085
Newcastle	Sand	1	0.091
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.084
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.087
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.097

^a All measurements are made on behalf of the Northern Ireland Environment Agency

Table 8.6. Concentrations of radionuclides in regional diet (TDS survey), 2009^a

Country	Town	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹								
			³ H	¹⁴ C	³⁵ S	⁶⁰ Co	⁴⁰ K	⁹⁰ Sr	¹³⁷ Cs	²¹⁰ Pb	²¹⁰ Po
England	Heywood	1	<2.0	14	<0.17	<0.05	60	0.041	0.02	0.011	0.023
England	Ashington	1	<2.4	25	<0.41	<0.07	70	0.045	<0.07	0.0080	0.027
England	Morley	1	<2.4	30	<0.28	<0.05	70	<0.059	<0.05	0.010	0.026
England	Sutton in Ashfield	1	<2.5	<16	<0.20	<0.07	60	<0.062	<0.06	0.0080	0.028
England	Harlow	1	<2.4	<15	<0.22	<0.05	70	0.052	0.03	0.017	0.014
England	Gerrards Cross	1	<2.5	21	<0.15	<0.07	60	<0.074	0.05	0.0074	0.024
England	Norbury	1	<2.3	23	<0.20	<0.05	70	<0.074	0.02	0.012	0.057
Wales	Port Talbot	1	<2.4	18	<0.22	<0.07	70	<0.078	<0.06	0.020	0.052
England	Dartmouth	1	<2.4	19	<0.27	<0.06	60	<0.061	<0.05	<0.010	0.023
England	Stourport-on-Severn	1	<2.3	22	<0.26	0.03	70	<0.072	<0.04	0.0030	0.010
Northern Ireland	Banbridge	1	<2.4	18	<0.28	<0.05	70	<0.081	0.03	0.0080	0.032
Mean			<2.4	<20	<0.24	<0.06	66	<0.064	<0.04	<0.010	0.029

Country	Town	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹							
			²²⁶ Ra	²³² Th	²³⁴ U	²³⁵ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu+ ²⁴⁰ Pu	²⁴¹ Am
England	Heywood	1	0.029	<0.00036	0.019	<0.00090	0.020	<0.00013	<0.00011	0.00028
England	Ashington	1	0.033	0.00090	0.016	<0.00060	0.015	<0.00013	0.00016	<0.00011
England	Morley	1	0.037	0.00056	0.017	<0.00060	0.014	<0.00015	0.000078	0.00025
England	Sutton in Ashfield	1	0.029	0.00041	0.021	0.0010	0.023	<0.00071	<0.00051	0.00037
England	Harlow	1	0.024	0.00070	0.0090	<0.00050	0.0095	<0.00026	<0.00025	0.00021
England	Gerrards Cross	1	0.055	0.0024	0.011	<0.00040	0.0094	<0.0028	<0.0017	0.00029
England	Norbury	1	0.028	0.00042	0.012	<0.00060	0.012	<0.0010	<0.00081	<0.00015
Wales	Port Talbot	1	0.031	0.00046	0.012	<0.00090	0.0087	<0.0017	<0.0024	0.00050
England	Dartmouth	1	0.027	0.0034	0.012	<0.00070	0.011	0.0010	0.0013	0.00067
England	Stourport-on-Severn	1	0.037	0.00081	0.015	<0.00060	0.012	0.00027	<0.00038	0.00027
Northern Ireland	Banbridge	1	0.020	0.00068	0.012	<0.00070	0.014	0.00013	0.00039	0.00075
Mean			0.032	<0.0010	0.014	<0.00068	0.014	<0.00075	<0.00074	<0.00035

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

Table 8.7. Estimates of radiation exposure from radionuclides in diet, 2009^a

Region	Mean ^b exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides ^c	Naturally occurring radionuclides ^d	All radionuclides	Location	All radionuclides
England	0.001	0.021	0.022	Norbury	0.035
Wales	0.002	0.033	0.035	Port Talbot	0.035
Northern Ireland	0.001	0.019	0.021	Banbridge	0.021
Scotland ^e	0.001		0.001	Dingwall	0.002
UK	0.001	0.022	0.023	Norbury	0.035

^a Assessments of dose are based on some concentration results at limits of detection.
Exposures due to potassium-40 content of diet are not included here because they do not vary according to the potassium-40 content of diet.

Levels of potassium are homeostatically controlled. The average annual dose from potassium-40 in general diet is 0.17mSv which is in addition to the above figures

^b Average of the doses to the most exposed age group at each location

^c Including tritium

^d Including carbon-14

^e Analysis of naturally occurring radionuclides was not undertaken

Table 8.8. Concentrations of radionuclides in canteen meals, 2009^a

Region	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg ⁻¹			
		¹⁴ C	⁴⁰ K	⁹⁰ Sr	¹³⁷ Cs
England	4	27	88	0.065	0.03
Northern Ireland	4	21	110	<0.080	<0.05
Scotland	12	<27		<0.040	<0.03
Wales	4	29	80	<0.068	<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 8.9. Concentrations of radionuclides in milk remote from nuclear sites, 2009

Location	Selection ^a	No. of farms/dairies ^b	Mean radioactivity concentration, Bq l ⁻¹			
			³ H	¹⁴ C	⁹⁰ Sr	Total Cs
Co. Antrim		1	<4.0	20	0.019	0.15
Co. Armagh		1	<4.0	21	0.023	0.14
Cambridgeshire		1	<2.3	15	<0.014	0.071
Cardiganshire		1	<4.0	18	0.036	0.077
Cheshire		1	<5.0	18	0.018	0.13
Clwyd		1	<2.4	16	0.023	0.079
Cornwall		1	<4.0	20	0.025	0.074
Devon		1	<4.0	17	0.030	0.063
Dorset		1	<4.5	9.5	0.016	0.088
Co. Down		1	<5.0	20	0.026	0.12
Essex		1	<4.5	17	0.019	0.078
Co. Fermanagh		1	<4.5	18	0.022	0.10
Gloucestershire		1	<4.5	18	0.026	0.078
Guernsey		1	<3.2	12	0.019	0.078
Gwent		1	<2.2	17	0.026	0.069
Gwynedd		1	<4.0	20	0.025	0.050
Hampshire		1	<4.5	18	0.017	0.068
Humberside		1	<4.5	19	0.019	0.064
Kent		1			0.022	0.082
Kirkcudbrightshire		1	<5.0	<15	<0.10	<0.05 ^c
Lanarkshire		1			0.028	0.03 ^c
Lancashire		1	<4.5	16	0.021	0.088
Leicestershire		1	<4.0	18	0.018	0.076
Lincolnshire		1	<4.0	22	0.014	0.084
Middlesex		1	<4.5	20	0.018	0.066
Midlothian		1	<5.0	<28	<0.10	<0.05 ^c
Nairnshire		1	<5.7	<15	<0.10	<0.05 ^c
Norfolk		1	<4.5	17	0.017	0.068
North Yorkshire		1	<4.5	18	0.019	0.069
Renfrewshire		1	<5.0	<15	<0.10	<0.05 ^c
Tyneside		1	<4.0	26	0.021	0.078
Co. Tyrone		2	<2.8	17	0.019	0.12
	max		<5.0	18	0.021	0.13
Mean Values						
Channel Islands			<3.2	12	0.019	0.078
England			<4.2	18	<0.020	<0.078
Northern Ireland			<4.1	19	0.022	0.13
Wales			<3.2	18	0.028	0.069
Scotland			<5.2	<18	<0.086	<0.05 ^c
United Kingdom			<4.2	<18	<0.039	<0.081

^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 ¹³⁷Cs only

Table 8.10. Concentrations of radionuclides in animals and crops remote from nuclear sites, 2009^a

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg ⁻¹						
			³ H	¹⁴ C	⁹⁰ Sr	Total Cs	²¹⁰ Pb	²¹⁰ Po	²²⁶ Ra
Cambridgeshire									
St Neots	Chard	1	<5.0	7.0	0.15	0.14	0.86	0.27	0.079
	Potatoes	1	<5.0	11	0.010	0.039	<0.041	0.010	0.0040
Ceredigion									
Aberaeron	Lettuce/spinach	1	<4.0	4.0	0.37	0.071	0.34	0.16	0.083
	Potatoes	1	<5.0	20	0.036	0.079	<0.028	0.0047	0.010
Channel Islands									
Guernsey	Blackberries	1	<4.0	18	0.073	0.028	0.084	0.031	0.022
	Lettuce	1	<4.0	4.0	0.070	<0.017	<0.067	0.040	0.014
Jersey	Potatoes	1	<4.0	19	0.039	0.064			
	Strawberries	1	<4.0	10	0.029	0.043			
Cheshire									
Crewe	Leaf Beet	1	<5.0	7.0	1.2	0.082	1.0	0.38	0.17
	Raspberries	1	<4.0	14	0.076	0.021	<0.032	0.034	0.010
Cornwall									
Truro	Carrots/Potatoes	1	<4.0	9.0	0.046	0.084	0.048	0.0071	0.034
	Lettuce	1	<4.0	7.0	0.19	0.11	0.25	0.086	0.0020
Cumbria									
Penrith	Cabbage	1	<4.0	10	0.11	0.051	0.20	0.067	0.019
	Raspberries	1	<4.0	10	0.065	0.028	<0.038	0.024	0.035
Devon									
Newton Abbot	Chard	1	<4.0	5.0	0.70	0.096	0.36	0.17	0.17
	Strawberries	1	<4.0	10	0.075	0.057	0.032	0.021	0.025
Dumfriesshire									
Dumfries	Mixed diet	4			<0.10	<0.05 ^b			
East Lothian									
North Berwick	Mixed diet	4			<0.10	<0.05 ^b			
Hampshire									
Brockenhurst	Potatoes	1	<4.0	17	0.021	0.052	0.21	0.012	0.011
	Spring cabbage	1	<4.0	11	0.33	0.019	0.11	0.046	0.021
Herefordshire									
Hereford	Cabbage	1	<5.0	<3.0	0.41	<0.014	0.13	0.047	0.048
	Potatoes	1	<5.0	23	0.014	0.019	0.057	<0.0029	0.012
Monmouthshire									
Abergavenny	Cabbage	1	<5.0	<3.0	1.1	0.098	0.13	0.059	0.078
	Raspberries	1	<4.0	8.0	0.076	0.021	0.081	0.038	0.0050
Norfolk									
Downham Market	Spinach	1	4.0	6.0	0.11	0.034	0.13	0.079	0.031
	Strawberries	1	<4.0	12	0.026	0.038	0.042	0.0077	0.034
North Yorkshire									
Malton	Cabbage	1	<4.0	19	0.17	<0.012	<0.033	0.025	0.027
	Raspberries	1	<4.0	18	0.024	<0.012	<0.034	0.012	0.013
Northumberland									
Berwick-Upon-Tweed	Cabbage	1	<4.0	<3.0	0.12	0.092	0.14	0.031	0.014
	Potatoes	1	<5.0	16	0.017	0.084	0.092	0.0039	<0.0020
Nottinghamshire									
Worksop	Potatoes	1	<5.0	11	0.014	0.042	<0.035	0.0049	0.0080
	Spinach	1	<5.0	<3.0	0.19	0.093	0.79	0.23	0.072
Redcar & Cleveland									
Guisborough	Cabbage	1	<5.0	8.0	0.22	<0.015	0.084	0.020	0.041
	Potatoes	1	<5.0	11	0.034	<0.016	<0.033	0.0063	0.015
Renfrewshire									
Paisley	Mixed diet	4			<0.10	<0.05 ^b			
Ross-shire									
Dingwall	Mixed diet	4			<0.10	<0.10 ^b			
Shropshire									
Telford	Lettuce	1	<4.0	<3.0	0.14	0.020	0.19	0.061	0.020
	Potatoes	1	<5.0	22	0.026	<0.013	0.047	0.0073	0.0040
Somerset									
Midsomer Norton	Mustard greens	1	<4.0	9.0	0.22	0.12	0.062	0.078	0.069
	Potatoes	1	<4.0	18	0.013	0.067	<0.035	0.0095	0.0070
Surrey									
Weybridge	Bovine Kidney	1	<8.0	29	0.17	0.29			
	Bovine Liver	1	<7.0	20	0.044	0.57			
	Bovine Muscle	1	<6.0	16	0.048	0.42			
	Ovine Kidney/Liver	1	9.0	31	0.23	0.25			
	Ovine Muscle	1	<5.0	45	<0.0070	0.16			
Worcestershire									
Worcester	Gooseberries	1	4.0	16	0.021	0.034	0.076	0.023	0.0070
	Lettuce	1	5.0	<3.0	0.13	0.028	0.18	0.090	0.022
Mean Values ^c									
Channel Islands			<4.0	13	0.053	<0.038	<0.076	0.036	0.018
England			<4.8	<13	<0.15	<0.092	<0.18	<0.062	<0.034
Wales			<4.5	<8.8	0.40	0.067	<0.14	0.065	0.044
Scotland					<0.10	<0.063 ^b			
Great Britain			<4.7	<13	<0.17	<0.087	<0.18	<0.062	<0.035

Table 8.10. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg ⁻¹						
			²³² Th	²³⁴ U	²³⁵ U	²³⁸ U	²³⁹ Pu+ ²³⁸ Pu	²⁴⁰ Pu	²⁴¹ Am
Cambridgeshire									
St Neots	Chard	1	0.016	0.022	0.00060	0.019			
	Potatoes	1	<0.0014						
Ceredigion									
Aberaeron	Lettuce/spinach	1	0.0033						
	Potatoes	1	0.0036	0.0069	<0.00080	0.0051			
Channel Islands									
Guernsey	Blackberries	1	<0.0017				<0.00010	0.00010	<0.00030
	Lettuce	1	0.0013	0.0058	<0.00060	0.0048	<0.00010	<0.00010	0.00020
Jersey	Potatoes	1					<0.00010	0.00010	<0.00030
	Strawberries	1					<0.00010	<0.00010	0.00040
Cheshire									
Crewe	Leaf Beet	1	0.046						
	Raspberries	1	<0.00070						
Cornwall									
Truro	Carrots/Potatoes	1	0.0012						
	Lettuce	1	0.0062						
Cumbria									
Penrith	Cabbage	1	<0.0012						
	Raspberries	1	<0.00090						
Devon									
Newton Abbot	Chard	1	0.016						
	Strawberries	1	0.0019	0.0015	<0.00080	<0.0012			
Hampshire									
Brockenhurst	Potatoes	1	0.0073						
	Spring cabbage	1	<0.0011	0.0036	0.00080	0.0017			
Herefordshire									
Hereford	Cabbage	1	0.0061						
	Potatoes	1	0.0063						
Monmouthshire									
Abergavenny	Cabbage	1	0.0063						
	Raspberries	1	<0.00080						
Norfolk									
Downham Market	Spinach	1	0.0052						
	Strawberries	1	<0.0010						
North Yorkshire									
Malton	Cabbage	1	0.0011						
	Raspberries	1	<0.0012	0.0022	<0.00070	<0.0012			
Northumberland									
Berwick-Upon-Tweed	Cabbage	1	<0.0010						
	Potatoes	1	<0.0012	0.0045	<0.0006	0.0042			
Nottinghamshire									
Worksop	Potatoes	1	0.0028	0.0025	0.00070	0.0029			
	Spinach	1	0.012						
Redcar & Cleveland									
Guisborough	Cabbage	1	<0.0010						
	Potatoes	1	0.0024						
Shropshire									
Telford	Lettuce	1	0.010	0.020	<0.00080	0.019			
	Potatoes	1	<0.0010						
Somerset									
Midsomer Norton	Mustard greens	1	0.025	0.036	0.0011	0.033			
	Potatoes	1	0.0048						
Surrey									
Weybridge	Bovine Kidney	1		0.0062	0.0018	0.0047	<0.00010	0.00020	0.0010
	Bovine Liver	1					<0.00010	0.00010	<0.00030
	Bovine Muscle	1					<0.00010	<0.00010	<0.00030
	Ovine Kidney/Liver	1					0.00010	0.00060	0.00030
	Ovine Muscle	1					<0.00010	<0.00010	<0.00030
Worcestershire									
Worcester	Gooseberries	1	<0.00080	<0.00080	<0.00050	0.00090			
	Lettuce	1	0.0031						
Mean Values^c									
Channel Islands			<0.0015	0.0058	<0.00060	0.0048	<0.00010	<0.00010	<0.00030
England			<0.0062	<0.0099	<0.00084	<0.0088	<0.00010	<0.00022	<0.00044
Wales			<0.0035	0.0069	<0.00080	0.0051			
Scotland									
Great Britain			<0.0059	<0.0097	<0.00084	<0.0084	<0.00010	<0.00022	<0.00044

^a Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection

^b ¹³⁷Cs only

^c Great Britain mean excludes Channel Islands. Mean values include crops and animals

Table 8.11. Concentrations of caesium-137 in imported foods monitored at ports, 2009

Port	Country of origin	Foodstuff	No. of sampling observations	Mean radioactivity concentration, Bq kg ⁻¹ (fresh) ^a ¹³⁷ Cs	Dilution factor
Dover					
	Ukraine	Blueberries	1	140	Nil
Felixstowe					
	Holland	Blueberry juice concentrate	2	520	0.05

^a Except for juice concentrates where the units are Bq l⁻¹

Table 8.12. Concentrations of radionuclides in rainwater and air 2009

Location	Sample	Number of sampling observations	Mean radioactivity concentration ^a				
			³ H	⁷ Be	⁷ Be ^d	⁹⁰ Sr ^b	¹³⁷ Cs
Ceredigion							
	Aberporth	Rainwater	4	<1.2	1.3		<0.016
		Air	3		0.0019		<4.2 10 ⁻⁷
Co. Down							
	Conlig	Rainwater	4		1.1		<0.016
		Air	3		0.0020		<6.3 10 ⁻⁷
Dumfries and Galloway							
	Eskdalemuir	Rainwater	4	<1.3	0.94		<0.0094
		Air	4		0.0014		<5.1 10 ⁻⁷
Glasgow							
	Glasgow	Air	12				<0.010
North Yorkshire							
	Dishforth	Rainwater	4		1.2		<0.017
		Air	4		0.0014		<6.6 10 ⁻⁷
Oxfordshire							
	Chilton	Rainwater	4		1.5	<4.8 10 ⁻⁴	<0.026
		Air	12		0.0017		<3.3 10 ⁻⁷
Shetland							
	Lerwick	Rainwater	4		1.3		<0.016
		Air	4		0.0017		<5.7 10 ⁻⁷
Suffolk							
	Orfordness	Rainwater	4	<1.2	2.4		<0.020
		Air	4		0.0020		<6.9 10 ⁻⁷
Location	Sample	Number of sampling observations	Mean radioactivity concentration ^a				
			¹³⁷ Cs ^d	²³⁹ Pu+ ²⁴⁰ Pu ^c	²⁴¹ Am ^c	Gross alpha ^d	Gross beta ^d
Ceredigion							
	Aberporth	Rainwater	4	<2.0 10 ⁻⁵	<2.0 10 ⁻⁵		
		Air	3	<1.0 10 ⁻⁹	<3.0 10 ⁻⁹		
Glasgow							
	Glasgow	Air	12				<0.0020
Oxfordshire							
	Chilton	Rainwater	4	<0.0016		<0.018	<0.13

^a Bq l⁻¹ for rainwater and Bq kg⁻¹ for air. 1.2 kg air occupies 1 m³ at standard temperature and pressure

^b Bulkied from 4 quarterly samples

^c Separate annual sample for rain, annual bulkied sample for air

^d Bulkied from 12 monthly samples

Table 8.13. Concentrations of radionuclides in sources of drinking water in Scotland, 2009

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹				
			³ H	⁹⁰ Sr	¹³⁷ Cs	Gross alpha	Gross beta
Angus	Loch Lee	4	<1.3	<0.0039	<0.01	<0.032	<0.050
Argyll and Bute	Auchengaich	1	<1.3		<0.01	<0.010	0.065
Argyll and Bute	Helensburgh Reservoir	1	<1.3		<0.01	<0.010	0.024
Argyll and Bute	Loch Ascog	1	<1.3		<0.01	<0.010	0.12
Argyll and Bute	Loch Eck	1	<1.3		<0.01	<0.010	0.021
Argyll and Bute	Loch Finlas	1	<1.3		<0.01	<0.010	0.038
Clackmannanshire	Gartmorn	1	<1.3		<0.01	<0.010	0.078
Dumfries and Galloway	Black Esk	1	<1.1		<0.01	<0.010	0.038
Dumfries and Galloway	Purdomstone	1	2.0		<0.01	<0.011	0.088
Dumfries and Galloway	Winterhope	1	3.1		<0.01	<0.010	0.046
East Lothian	Hopes Reservoir	1	<1.2		<0.01	0.016	0.031
East Lothian	Thorters Reservoir	1	<1.2		<0.01	<0.010	0.038
East Lothian	Whiteadder	1	<1.2		<0.01	<0.010	0.042
Fife	Holl Reservoir	1	<1.3		<0.01	<0.010	0.038
Highland	Loch Baligill	1	<1.2		<0.01	<0.010	0.034
Highland	Loch Calder	1	<1.2		<0.01	<0.010	0.084
Highland	Loch Glass	4	<1.2	<0.0045	<0.01	<0.011	0.048
Highland	Loch Shurrerey	1	<1.2		<0.01	<0.010	0.047
North Ayrshire	Camphill	1	<1.2		<0.01	<0.010	0.019
North Ayrshire	Knockendon Reservoir	1	<1.1		<0.01	<0.010	0.022
North Ayrshire	Munnoch Reservoir	1	<1.3		<0.01	<0.010	0.053
North Ayrshire	Outerwards	1	<1.1		<0.01	<0.010	0.017
Orkney Islands	Heldale Water	1	<1.2		<0.01	<0.010	0.047
Perth and Kinross	Castlehill	1	<1.3		<0.01	<0.010	0.069
Scottish Borders	Knowesdean	4	<1.2	<0.0050	<0.01	<0.033	<0.11
Stirling	Loch Katrine	12	<1.1	0.0044	<0.002	<0.0079	<0.030
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.1		<0.01	<0.010	0.019
West Lothian	Morton No 2	1	<1.2		<0.01	<0.010	0.037

Table 8.14. Concentrations of radionuclides in sources of drinking water in England and Wales, 2009

Location	Sample source	No. of sampling observations	Mean radioactivity concentration , Bq l ⁻¹			
			³ H	⁴⁰ K	⁹⁰ Sr	¹²⁵ I
England						
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.033	<0.0010	
Cambridgeshire	Grafham Water	4	<4.0	0.30	0.0018	
Cheshire	River Dee, Chester	3	<4.0	0.077	0.0027	<0.0035
Cornwall	River Fowey	4	<4.0	0.051	<0.0010	<0.0020
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.070	0.0024	
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.053	0.0036	
County Durham	River Tees, Darlington	4	<4.0	0.044	0.0029	<0.0020
Cumbria	Haweswater Reservoir	4	<4.0	<0.024	0.0020	
Cumbria	Ennerdale Lake	4	<4.0	<0.016	0.0020	
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.028	0.0017	
Derbyshire	Matlock, Groundwater ^a	4	<4.0	0.058	0.0010	
Devon	River Exe, Exeter	4	<4.0	0.081	0.0015	<0.0030
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.15	0.0022	<0.0023
Greater London	River Lee, Chingford	4	<4.0	0.28	<0.0011	<0.0020
Hampshire	River Avon, Christchurch	4	<4.0	0.075	<0.0010	<0.0027
Humberside	Littlecoates, Groundwater	4	<4.0	0.13	<0.0010	
Kent	Denge, Shallow Groundwater	4	<4.0	0.13	0.0022	
Kent	Chatham, Deep Groundwater	4	<4.0	0.048	<0.0010	
Lancashire	Corn Close, Groundwater	4	<4.0	0.11	<0.0010	
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.11	0.0013	<0.0023
Northumberland	Kielder Reservoir	4	<4.0	<0.036	0.0026	
Oxfordshire	River Thames, Oxford	4	<4.0	0.16	<0.0010	<0.0022
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.091	<0.0010	
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.14	0.0017	
Surrey	River Thames, Walton	4	<4.0	0.20	<0.0013	<0.0021
Surrey	River Thames, Chertsey	4	<4.0	0.21	<0.0010	<0.0021
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	4	<4.0	0.12	0.0043	
Yorkshire	Chellow Heights, Bradford	4	<4.0	<0.020	0.0030	

Location	Sample source	No. of sampling observations	Mean radioactivity concentration , Bq l ⁻¹			
			¹³⁷ Cs	Gross alpha	Gross beta ¹	Gross beta ²
England						
Buckinghamshire	Bourne End, Groundwater	4	<0.0010	<0.019	0.054	<0.050
Cambridgeshire	Grafham Water	4	<0.0010	0.023	0.42	0.27
Cheshire	River Dee, Chester	3	0.0039	0.033	0.13	0.082
Cornwall	River Fowey	4	<0.0010	0.022	0.095	0.060
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.0010	<0.020	0.087	0.055
County Durham	Honey Hill Water Treatment Works, Consett	4	0.0042	0.056	0.13	0.082
County Durham	River Tees, Darlington	4	<0.0010	0.018	0.074	0.050
Cumbria	Haweswater Reservoir	4	<0.0010	<0.020	<0.050	<0.050
Cumbria	Ennerdale Lake	4	<0.0010	<0.020	<0.050	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<0.0013	0.020	0.047	<0.050
Derbyshire	Matlock, Groundwater ^a	4	<0.0010	0.090	0.11	0.067
Devon	River Exe, Exeter	4	<0.0011	<0.031	0.14	0.085
Gloucestershire	River Severn, Tewkesbury	4	<0.0010	0.037	0.26	0.16
Greater London	River Lee, Chingford	4	<0.0010	<0.029	0.41	0.26
Hampshire	River Avon, Christchurch	4	<0.0010	<0.019	0.12	0.075
Humberside	Littlecoates, Groundwater	4	<0.0011	0.022	0.14	0.088
Kent	Denge, Shallow Groundwater	4	<0.0010	0.019	0.17	0.11
Kent	Chatham, Deep Groundwater	4	<0.0010	<0.020	0.067	0.048
Lancashire	Corn Close, Groundwater	4	<0.0010	0.025	0.14	0.090
Norfolk	River Drove, Stoke Ferry	4	<0.0010	0.023	0.14	0.087
Northumberland	Kielder Reservoir	4	<0.0011	0.021	0.076	<0.062
Oxfordshire	River Thames, Oxford	4	<0.0010	0.018	0.21	0.13
Somerset	Ashford Reservoir, Bridgwater	4	<0.0010	0.021	0.13	0.079
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.0010	0.024	0.18	0.12
Surrey	River Thames, Walton	4	<0.0010	0.023	0.31	0.20
Surrey	River Thames, Chertsey	4	<0.0010	<0.022	0.29	0.19
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	4	<0.0023	0.054	0.13	0.083
Yorkshire	Chellow Heights, Bradford	4	<0.0012	<0.020	0.048	<0.050

Table 8.14. continued

Location	Sample source	No. of sampling observations	Mean radioactivity concentration , Bq l ⁻¹		
			³ H	⁴⁰ K	⁹⁰ Sr
Wales					
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.010	0.0035
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.029	0.0026
Powys	Elan Valley Reservoir	4	<4.0	<0.011	0.0032

Location	Sample source	No. of sampling observations	Mean radioactivity concentration , Bq l ⁻¹			
			¹³⁷ Cs	Gross alpha	Gross beta ¹	Gross beta ²
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.0011	<0.020	<0.054	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.0010	<0.019	0.061	<0.052
Powys	Elan Valley Reservoir	4	<0.0010	<0.020	0.052	<0.050

¹ Using ¹³⁷Cs standard² Using ⁴⁰K standard^a The concentrations of ²¹⁰Po, ²²⁶Ra, ²³⁴U, ²³⁵U and ²³⁸U were <0.010, 0.011, 0.043, <0.010 and 0.024 Bq l⁻¹ respectively

Table 8.15. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2009

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹									
			³ H	⁹⁰ Sr	¹³⁷ Cs	²¹⁰ Po	²²⁶ Ra	²³⁴ U	²³⁵ U	²³⁸ U	Gross alpha	Gross beta
Co. Londonderry	R Faughan	4	<1.1	0.0033	<0.05	<0.010	<0.010	0.011	<0.010	<0.010	<0.020	0.085
Co. Antrim	Lough Neagh	4	<1.1	0.0026	<0.05	<0.010	<0.010	0.013	<0.010	0.0011	<0.020	0.12
Co. Down	Silent Valley	4	<1.1	0.0025	<0.05	<0.010	<0.010	0.017	<0.010	<0.010	<0.027	0.065

Table 8.16. Estimates of radiation exposure from radionuclides in drinking water, 2009^a

Region	Mean exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides ^{b,c}	Naturally occurring radionuclides ^{b,d}	All radionuclides	Location	All radionuclides
England	<0.001	0.028	0.029	Matlock, Groundwater, Derbyshire	0.029
Wales ^e	<0.001			Cwm Ystradllyn Treatment Works Gwynedd	<0.001 ^e
Northern Ireland	<0.001	0.026	0.027	Silent Valley, Co. Down	0.027
Scotland ^e	<0.001			Knowesdean, Scottish Borders	<0.001 ^e
UK	<0.001	0.027	0.027	Matlock, Groundwater, Derbyshire	0.029

^a Assessments of dose are based on some concentration results at limits of detection.

Exposures due to potassium-40 content of water are not included here because they do not vary according to the potassium-40 content of water.

Levels of potassium are homeostatically controlled

^b Average of the doses to the most exposed age group at each location.^c Including tritium^d Including carbon-14^e Analysis of naturally occurring radionuclides was not undertaken

Table 8.17. Analysis of groundwater in Scotland, 2009

Location	Sample source	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹			
			³ H	¹³⁷ Cs	Gross alpha	Gross beta
Aberdeenshire	Lumsden	2	<4.0	<0.01	<0.010	0.042
Aberdeenshire	Turriff, Borehole	2	<4.0	<0.01	0.018	0.076
Angus	Arbroath	2	<4.0	<0.01	<0.022	0.042
Borders	Yarrowford	2	<4.0	<0.01	<0.011	0.042
Dumfriesshire	Deep borehole	2	<4.0	<0.01	<0.012	0.064
Dumfriesshire	Dumfries, Borehole	2	<4.0	<0.01	<0.013	0.048
Dunbartonshire	Alexandria	2	<4.0	<0.01	<0.013	0.075
Fife	Deep borehole	2	<4.0	<0.01	<0.012	0.089
Fife	Falkland	2	<4.0	<0.01	0.023	0.081
Ross-shire	Torridon, Borehole	2	<4.0	<0.01	<0.010	0.026

Table 8.18. Concentrations of radionuclides in sediments in Scotland, 2009

Area	Location	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg ⁻¹					
			³ H	¹³⁷ Cs	¹⁵⁵ Eu	²⁴¹ Am	Gross alpha	Gross beta
Marine samples								
Inverness-shire	Inverness Firth	1	<5.0	8.0			170	1400
Freshwater samples								
Inverness-shire	Loch Oich	1	<5.0	2.1			110	250
	Loch Lochy central	1	<5.0	120	2.5	1.4	270	870
	Loch Ness north	1	<5.0	1.3	3.6		220	500
	Loch Ness central	1	<5.0	7.8			250	650
	Loch Ness south	1	<5.0	190			240	950

Table 8.19. Concentrations of radionuclides in seawater, 2009

Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹						
		³ H	¹⁴ C	⁶⁰ Co	⁹⁰ Sr	⁹⁹ Tc	¹⁰⁶ Ru	^{110m} Ag
Dounreay (Sandside Bay)	4	<1.1		<0.10			<0.41	<0.10
Dounreay (Brims Ness)	4	<1.2		<0.10			<0.50	<0.10
Rosyth	2	<1.1		<0.10			<0.42	<0.10
Torness	2	<11		<0.10			<0.40	<0.10
Hartlepool (North Gare)	2	<9.5		<0.34			<2.5	<0.31
Sizewell	2	<4.0		<0.30			<2.4	<0.28
Bradwell	2			<0.38			<2.6	<0.31
Dungeness south	2	<4.0		<0.46			<3.3	<0.40
Winfrith (Lulworth Cove)	1			<0.32			<2.5	<0.29
Alderney	4 ^F	4.4						
Devonport (Millbrook Lake)	2	<4.0	<4.5	<0.34				
Devonport (Tor Point South)	2	<4.5	<3.5	<0.49				
Hinkley	2			<0.40	<0.035		<2.7	<0.33
Berkeley and Oldbury	2			<0.39			<2.8	<0.34
Cardiff (Orchard Ledges) ^a	2	<14	<4.0	<0.33				
Holyhead	4 ^C	<1.5						
Wylfa (Cemaes Bay)	2	<4.0		<0.34			<2.6	<0.31
Wylfa (Cemlyn Bay West)	2			<0.36			<2.8	<0.31
Heysham (inlet)	2	1300		<0.35			<2.6	<0.30
Seascale (Particulate)	2			<0.07	<0.26		<0.56	<0.09
Seascale (Filtrate)	2			<0.48	<0.075	<0.25	<3.8	<0.47
St. Bees	4	<5.9				<0.42		
St. Bees (Particulate)	2			<0.06	<0.020		<0.49	<0.07
St. Bees (Filtrate)	2	9.0		<0.24	<0.054	<0.48	<1.8	<0.28
Seafeld	4	3.0		<0.10			<0.40	<0.10
Southernness ^b	4	4.4		<0.10			<0.40	<0.10
Auchencairn	4	3.5		<0.10			<0.50	<0.10
Knock Bay	4	<1.1		<0.10			<0.42	<0.10
Knock Bay	4 ^C	<1.9						
Hunterston	2	5.0		<0.10			<0.29	<0.10
North of Larne	12 ^N					0.0035		
Faslane (Carnban)	2	<1.1		<0.10			<0.46	<0.10

Table 8.19. continued

Location	No. of sampling observations	Mean radioactivity concentration, Bq l ⁻¹					
		¹³⁴ Cs	¹³⁷ Cs	¹⁴⁴ Ce	²⁴¹ Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	4	<0.10	<0.10	<0.26	<0.10		
Dounreay (Brims Ness)	4	<0.10	<0.10	<0.29	<0.10		
Rosyth	2	<0.10	<0.10	<0.26	<0.10		
Torness	2	<0.10	<0.10	<0.24	<0.10		
Hartlepool (North Gare)	2	<0.27	<0.29	<1.3	<0.38	<5.0	18
Sizewell	2	<0.24	<0.27	<1.1	<0.35	<3.5	18
Bradwell	2	<0.30	<0.32	<1.2	<0.39	<4.0	20
Dungeness south	2	<0.34	<0.37	<1.5	<0.43	<4.0	15
Winfrith (Lulworth Cove)	1	<0.25	<0.29	<1.1	<0.36	<2.0	10
Alderney	4 ^F	*	<0.001				
Jersey	1 ^F	*	0.001				
Guernsey	4 ^F	*	0.001				
Hinkley	2	<0.28	<0.33	<1.3	<0.39	<3.5	14
Berkeley and Oldbury	2	<0.31	<0.33	<1.4	<0.41	<2.5	8.3
Cardiff (Orchard Ledges) ^a	2		<0.29				
Holyhead	4 ^C	*	0.02				
Wylfa (Cemaes Bay)	2	<0.27	<0.29	<1.4	<0.41	<3.5	12
Wylfa (Cemlyn Bay West)	2	<0.28	<0.28	<1.3	<0.41	<3.5	18
Llandudno	1 ^C	*	0.03				
Prestatyn	1 ^C	*	0.04				
New Brighton	1 ^C	*	0.05				
Ainsdale	1 ^C	*	0.06				
Rossall	1 ^C	*	0.08				
Heysham (inlet)	2	<0.27	<0.30	<1.3	<0.41	<2.5	20
Half Moon Bay	1 ^C	*	0.12				
Silecroft	1 ^C	*	0.07				
Seascale (Particulate)	2	<0.06	<0.06	<0.24	<0.16	0.19	0.090
Seascale (Filtrate)	2	<0.38	<0.42	<1.7	<0.47	<2.0	14
St. Bees	4	<0.17	<0.16				
St. Bees (Particulate)	2	<0.05	<0.05	<0.21	<0.05	<0.080	<0.075
St. Bees (Filtrate)	2	<0.21	<0.19	<1.0	<0.30	<2.5	12
Whitehaven	1 ^C	*	0.09				
Maryport	1 ^C	*	0.11				
Silloth	1 ^C	*	0.07				
Seafeld	4	<0.10	<0.11	<0.23	<0.10		
Southernness ^b	4	<0.10	0.17	<0.26	<0.028		
Auchencairn	4	<0.10	<0.13	<0.29	<0.10		
Ross Bay	1 ^C	*	0.06				
Isle of Whithorn	1 ^C	*	0.04				
Drummore	1 ^C	*	0.05				
Knock Bay	4	<0.10	<0.10	<0.26	<0.10		
Knock Bay	4 ^C	*	0.02				
Hunterston	2	<0.10	<0.10	<0.17	<0.10		
North of Larne	12 ^N	*	0.02				
Faslane (Carnban)	2	<0.10	<0.10	<0.28	<0.10		

* Not detected by the method used

^a The concentration of ³H as tritiated water was <4.0 Bq l⁻¹, and the concentration of ¹²⁵I was <0.35 Bq l⁻¹

^b The concentrations of ²³⁸Pu and ²³⁹⁺²⁴⁰Pu were <0.026 and <0.028 Bq l⁻¹ respectively

^c Measurements labelled "C" are made by Cefas on behalf of Defra

^f Measurements labelled "F" are made on behalf of the Food Standards Agency and the Channel Island States

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

9. References

(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 printed report.

If the CD is missing, or you experience problems with accessing the contents of the CD, please contact one of the organisations given at the start of the report, via the E-Mail address.

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2009

Establishment	Radioactivity	Discharge limit (annual equivalent) ^x , TBq	Discharges during 2009	
			TBq	% of annual limit ^b
Nuclear fuel production and reprocessing				
Capenhurst (Sellafield Ltd)				
Other authorised outlets	Alpha	BPM	2.59E-07	NA
	Beta	BPM	9.52E-07	NA
Incinerator	Alpha	2.00E-04	Nil	Nil
	Beta	2.50E-04	Nil	Nil
Capenhurst ¹ (Urenco UK)				
	Uranium	1.50E-05	1.23E-07	<1
	Other alpha	4.80E-06	Nil	Nil
	Technetium-99	2.00E-04	Nil	Nil
	Others	4.50E-03	Nil	Nil
Sellafield ^{d,2}				
	Alpha	8.80E-04	9.85E-05	11
	Beta	4.20E-02	1.42E-03	3.4
	Tritium	1.10E+03	1.88E+02	17
	Carbon-14	3.30E+00	3.79E-01	11
	Krypton-85	4.40E+05	4.17E+04	9.5
	Strontium-90	7.10E-04	3.85E-05	5.4
	Ruthenium-106	2.80E-02	9.70E-04	3.5
	Antimony-125 ⁶	6.90E-03	1.13E-02	160
	Iodine-129	7.00E-02	7.62E-03	11
	Iodine-131	5.50E-02	6.89E-04	1.3
	Caesium-137	5.80E-03	1.23E-04	2.1
	Plutonium alpha	1.90E-04	2.86E-05	15
	Plutonium-241	3.00E-03	3.57E-04	12
	Americium-241 and curium-242	1.20E-04	1.85E-05	15
Springfields	Uranium	5.30E-03	7.10E-04	13
Springfields (National Nuclear Laboratory) ^c	Tritium	1.00E-04	3.60E-06	3.6
	Carbon-14	1.00E-05	3.30E-08	<1
	Other alpha radionuclides	1.00E-06	Nil	Nil
	Other beta radionuclides	1.00E-05	2.20E-09	<1
Research establishments				
Dounreay (Fuel Cycle Area)				
	Alpha ^e	9.80E-04	1.21E-05	1.2
	Beta ^{f,g}	4.50E-02	1.82E-04	<1
	Tritium	2.00E+00	2.24E-01	11
	Krypton-85	3.00E+03	Nil	Nil
	Strontium-90	4.20E-03	4.36E-05	1.0
	Ruthenium-106	3.90E-03	5.78E-06	<1
	Iodine-129	1.10E-03	9.09E-05	8.3
	Iodine-131	1.50E-04	3.26E-05	22
	Caesium-134	8.40E-04	7.56E-07	<1
	Caesium-137	7.00E-03	1.13E-05	<1
	Cerium-144	7.00E-03	4.30E-06	<1
	Plutonium-241	3.30E-03	3.98E-06	<1
	Curium-242	2.70E-04	2.62E-08	<1
	Curium-244 ^h	5.40E-05	2.68E-09	<1
Dounreay (Fast Reactor)				
	Alpha	1.00E-05	9.88E-09	<1
	Beta	1.50E-03	3.63E-08	<1
	Tritium	4.50E+00	1.82E-03	<1
	Krypton-85	4.00E-04	1.65E-06	<1
Dounreay (Prototype Fast Reactor)				
	Alpha	6.00E-06	3.07E-08	<1
	Beta	5.10E-05	2.57E-07	<1
	Tritium	1.05E+01	2.54E-01	2.4
	Krypton-85	4.00E+00	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq	% of annual limit ^b
Dounreay (PFR minor sources)	Alpha ⁱ	6.00E-08	4.88E-10	<1
	Beta ^f	5.00E-07	1.91E-09	<1
	Tritium	2.00E-01	2.11E-03	1.1
Dounreay (East minor sources)	Alpha ⁱ	1.37E-05	9.26E-08	<1
	Beta ^{f,g}	3.71E-04	3.49E-07	<1
	Krypton-85 ⁱ	1.00E+00	Nil	Nil
Dounreay (West minor sources)	Alpha ⁱ	3.00E-07	2.39E-09	<1
	Beta ^f	7.50E-05	1.09E-08	<1
	Tritium	1.00E-02	2.68E-04	2.7
Harwell (AEA Technology)	Alpha	7.00E-07	Nil	Nil
	Beta	3.00E-05	Nil	Nil
	Tritium	2.00E-04	Nil	Nil
Harwell Research Sites Restoration Ltd (UKAEA)	Alpha	8.00E-07	6.20E-08	7.8
	Beta	2.00E-05	7.70E-07	3.9
	Tritium	1.50E+01	2.50E-01	1.7
	Krypton-85	2.00E+00	Nil	Nil
	Radon-220	1.00E+02	5.88E+00	5.9
	Radon-222	3.00E+00	2.90E-01	9.7
	Iodines	1.00E-02	Nil	Nil
	Other radionuclides	1.00E-01	Nil	Nil
Harwell ⁵ (GE Healthcare B10.23)	Alpha	5.00E-08	Nil	Nil
	Beta/gamma	1.50E-05	Nil	Nil
Harwell (GE Healthcare B443.26)	Alpha	1.00E-07	3.47E-09	3.5
	Beta/gamma	3.00E-05	9.93E-08	<1
	Radon-222	1.00E+00	1.10E-02	1.1
	Tritium	2.00E+00	5.46E-03	<1
	Krypton-85	6.00E-02	Nil	Nil
Winfrith (WMT Ltd)	Alpha	1.00E-07	Nil	Nil
	Tritium	1.95E+01	3.13E+00	16
	Carbon -14	3.00E-02	3.87E-06	<1
	Other	1.00E-07	Nil	Nil
Winfrith ⁴ Research Sites Restoration Ltd (RSRL)	Alpha	2.00E-06	1.22E-09	<1
	Tritium	5.00E+01	3.70E-02	<1
	Carbon-14	6.00E-03	3.11E-04	5.2
	Other	5.00E-06	2.04E-08	<1
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	3.00E-04	2.14E-05	7.1
	Argon-41	1.70E+00	3.96E-03	<1
Scottish Universities Environmental Research Centre East Kilbride	Beta	5.00E-07	Nil	Nil
	Tritium	5.00E-02	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq	% of annual limit ^b
Nuclear power stations				
Berkeley ^k	Beta	2.00E-05	5.10E-07	2.6
	Tritium	2.00E-02	3.39E-03	17
	Carbon-14	5.00E-03	2.24E-04	4.5
Bradwell	Beta	6.00E-04	2.08E-07	<1
	Tritium	1.50E+00	9.87E-03	<1
	Carbon-14	6.00E-01	6.24E-04	<1
Chapelcross	Tritium	5.00E+03	9.51E+01	1.9
	Sulphur-35	5.00E-02	Nil	Nil
	Argon-41	4.50E+03	Nil	Nil
Dungeness				
A Station	Beta ^q	5.50E-04	3.91E-05	7.1
	Tritium	2.60E+00	2.38E-02	<1
	Carbon-14	5.00E+00	3.01E-02	<1
	Sulphur-35	1.50E-01	9.87E-04	<1
	Argon-41	1.70E+03	Nil	Nil
Dungeness B Station	Tritium	1.20E+01	9.06E+00	76
	Carbon-14	3.70E+00	6.34E-01	17
	Sulphur-35	3.00E-01	9.57E-02	32
	Argon-41	7.50E+01	2.44E+01	33
	Cobalt-60 ^q	1.00E-04	6.82E-07	<1
	Iodine-131	1.50E-03	1.68E-05	1.1
Hartlepool	Tritium	1.00E+01	7.04E-01	7.0
	Carbon-14	4.50E+00	1.17E+00	26
	Sulphur-35	2.30E-01	1.90E-02	8.3
	Argon-41	1.50E+02	6.12E+00	4.1
	Cobalt-60 ^q	1.00E-04	1.19E-05	12
	Iodine-131	1.50E-03	1.69E-04	11
Heysham Station 1	Tritium	1.00E+01	7.85E-01	7.9
	Carbon-14	4.50E+00	1.30E+00	29
	Sulphur-35	2.00E-01	1.94E-02	9.7
	Argon-41	1.50E+02	3.14E-01	<1
	Cobalt-60 ^q	1.00E-04	5.55E-06	5.6
	Iodine-131	1.50E-03	7.96E-05	5.3
Heysham Station 2	Tritium	1.00E+01	8.50E-01	8.5
	Carbon-14	3.70E+00	1.40E+00	38
	Sulphur-35	2.30E-01	1.08E-02	4.7
	Argon-41	7.50E+01	1.78E+01	24
	Cobalt-60 ^q	1.00E-04	1.35E-05	14
	Iodine-131	1.50E-03	9.36E-05	6.2
Hinkley Point A Station	Beta	1.50E-04	3.67E-07	<1
	Tritium	1.50E+00	6.62E-02	4.4
	Carbon-14	6.00E-01	7.25E-04	<1
Hinkley Point B Station	Tritium	1.20E+01	2.55E+00	21
	Carbon-14	3.70E+00	9.08E-01	25
	Sulphur-35	3.50E-01	1.06E-01	30
	Argon-41	1.00E+02	1.21E+01	12
	Cobalt-60 ^q	1.00E-04	7.55E-06	7.6
	Iodine-131	1.50E-03	6.33E-06	<1
Hunterston				
A Station	Beta ^q	6.00E-05	4.40E-07	<1
	Tritium	2.00E-02	1.13E-03	5.7
	Carbon-14	2.00E-03	1.17E-04	5.9

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq	% of annual limit ^b
Hunterston B Station	Particulate beta	5.00E-04	1.14E-04	23
	Tritium	1.50E+01	3.31E+00	22
	Carbon-14	4.50E+00	1.32E+00	29
	Sulphur-35	5.00E-01	6.84E-02	14
	Argon-41	1.50E+02	1.27E+01	8.5
	Iodine-131	2.00E-03	1.30E-04	6.5
Oldbury	Beta	1.00E-04	4.42E-05	44
	Tritium	9.00E+00	2.05E+00	23
	Carbon-14	4.00E+00	1.44E+00	36
	Sulphur-35	4.50E-01	8.21E-02	18
	Argon-41	5.00E+02	2.91E+01	5.8
Sizewell				
A Station	Beta	8.50E-04	1.90E-06	<1
	Tritium	3.50E+00	2.14E-01	6.1
	Carbon-14	2.00E+00	1.31E-02	<1
	Sulphur-35	3.50E-01	1.00E-03	<1
	Argon-41	3.00E+03	Nil	Nil
Sizewell B Station	Noble gases	3.00E+01	3.92E+00	13
	Particulate Beta	1.00E-04	5.00E-06	5.0
	Tritium	3.00E+00	7.14E-01	24
	Carbon-14	5.00E-01	2.97E-01	59
	Iodine-131	5.00E-04	2.11E-04	42
Torness	Particulate beta	4.00E-04	5.57E-06	1.4
	Tritium	1.10E+01	1.44E+00	13
	Carbon-14	4.50E+00	1.07E+00	24
	Sulphur-35	3.00E-01	9.70E-03	3.2
	Argon-41	7.50E+01	4.90E+00	6.5
	Iodine-131	2.00E-03	2.83E-06	<1
Trawsfynydd	Beta	5.00E-05	6.85E-07	1.4
	Tritium	7.50E-01	7.27E-02	9.7
	Carbon-14	1.00E-02	2.27E-03	23
Wylfa	Beta	7.00E-04	4.22E-05	6.0
	Tritium	1.80E+01	2.86E+00	16
	Carbon-14	2.30E+00	1.42E+00	62
	Sulphur-35	4.50E-01	1.72E-01	38
	Argon-41	1.00E+02	1.79E+01	18
Defence establishments				
Aldermaston ^m	Alpha	1.65E-07	3.75E-08	23
	Particulate Beta	6.00E-07	2.05E-08	3.4
	Tritium	3.90E+01	5.20E-01	1.3
	Carbon-14	6.00E-06	6.90E-07	12
	Argon-41	1.00E-03	Nil	Nil
	Krypton-85	7.50E-02	3.39E-03	4.5
	Volatile beta	4.40E-06	Nil	Nil
Barrow ^l	Tritium	3.20E-06	Nil	Nil
	Argon-41	4.80E-02	Nil	Nil
Burghfield ^{a,m}	Tritium	1.00E-02	Nil	Nil
	Alpha	6.00E-09	8.40E-10	14
Coulport	Tritium	5.00E-02	3.29E-03	6.6
Derby ^{n,r}	Uranium	4.00E-06	1.16E-06	29
	Alpha ^q	2.40E-08	1.60E-10	<1
	Beta ^q	1.80E-06	4.20E-08	2.3

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq	% of annual limit ^b
Devonport ^o	Beta/gamma ^q	3.00E-07	3.10E-08	10
	Tritium	4.00E-03	1.40E-03	35
	Carbon-14	4.30E-02	3.48E-02	81
	Argon-41	1.50E-02	3.80E-05	<1
Dounreay ³ (Vulcan)	Alpha ^q	1.00E-06	3.51E-08	3.5
	Beta ^q	1.00E-04	1.20E-06	1.2
	Noble gases	2.70E-02	1.36E-04	<1
	Iodine-131	3.70E-04	1.95E-05	5.3
Rosyth ^p	Beta (particulate)	1.00E-07	Nil	Nil
	Tritium	2.00E-04	Nil	Nil
	Carbon-14	5.00E-04	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	2.25E-06	2.56E-07	11
	Radionuclides T1/2<2hr	7.50E-01	5.31E-02	7.1
	Tritium	2.00E+00	1.08E-06	<1
	Sulphur-35	3.50E-02	5.77E-03	16
	Iodine-125	2.00E-02	8.83E-04	4.4
	Radon-222	1.00E+01	3.68E+00	37
	Other noble gases	5.00E+01	Nil	Nil
Cardiff (GE Healthcare)	Other including selenium-75 and iodine-131	1.60E-02	2.52E-04	1.6
	Soluble tritium	1.56E+02	2.96E+01	19
	Insoluble tritium	6.00E+02	1.20E+02	20
	Carbon-14	2.38E+00	1.01E+00	42
	Phosphorus-32/33	5.00E-06	6.00E-07	12
	Iodine-125	1.80E-04	6.21E-06	3.5
	Other radionuclides	1.00E-03	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.

^b Data quoted to 2 significant figures except where values are <1%

^c Formerly Nexia Solutions

^d Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP

^e Excluding curium-242 and 244

^f Excluding tritium

^g Excluding krypton-85

^h Data excludes any curium-243 present

ⁱ Excluding radon and daughter products

^j Krypton-85 discharges are calculated monthly

^k Combined data for Berkeley Power Station and Berkeley Centre

^l Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd

^m Discharges were made by AWE plc

ⁿ Discharges were made by Rolls Royce Marine Power Operations Ltd

^o Discharges were made by Devonport Royal Dockyard Ltd

^p Discharges were made by Rosyth Royal Dockyard Ltd

^q Particulate activity

^r Annual limits on beta and alpha derived from monthly and weekly notification levels

^x In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites

¹ Discharge permits revised with effect from 1 January 2009, resulting in a change in reporting returns from this date

² Windscale permits transferred from UKAEA to Sellafield Ltd (into one permit) with effect from 1 April 2008

³ An Approval for Arrangements for Vulcan was issued with effect from 28 September 2009. Discharge limits were revised

⁴ Discharge permits revised with effect from 1 January 2008, and re-issued in February 2009 to reflect transition from UKAEA to RSRL

⁵ Discharge permits revoked (B10.23) with effect from 1 February 2009

⁶ Discharge permits revised with effect from 1 April 2008, with a further variation with effect from 1 April 2010 (limit revised to 3.00E-02 TBq), to reflect the trend of increasing discharges in 2009

NA Not applicable under permit

BPM Best practicable means

Table A2.2. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2009

Establishment	Radioactivity	Discharge limit (annual equivalent) ⁿ , TBq	Discharges during 2009	
			TBq ^a	% of annual limit ^b
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Uranium	7.50E-04	8.00E-05	10
	Uranium daughters	1.36E-03	1.00E-05	<1
	Non-uranic alpha	2.20E-04	2.00E-05	9.1
	Technetium-99	1.00E-03	1.00E-05	1.0
Sellafield ^{c,9} (sea pipelines)	Alpha	1.00E+00	1.54E-01	15
	Beta	2.20E+02	1.78E+01	8.1
	Tritium	2.00E+04	1.51E+03	7.6
	Carbon-14	2.10E+01	8.19E+00	39
	Cobalt-60	3.60E+00	8.25E-02	2.3
	Strontium-90	4.80E+01	2.86E+00	6.0
	Zirconium-95 + Niobium-95	3.80E+00	1.93E-01	5.1
	Technetium-99	1.00E+01	3.08E+00	31
	Ruthenium-106	6.30E+01	3.16E+00	5.0
	Iodine-129	2.00E+00	2.53E-01	13
	Caesium-134	1.60E+00	1.41E-01	8.8
	Caesium-137	3.40E+01	4.27E+00	13
	Cerium-144	4.00E+00	4.98E-01	12
	Neptunium-237	1.00E+00	5.21E-02	5.2
	Plutonium alpha	7.00E-01	1.20E-01	17
	Plutonium-241	2.50E+01	2.87E+00	11
	Americium-241	3.00E-01	4.63E-02	15
	Curium-243+244	6.90E-02	4.52E-03	6.6
	Uranium ^e	2.00E+03	4.09E+02	20
	Sellafield (factory sewer)	Alpha	3.00E-04	5.02E-05
Beta		6.10E-03	1.09E-03	18
Tritium		6.80E-02	9.82E-03	14
Springfields ¹⁰	Alpha	1.00E-01	1.70E-02	17
	Beta	2.00E+01	3.27E+00	16
	Technetium-99	6.00E-01	5.35E-03	<1
	Thorium-230	2.00E-02	4.05E-03	20
	Thorium-232	1.50E-02	2.05E-04	1.4
	Neptunium-237	4.00E-02	2.23E-04	<1
	Other transuranic radionuclides	2.00E-02	1.59E-03	8.0
	Uranium	4.00E-02	1.09E-02	27
Research establishments				
Dounreay PFR liquid metal disposal plant	Alpha ⁴	2.00E-02	5.65E-08	<1
	Beta ¹	1.10E-01	1.79E-06	<1
	Tritium	1.40E+00	1.01E-05	<1
	Sodium-22	1.80E+00	1.19E-05	<1
	Caesium-137	6.60E-02	1.27E-06	<1
Dounreay Other facilities	Alpha ⁴	9.00E-02	2.58E-04	<1
	Beta ²	6.20E-01	6.03E-04	<1
	Tritium	5.50E+00	1.04E-01	1.9
	Strontium-90	7.70E-01	3.09E-02	4.0
	Caesium-137	1.00E+00	6.18E-03	<1
Harwell (pipeline)	Alpha	5.00E-05	2.15E-06	4.3
	Beta	3.30E-03	2.10E-04	6.4
	Tritium	3.00E-01	2.25E-03	<1
	Cobalt-60	1.20E-04	7.19E-07	<1
	Caesium-137	5.40E-04	4.35E-05	8.1
Harwell (Lydebank Brook)	Alpha	1.00E-04	7.16E-06	7.2
	Beta	6.00E-04	4.38E-05	7.3
	Tritium	8.00E-02	5.66E-03	7.1
Winfrith (inner pipeline)	Alpha	2.00E-02	5.20E-05	<1
	Tritium	2.20E+02	1.07E+00	<1
	Caesium-137	2.00E+00	4.90E-02	2.5
	Other radionuclides	1.00E+00	8.17E-03	<1

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq ^a	% of annual limit ^b
Winfrith (outer pipeline)	Alpha	2.00E-03	4.09E-06	<1
	Tritium	1.50E-01	1.04E-03	<1
	Other radionuclides	1.00E-03	2.33E-05	2.3
Winfrith (River Frome)	Tritium	7.50E-01	Nil	Nil
Minor sites				
Imperial College Reactor Centre	Tritium	4.00E-05	5.39E-06	13
Ascot	Other radioactivity	1.00E-04	<1	<1
Scottish Universities Environmental Research Centre East Kilbride	Total activity	1.69E-03	Nil	Nil
Nuclear power stations				
Berkeley	Tritium	1.00E+00	1.99E-03	<1
	Caesium-137	2.00E-01	1.12E-03	<1
	Other radionuclides	2.00E-01	1.94E-03	<1
Bradwell	Tritium	7.00E+00	2.37E-02	<1
	Caesium-137	7.00E-01	8.19E-02	12
	Other radionuclides	7.00E-01	8.17E-02	12
Chapelcross	Alpha	1.00E-01	7.73E-05	<1
	Beta ¹	2.50E+01	7.39E-04	<1
	Tritium	5.50E+00	2.38E-02	<1
Dungeness A Station	Tritium	8.00E+00	7.69E-02	<1
	Caesium-137	1.10E+00	1.56E-02	1.4
	Other radionuclides	8.00E-01	5.52E-03	<1
Dungeness B Station	Tritium	6.50E+02	2.25E+02	35
	Sulphur-35	2.00E+00	1.99E-01	10
	Cobalt-60	1.00E-02	1.95E-03	20
	Caesium-137	1.00E-01	1.52E-03	1.5
	Other radionuclides	8.00E-02	4.11E-03	5.1
Hartlepool	Tritium	6.50E+02	2.680E+02	41
	Sulphur-35	3.00E+00	3.630E-01	12
	Cobalt-60	1.00E-02	1.400E-04	1.4
	Caesium-137	1.00E-01	1.420E-03	1.4
	Other radionuclides	8.00E-02	2.090E-03	2.6
Heysham Station 1	Tritium	6.50E+02	2.770E+02	43
	Sulphur-35	2.00E+00	2.200E-01	11
	Cobalt-60	1.00E-02	9.800E-05	<1
	Caesium-137	1.00E-01	2.400E-03	2.4
	Other radionuclides	8.00E-02	4.880E-03	6.1
Heysham Station 2	Tritium	6.50E+02	3.222E+02	50
	Sulphur-35	2.00E+00	7.730E-02	3.9
	Cobalt-60	1.00E-02	5.400E-05	<1
	Caesium-137	1.00E-01	1.270E-03	1.3
	Other radionuclides	8.00E-02	1.090E-02	14
Hinkley Point A Station	Tritium	1.80E+00	2.32E-01	13
	Caesium-137	1.00E+00	6.27E-02	6.3
	Other radionuclides	7.00E-01	3.71E-01	53
Hinkley Point B Station	Tritium	6.50E+02	1.05E+02	16
	Sulphur-35	2.00E+00	2.16E-01	11
	Cobalt-60	1.00E-02	3.83E-04	3.8
	Caesium-137	1.00E-01	4.48E-03	4.5
	Other radionuclides	8.00E-02	6.96E-03	8.7

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq ^a	% of annual limit ^b
Hunterston A Station	Alpha	4.00E-02	2.06E-04	<1
	Beta	6.00E-01	2.33E-02	3.9
	Tritium	7.00E-01	3.90E-04	<1
	Plutonium-241	1.00E+00	1.02E-04	<1
Hunterston B Station	Alpha	1.00E-03	5.71E-05	5.7
	All other non-alpha	1.50E-01	1.24E-02	8.3
	Tritium	7.00E+02	1.53E+02	22
	Sulphur-35	6.00E+00	5.60E-01	9.3
	Cobalt-60	1.00E-02	2.70E-04	2.7
Oldbury	Tritium	1.00E+00	1.52E-01	15
	Caesium-137	7.00E-01	1.99E-01	28
	Other radionuclides	7.00E-01	9.07E-02	13
Sizewell A Station	Tritium	1.10E+01	5.25E-02	<1
	Caesium-137	1.00E+00	1.17E-01	12
	Other radionuclides	7.00E-01	6.01E-02	8.6
Sizewell B Station	Tritium	8.00E+01	5.27E+01	66
	Caesium-137	2.00E-02	5.00E-03	25
	Other radionuclides	1.30E-01	2.20E-02	17
Torness	Alpha	5.00E-04	6.71E-06	1.3
	All other non-alpha	1.50E-01	2.67E-03	1.8
	Tritium	7.00E+02	3.64E+02	52
	Sulphur-35	3.00E+00	2.21E-02	<1
	Cobalt-60	1.00E-02	1.16E-04	1.2
Trawsfynydd	Tritium	5.00E-01	5.660E-03	1.1
	Strontium-90	5.00E-02	2.200E-05	<1
	Caesium-137	3.00E-02	5.430E-04	1.8
	Other radionuclides ⁵	1.70E-01	1.030E-03	<1
Wylfa	Tritium	1.50E+01	1.91E+00	13
	Other radionuclides	1.10E-01	9.48E-03	8.6
Defence establishments				
Aldermaston (Silchester)	Alpha	1.00E-05	2.67E-06	<1
	Other beta emitting radionuclides	2.00E-05	1.44E-05	72
	Tritium	2.50E-02	3.72E-04	1.5
Aldermaston (to Stream) ^d	Tritium	Nil	Nil	Nil
Barrow ^h	Tritium	1.20E-02	1.82E-04	1.5
	Other gamma emitting radionuclides	3.50E-06	2.80E-08	<1
Derby ⁱ	Alpha ^j	2.00E-03	1.14E-04	5.7
	Alpha ^k	3.00E-07	1.20E-08	4.0
	Beta ^k	3.00E-04	7.20E-07	<1
Devonport ^g (sewer)	Tritium	2.00E-03	9.94E-05	5.0
	Cobalt-60	3.50E-04	7.78E-06	2.2
	Other radionuclides	6.50E-04	2.06E-04	32

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent), TBq	Discharges during 2009	
			TBq ^a	% of annual limit ^b
Devonport ^g (estuary)	Tritium	7.00E-01	2.08E-01	30
	Carbon-14	1.70E-03	6.16E-04	36
	Cobalt-60	8.00E-04	2.22E-04	28
	Other radionuclides	3.00E-04	9.41E-05	31
Faslane	Alpha	2.00E-04	1.40E-07	<1
	Beta ^{3,6}	5.00E-04	5.33E-06	1.1
	Tritium	1.00E+00	0.061	6.1
	Cobalt-60	5.00E-04	1.81E-06	<1
Rosyth ^f	Tritium	3.00E-03	6.02E-04	20
	Cobalt-60	3.00E-04	1.44E-05	4.8
	Other radionuclides	3.00E-04	5.77E-06	1.9
Radiochemical production				
Amersham (GE Healthcare) ³	Alpha	3.00E-04	8.33E-06	2.8
	Tritium	1.41E-01	3.30E-04	<1
	Iodine-125	4.00E-03	9.08E-06	<1
	Caesium-137	5.00E-03	5.96E-06	<1
	Other radionuclides	6.50E-02	8.42E-04	1.3
Cardiff (GE Healthcare)	Tritium	1.30E+02	2.07E+01	16
	Carbon-14	9.10E-01	4.14E-02	4.5
	Phosphorus-32/33	8.50E-05	Nil	Nil
	Iodine-125	3.00E-04	1.41E-06	<1
	Others	1.20E-04	Nil	Nil
Industrial and landfill sites				
LLWR	Alpha	BPM	7.06E-05	NA
	Beta	BPM	8.37E-04	NA
	Tritium	BPM	9.33E-02	NA

^a Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 3 significant figures except where fewer significant figures are provided in source documents

^b Data quoted to 2 significant figures except when values are less than 1%

^c Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant

^d The discharge permit has been replaced by an activity notification level of 30 Bq l⁻¹

^e The limit and discharge data are expressed in kg

^f Discharges were made by Rosyth Royal Dockyard Ltd. Discharge permit revised with effect from 1 April 2008

^g Discharges were made by Devonport Royal Dockyard Ltd

^h Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd

ⁱ Discharges were made by Rolls Royce Marine Power Operations Ltd

^j Discharge limit is for Nuclear Fuel Production Plant

^k Discharge limit is for Neptune Reactor and Radioactive Components Facility

ⁿ In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites

¹ All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together

² All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together

³ Excluding cobalt-60

⁴ All alpha emitting radionuclides taken together

⁵ Including strontium

⁶ Excluding tritium

⁹ Windscale permit transferred from UKAEA to Sellafield (into one combined permit) with effect from 1 April 2008 with no overall change in limits

¹⁰ Discharge permit revised with effect from 1 January 2008

NA Not applicable under new permit

BPM Best practicable means

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2009

Establishment	Radioactivity	Disposal Limit TBq	Disposals during 2009	
			TBq	% of limit ^a
LLWR ^b	Tritium	1.00E+01	4.59E-01	4.6
	Carbon-14	5.00E-02	5.35E-03	11
	Cobalt-60	2.00E+00	4.84E-02	2.4
	Iodine-129	5.00E-02	5.14E-05	<1
	Radium-226 plus			
	thorium-232	3.00E-02	3.74E-03	12
	Uranium	3.00E-01	3.54E-02	12
	Other alpha ^d	3.00E-01	5.66E-02	19
	Others ^{d,e}	1.50E+01	9.08E-01	6.1
Dounreay ^c	Alpha		Nil	Nil
	Beta/gamma		Nil	Nil

^a Data quoted to 2 significant figures except where values are less than 1%

^b Under current planning permission at the LLWR near to Drigg, certain wastes are temporarily stored, as opposed to being disposed, pending disposal/storage elsewhere or permission for disposal in-situ

^c The current permit includes limits on concentrations of activity. At no time did the concentrations exceed the limits

^d With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232

^e Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table

Table A2.4. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2009

Site	Month	Summary of occurrence	Consequences and action taken
Devonport	March	A spill of active system flush water (a few litres) from HMS Turbulent onto the top of the submarine casing occurred. There was no spillage into the Tamar Estuary	This water was cleared up by Naval Base operators so that none entered the Tamar Estuary. Samples of materials used to absorb the spill and filter paper wipes were analysed by the site and by the Environment Agency for gamma emitting radionuclides and tritium. A small amount of tritium was detected in the paper used to absorb the spillage and trace amounts of cobalt-60 were detected in the paper and one of the filter paper wipes. There was no significant hazard to people or the environment.
Dungeness B	May and September	In May, station operators identified elevated concentrations of tritium (100 – 350 Bq l ⁻¹) in groundwater samples from 4 monitoring wells, close to the site's surface water drainage system which is a permitted minor discharge route used for discharging excess boiler water to the sea outfall. At the same time, operator surveys of this drainage system found cracks and severe degradation in the pipework. In September, while repairs to the permanent pipework were being undertaken, temporary pipework failed and, although the discharge was then stopped, boiler water leaked to ground. The testing procedures and risk assessment for the temporary pipework were inadequate.	The environmental impact was very low. The concentrations of tritium in ground water were greater than the UK Drinking Water Inspectorate investigative levels for tritium in drinking water (measured at the supplier's abstraction point), but less than 10% of the World Health Organisation (WHO) recommended values. The elevated ground water tritium levels were 600m down gradient of an aquifer used to supply drinking water, within 200m of the coast. A warning letter was issued to British Energy regarding discharge by an unpermitted route and failure to maintain discharge equipment. They were also required to enhance their monitoring programme whilst the surface water drainage system was being repaired. After the September event, results of groundwater monitoring were indistinguishable from those before the event. The amount of boiler water lost was much smaller than if the degraded surface water drainage system had been used. A further warning letter was issued to British Energy regarding discharge by an unpermitted route and failure to maintain discharge equipment.
GE Healthcare Maynard Centre	September	Small leak of radioactive effluent (< 5 litres) containing short-lived radionuclides (Mo-99) from a corroded filter housing in a pump room for the on-site effluent handling system.	The environmental impact was negligible. GE Healthcare undertook the following actions: <ul style="list-style-type: none"> • Its Qualified Expert undertook a site-wide review/inspection of similar equipment (i.e. pumps, filters) • It reviewed the design intent of filters • It revised maintenance requirements regarding filters • It improved the bunding of the pump room where the incident occurred • It instigated the use of log books for recording the maintenance of the filters The effluent system is already undergoing a rationalisation to reduce its size to reflect the smaller number of effluent generating facilities and the reduced volumes of effluent now generated on-site.
Hartlepool	December	Discharges of tritium to atmosphere were elevated during the return to service of one of the reactors from a maintenance outage. No discharge limits were breached.	The environmental impact was very low. The circumstances of the event are being followed up with British Energy.
Heysham 2	May	Air ingress to one of the reactors led to increased activity levels in the coolant circuit. Purging to return gas purity and subsequent (normal) coolant leakage led to increased discharges of argon-41 to atmosphere. No discharge limits were breached.	The environmental impact was very low. A warning letter was issued to British Energy regarding breaches of their permit in terms of limiting the activity of waste requiring disposal and maintenance of relevant systems.

Table A2.4. continued

Site	Month	Summary of occurrence	Consequences and action taken
Sellafield	Rolling 12 month period to end of July 2009, and subsequent months to the year end	Breach of site limit for antimony-125 (Sb-125) discharges to air (known to be associated with elevated levels of Sb-125 in higher burn up Magnox fuels; Sb-125 discharges and their investigation have previously been reported on in RIFE12, 13 and 14)	Elevated Sb-125 discharges from the fuel handling plant are associated with decanning an increasing proportion of higher burn-up Magnox fuels, which arise from the remaining Magnox power stations as they approach the ends of their operating lives. The Environment Agency agreed to a formal request from Sellafield Limited to increase the Sb-125 plant and site discharge limit as part of the RSA Authorisation review for 2008-09, to accommodate expected trends associated with continuing reprocessing of an increasing proportion of higher burn up Magnox fuels. A new site limit of 30,000 MBq y-1 was established by variation on 1 April 2010. The new limit will not lead to any significant impact on radiation doses to the public.
Sellafield	January	Leak of active ventilation system condensate to ground via a faulty drain line.	The leakage was in the form of a steady drip of active condensate from the Magnox reprocessing vessel vent system. The leakage was on-going for at least 15 months, and possibly many years. The area affected by the leak is small (a few m ²), and is well within the site boundary. No public areas have been affected. The total inventory of activity lost to ground is estimated at around 73 GBq, the majority of this activity being in the form of isotopes of plutonium. The leak has since been stopped. In July 2009, the Environment Agency issued an Enforcement Notice to Sellafield Limited, requiring a range of improvements to be put in place to address the shortcomings leading to the incident, and to deal with the contamination caused. The full circumstances leading to this incident are subject to formal investigation.
Sellafield	January - December	Contamination of local beaches by radioactive particles, the finds from the monitoring programme for 2009 being 178 (comprising 53 stones and 125 particles) in 290 Ha of beach area surveyed.	Work on beach monitoring and particle analysis continued throughout 2009. The monitoring programme covered over 290 Ha of beach area during the year, revealing 178 finds (53 stones and 125 particles). All of these finds have been removed from the beaches. In August 2009, a new, enhanced detector was implemented, which has resulted in an increase in the number of 'α-rich' finds being detected. The 'α-rich' category consists mainly of <2 mm diameter particles containing americium-241 and associated plutonium isotopes. Further detailed analysis of a selection of the particles that have been recovered has been undertaken to support the assessment of hazards and risks, and to understand the potential sources of these finds. The Health Protection Agency (HPA) has been engaged by the Environment Agency to provide advice on risks to the public associated with the radioactive particle contamination issue. A report on these risks is expected to be published by HPA in the autumn of 2010. Their interim advice remains that no special precautions, such as access restrictions or the placing of warning signs, are necessary to protect the public.
Sizewell B	October	Quarterly notification levels for carbon-14 and iodine-131 were exceeded for gaseous discharges.	The Food Standards Agency carry out additional analyses for iodine-131 on weekly milk samples from routine monitoring. No elevated concentrations of carbon-14 were found in combined monthly samples, and iodine-131 activities were below the LoD during the period.
Torness	August	A leak of radioactive effluent within the fuel handling building.	The leak was believed to be retained within the building. SEPA carried out ground water sampling from boreholes around the station which showed no evidence of the effluent leak. Whilst SEPA considers that the incident had no discernable environmental impact it was concerned about the events that lead to the incident and issued a Final Warning Letter in relation to the incident. The power station has since made a number of improvements to the appropriate facilities.

APPENDIX 3. Abbreviations and glossary

AGIR	Advisory Group on Ionising Radiation	LLW	Low level Waste
AGR	Advanced Gas-Cooled Reactor	LLWR	Low level Waste Repository
AWE	Atomic Weapons Establishment	LoD	Limit of Detection
BAT	Best Available Techniques or Best Available Technology	MAC	Medium Active Concentrate
BNFL	British Nuclear Fuels plc	MAFF	Ministry of Agriculture, Fisheries & Food
BNGSL	British Nuclear Group Sellafield Limited	MMO	Marine Management Organisation
BPEO	Best Practicable Environmental Option	MoD	Ministry of Defence
BSS	Basic Safety Standards	MRL	Minimum reporting level
CEC	Commission of the European Communities	MRWS	Managing Radioactive Waste Safely
CEDA	Consultative Exercise on Dose Assessments	NaK	Sodium / Potassium
Cefas	Centre for Environment, Fisheries & Aquaculture Science	ND	Not detected
CoRWM	Committee on Radioactive Waste Management	NDA	Nuclear Decommissioning Authority
DECC	Department of Energy and Climate Change	NIEA	Northern Ireland Environment Agency
Defra	Department for Environment, Food and Rural Affairs	NII	Nuclear Installations Inspectorate
DETR	Department of the Environment, Transport and the Regions	NMP	Nuclear Management Partners Limited
DH	Department of Health	NNC	National Nuclear Corporation
DPAG	Dounreay Particles Advisory Group	NRPB	National Radiological Protection Board
DRDL	Devonport Royal Dockyard Limited	NRTE	Naval Reactor Test Establishment
DSRL	Dounreay Site Restoration Limited	NSL	Nexia Solutions Ltd
DSTL	Defence Science and Technology Laboratory	OBT	Organically bound tritium
EA	Environment Agency	OECD	Organisation for Economic Co-operation and Development
EARP	Enhanced Actinide Removal Plant	OSPAR	Oslo and Paris Convention
Euratom	European Atomic Energy Community	PBO	Parent Body Organisation
EC	European Commission	PWR	Pressurised Water Reactor
EDF	Electricité de France	REP	RSR Environmental Principle
EHS	Environment and Heritage Service	RIFE	Radioactivity in Food and the Environment
EPR 10	Environment Permitting (England and Wales) Regulations 2010	RRDL	Rosyth Royal Dockyard Limited
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management	RRMPOL	Rolls Royce Marine Power Operations Limited
EU	European Union	RNAS	Royal Naval Air Station
FEPA	Food and Environment Protection Act	RSA 93	Radioactive Substances Act 1993
FSA	Food Standards Agency	RSR	Radioactive Substances Regulation
GDA	Generic Design Assessment	RSRL	Research Sites Restoration Limited
GDL	Generalised Derived Limit	RSS	Radioactive Substances Strategy
GE	General Electric	SEPA	Scottish Environment Protection Agency
HMIP	Her Majesty's Inspectorate of Pollution	SFL	Springfields Fuels Limited
HMNB	Her Majesty's Naval Base	SIXEP	Site Exchange Effluent Plant
HMSO	Her Majesty's Stationery Office	SL	Scientifics Limited
HPA	Health Protection Agency	SRP	Society for Radiological Protection
HSE	Health & Safety Executive	STW	Sewage Treatment Works
HSL	Harwell Scientifics Limited	SWIMMER	Sustainable Water Integrated Management and Ecosystem Research
IAEA	International Atomic Energy Agency	TDS	Total Diet Study
ICRP	International Commission on Radiological Protection	THORP	Thermal Oxide Reprocessing Plant
IRPA	International Radiation Protection Association	TNORM	Technologically enhanced Naturally-Occurring Radioactive Material
ISO	International Standards Organisation	TPP	Tetraphenylphosphonium bromide
LGC	Laboratory of the Government Chemist	TRAMP	Terrestrial Radioactive Monitoring Programme
LLLETP	Low Level Liquid Effluent Treatment Plant	UKAEA	United Kingdom Atomic Energy Authority
		UKNWM	UK Nuclear Waste Management Limited
		UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
		UOC	Uranium Ore Concentrate

UUK	Urenco UK Limited	WFD	Water Framework Directive
VLA	Veterinary Laboratories Agency	WHO	World Health Organisation
WAG	Welsh Assembly Government	WWTW	Waste Water Treatment Works
WELL	Winfrith Environmental Level Laboratory	YP	Ystradyfodwg and Pontypridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J kg ⁻¹ .
Authorised Premises	This is a premises that has been authorised by the environment agencies to discharge to the environment.
Becquerel	One radioactive transformation per second.
Bioaccumulation	Excretion may occur, however the rate of excretion is less than the rate of intake + accumulation
Biota	Flora and fauna
Committed effective dose	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.
Critical group	Those (or the 'representative individual') who receive the largest dose from artificially-produced radionuclides due to their habits, diet and where they spend their time.
Direct shine	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.
Dose	Shortened form of 'effective dose' or 'absorbed dose'.
Dose limits	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv per year for the UK.
Dose rates	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the sievert (Sv).
Environmental materials	Environmental materials include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.
Equivalent dose	The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the sievert (Sv).

External dose	Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.
Fragments	'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.
Generalised derived limit	A convenient reference level against which the results of environmental monitoring can be compared. GDLs are calculated using deliberately cautious assumptions and are based on the assumption that the level of environmental contamination is uniform over the year. GDLs relate the concentrations of a single radionuclide in a single environmental material to the dose limit for members of the public.
Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the food chain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Millisievert	The millisievert is a 1/1000 of a sievert. A sievert is one of the International System of Units used for the measurement of dose equivalent.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting Factor	Factor used to weight the tissue or organ absorbed dose to take account of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative individual	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
TNORM	Naturally-occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally-occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally-occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to take. Factors account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01
<i>Total dose</i>	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation

APPENDIX 4. Assessment of the *total dose* integrated across pathways

A4.1 Introduction

This appendix describes the methods, data and results used to assess *total dose* to the public near nuclear sites from all exposure pathways. The approach uses dietary and occupancy data collected from integrated habit surveys conducted around nuclear sites. The habit surveys are targeted at those most likely to be exposed around the site and gather data on people's occupancy close to each site and local food intake rates. In 2009, an integrated habits survey was conducted for the first time at Derby, allowing this site to be assessed using this method. Habits surveys were also undertaken at Amersham and Wylfa, allowing the habits data for these sites to be updated, and an annual review of selected high-rate seafood consumers at Sellafield was conducted. The sites for which integrated habit survey data are currently available are: Aldermaston and Burghfield, Amersham, Berkeley and Oldbury, Bradwell, Capenhurst, Cardiff, Chapelcross, Derby, Devonport, Dounreay, Dungeness, Faslane, Hartlepool, Harwell, Heysham, Hinkley Point, Hunterston, Rosyth, Sellafield, Sizewell, Springfields, Torness, Trawsfynydd, Winfrith and Wylfa. In addition, a total dose assessment has been made the LLWR site, near Drigg, in 2009. The habits data used are an amalgamation of the most recent terrestrial habits survey for Drigg and aquatic data from the 2008 integrated Sellafield survey and the 2009 Sellafield review of high-rate seafood consumers.

A4.2 Objectives

The environment agencies are required to ensure that doses to the public do not exceed 1 mSv per year from all routine man made sources, except certain medical ones. Doses to the public are assessed and compared with the dose limit. For nuclear sites the dose assessment takes into account exposure to radionuclides in food and the environment and direct radiation. The assessment makes use of the monitoring results

reported elsewhere in this report. The monitoring and habits data used in the assessment are provided for each site on the CD accompanying this report.

A4.3 Methods and data

The calculation method relies on the application of data from site-specific habits surveys (Camplin *et al.*, 2005). This is possible because recent surveys have considered the habits of individuals in an integrated way, i.e. information for each individual has been recorded for all of the pathways of interest. Using the habits survey data, the people who are regarded as having the potential to receive the highest doses are identified for each major pathway at each site. Doses to the public from direct radiation are included in the assessment of *total dose* using information provided by the HSE, from data collected by the operators, who are responsible for regulating dose from direct radiation to the public (see Table A4.1) (Mayor, 2010).

A flow diagram of the method is given as Figure A4.1.

The habit profiles that gave rise to the highest doses in this assessment of RIFE 2009 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 people exposed to radiation through each pathway identified in the relevant habits survey using the same concentration and dose rate information used in the routine assessments earlier in this report. Pathways related to gaseous discharges, which are not included in the routine monitoring programmes (in particular inhalation and plume shine), were assessed using dispersion modelling within the PC CREAM assessment code (Mayall *et al.*, 1997). Using a similar approach as the routine assessments (see Appendix 1) the dose from

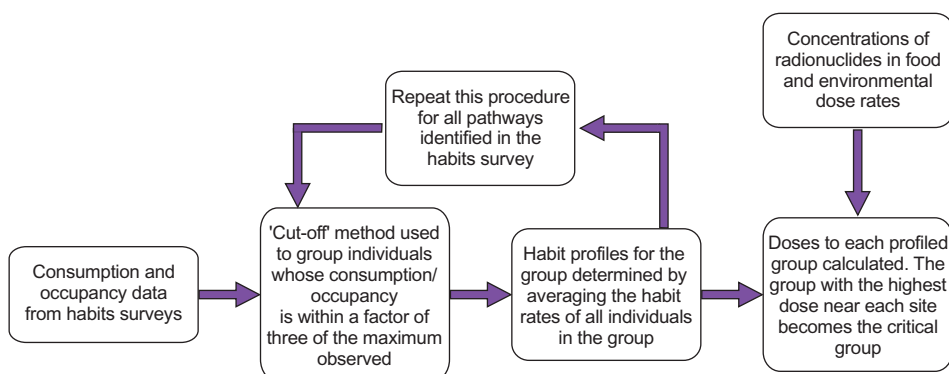


Figure A4.1. Steps in the total dose methodology

the plume is calculated for four age groups (adults, children, infants and prenatal children) in each of three concentric annuli representing the zones 0 – 0.25km, 0.25 – 0.5km and 0.5 – 1km from the site perimeter.

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 people receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in part A and those for liquid discharges in part B. Occasionally the people receiving the highest dose from all pathways are different from those in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented. An overview of part C is also given in the Technical Summary (Table S2).

In all cases, doses estimated for 2009 were less than the limit of 1 mSv for members of the public. The most important group for gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most important groups for liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose in 2009 was to local inhabitants near the Dungeness site; this dose was almost entirely due to direct radiation emanating from the site. The site's method of calculation of this component (as provided to the HSE) has been questioned, as it would have been expected to fall significantly following the shutdown of the Dungeness A generator in 2006. The next highest dose was to seafood consumers at Sellafield, Whitehaven and Drigg, though almost half of this was due to the legacy of discharges of naturally-occurring radionuclides from a phosphate processing works in Whitehaven. These consumers are common to each of the three sites which are located nearby to each other on the Cumbrian coastline. Small increases in gamma dose rates recorded around Heysham and Hinkley Point led to an increase in the dose to the most exposed people at these sites. At Chapelcross, a drop in the dose to infants from milk meant that adults spending time over contaminated sediments became the most exposed people. Changes in direct radiation remained the main driver of changes in *total dose* at other sites, particularly power stations. The first *total dose* assessment for Derby returned a very low dose, due mainly to the low levels of activity detected but also to the paucity of monitoring data available. 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 since 2003 using the methodology described in this Appendix. Over this time the number of sites with combined habits survey data has increased from six to the current 26. The *total doses* calculated for nuclear sites since 2003 are presented in Table A4.3. A time-series of *total dose* from 2004 – 2009 is shown in Figure A4.2, with doses not originally calculated for RIFE reports (due to a lack of suitable habits data at the time) retrospectively added according to the monitoring data for that year. Sites where the *total dose* has consistently been less than 0.005 mSv are not shown.

Many sites show little by way of a trend in *total dose*. Changes in direct radiation dominate the interannual variation at most of the power station sites, and small fluctuations in external dose rates can have relatively large effects at sites where high rates of intertidal occupancy have been recorded. One site that has seen a consistent downward trend in *total dose* is Cardiff, where the 2009 dose is now less than a fifth of the *total dose* in 2003. This continued trend echoes the reductions in levels of tritium and carbon-14 discharged in liquid wastes over the period and the associated reduction of concentrations in local seafood (Figures 6.2 and 6.3).

At Sellafield the component of the *total dose* attributable to man-made radionuclides has generally reduced, due to reductions in discharges and their effects on food and the environment, but this effect is often outweighed by the sensitivity of the *total dose* to small changes in the enhancement of naturally-occurring radionuclides such as lead-210 and polonium-210. In 2009, decreased concentrations of these natural radionuclides were responsible for lowering the total dose by 0.15 mSv (out of a total reduction of 0.19 mSv).

The increase in *total dose* observed at Dounreay in 2007 and 2008 was reversed in 2009, as caesium-137 concentrations in game meat (venison) decreased. The high consumption rate of game meat recorded during the 2008 habits survey makes this pathway more prominent than in the routine assessments earlier in this report.

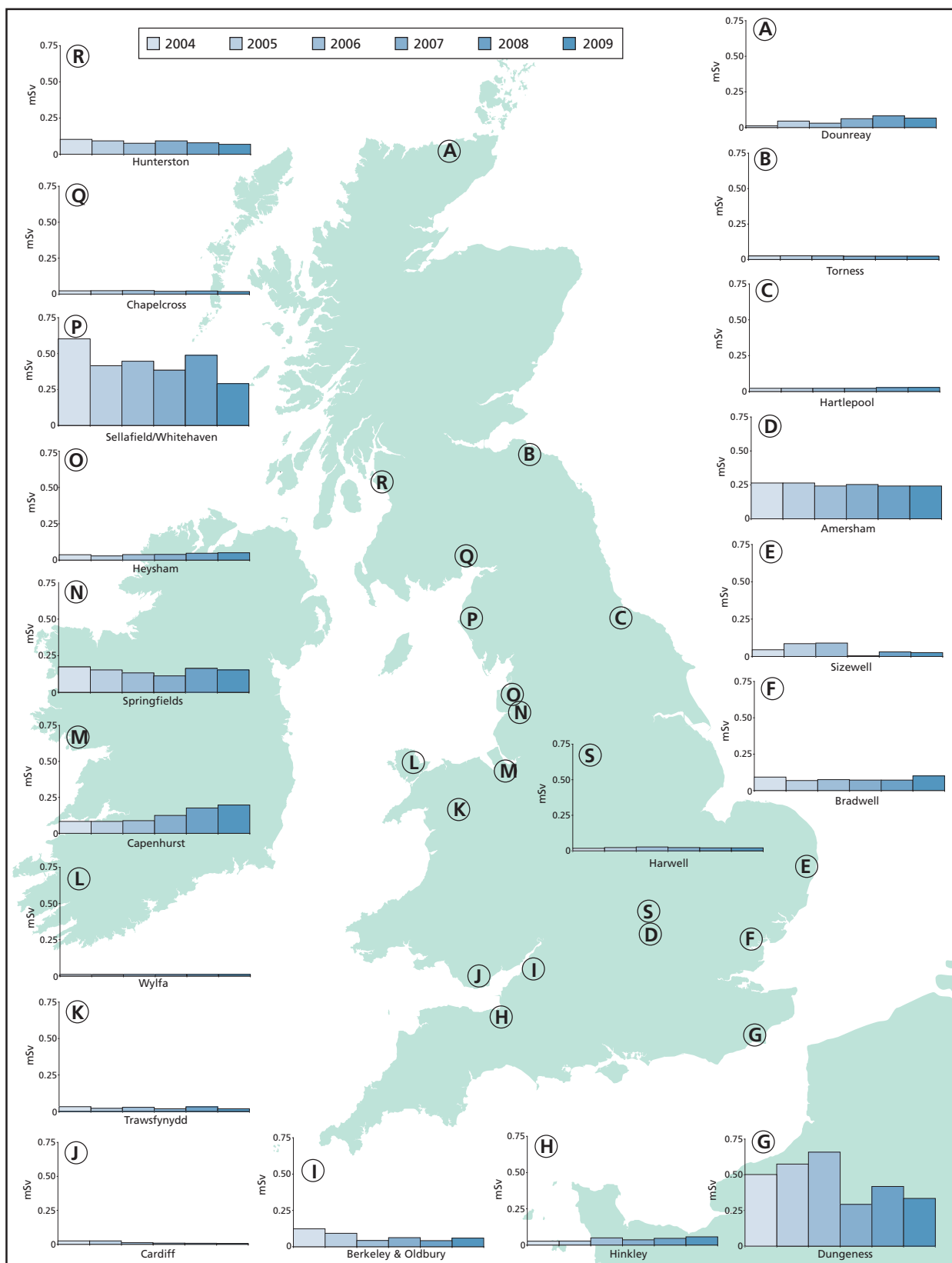


Figure A4.2. Total radiation exposures around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2009)*. (Exposures at Sellafield/Whitehaven receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)

* Trends at Aldermaston and Burghfield, Devonport, Faslane and Coulport, Rosyth and Winfrith are excluded from the figure as, throughout the time period, the total doses from all sources were assessed to have been less than 0.005mSv. Total dose assessments have been updated from values reported in previous RIFE publications, to take into account revised direct radiation data.

Table A4.1. Individual radiation exposures direct radiation pathway, 2009

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.19
Sellafield	0.001
Springfields	0.031
Research establishments	
Dounreay	0.005
Harwell	0.023
Winfrith	Bgd ^a
Nuclear power stations	
Berkeley	<0.057
Bradwell	0.098
Chapelcross	0.001
Dungeness	<0.32
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	0.004
Hunterston	<0.066
Oldbury	<0.007
Sizewell	<0.026
Torness	<0.020
Trawsfynydd	0.016
Wylfa	0.009
Defence establishments	
Aldermaston	Bgd ^a
Burghfield	Bgd ^a
Derby	Bgd ^a
Radiochemical production	
Amersham	0.22
Cardiff	Bgd ^a
Industrial and landfill sites	
LLWR near Drigg	0.030

^a Doses not significantly different from natural background

Table A4.2. Individual radiation exposures integrated across pathways, 2009

Site	Most exposed people ^a	Exposure, mSv	
		Total	Dominant contributions ^b
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1y	<0.005	Milk, ³ H, ¹³⁷ Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Prenatal children of local inhabitants (0 - 0.25km)	0.058	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.098	Direct radiation
Capenhurst	Local inhabitants aged 1y (0 - 0.25km)	0.19	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	0.006	Milk, ¹⁴ C, ³⁵ S, ⁹⁰ Sr
Derby	Local adult inhabitants (0.25 - 0.5km)	<0.005	²³⁴ U, ²³⁸ U
Devonport	Prenatal children of green vegetable consumers	<0.005	Green vegetables, ¹⁴ C
Dounreay	Adult consumers of game meat	0.063	Game meat, ¹³⁷ Cs
Dungeness	Local adult inhabitants (0 - 0.25km)	0.32	Direct radiation
Faslane	-	-	
Hartlepool	Local inhabitants aged 1y (0 - 0.25km)	0.020	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.023	Direct radiation
Heysham	Local adult inhabitants (0.25 - 0.5km)	0.021	Direct radiation
Hinkley Point	Local inhabitants aged 10y (0.5 - 1km)	<0.005	Direct radiation
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.067	Direct radiation
LLWR near Drigg	Local adult inhabitants (0.25 - 0.5km)	0.036	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Adult consumers of game meat	0.045	Crustaceans, fish, game meat, ¹³⁷ Cs, ²¹⁰ Po
Sizewell	Prenatal children of wild fruit and nut consumers	0.026	Direct radiation
Springfields	Adult mushroom consumers	0.032	Direct radiation
Torness	Prenatal children of root vegetable consumers	0.022	Direct radiation
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.018	Direct radiation, milk
Winfrith	Prenatal children of potato consumers	<0.005	Potatoes, ¹⁴ C
Wylfa	Local inhabitants aged 1y (0.25 - 0.5km)	0.011	Direct radiation, milk
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants of riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Adult occupants over riverbank	<0.005	Gamma dose rate over riverbank
Berkeley and Oldbury	Adult occupants over sediment	0.020	Gamma dose rate over sediment
Bradwell	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Capenhurst	Occupants over riverbank aged 10y	0.009	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment, fish, ³ H
Chapelcross	Adult occupants over sediment	0.017	Gamma dose rate over sediment
Derby	Consumers of locally sourced water aged 1y	<0.005	Water, ⁶⁰ Co
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Dungeness	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish, ²⁴¹ Am
Hartlepool	Adult occupants over sea coal/sand	0.015	Gamma dose rate over sea coal/sand
Harwell	Adult occupants of riverbank	0.006	Gamma dose rate over riverbank
Heysham	Adult occupants over sediment	0.049	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.055	Gamma dose rate over sediment
Hunterston	Adult fish consumers	<0.005	Fish, ¹³⁷ Cs, ²⁴¹ Am
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and LLWR ^d	Adult mollusc consumers	0.28 ^c	Crustaceans, molluscs, ²¹⁰ Po, ^{239/240} Pu, ²⁴¹ Am
Sizewell	Adult occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.15	Gamma dose rate over sediment
Torness	Adult occupants over sediment	0.007	Direct radiation, gamma dose rate over sediment
Trawsfynydd	Adult occupants on water	<0.005	Fish, gamma dose rate over sediment, ⁹⁰ Sr, ¹³⁷ Cs, ²⁴¹ Am
Winfrith	Prenatal children of occupants over sediment	<0.005	Gamma dose rate over sediment, potatoes, ¹⁴ C
Wylfa	Adult occupants over sediment	0.009	Gamma dose rate over sediment, direct radiation

Table A4.2. continued

Site	Critical group ^a	Exposure, mSv	
		Total	Dominant contributions ^b
C Combined releases from the site			
Aldermaston and Burghfield	Adult occupants of riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Prenatal children of local inhabitants (0 - 0.25km)	0.058	Direct radiation
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.098	Direct radiation
Capenhurst	Local inhabitants aged 1y (0 - 0.25km)	0.19	Direct radiation
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment, fish, ³ H
Chapelcross	Adult occupants over sediment	0.017	Gamma dose rate over sediment
Derby	Consumers of locally sourced water aged 1y	<0.005	Water, ⁶⁰ Co
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult consumers of game meat	0.063	Game meat, ¹³⁷ Cs
Dungeness	Local adult inhabitants (0.5 - 1km)	0.32	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud, fish, ²⁴¹ Am
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.027	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.023	Direct radiation
Heysham	Adult occupants over sediment	0.049	Gamma dose rate over sediment
Hinkley Point	Adult mollusc consumers	0.055	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.067	Direct radiation
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and LLWR ^d	Adult mollusc consumers	0.28 ^c	Crustaceans, molluscs, ²¹⁰ Po, ^{239/240} Pu, ²⁴¹ Am
Sizewell	Local adult inhabitants (0 - 0.25km)	0.026	Direct radiation
Springfields	Adult occupants on houseboats	0.15	Gamma dose rate over sediment
Torness	Prenatal children of root vegetable consumers	0.022	Direct radiation
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.018	Direct radiation, milk
Winfrith	Prenatal children of potato consumers	<0.005	Potatoes, ¹⁴ C
Wylfa	Local inhabitants aged 1y (0.25 - 0.5km)	0.011	Direct radiation, milk

^a Selected on the basis of providing the highest dose from the pathways associated with the sources as defined in A, B or C

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

^c The doses from man-made and naturally occurring radionuclides were 0.15 and 0.14 mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR site into the same area

^d Sellafield, Whitehaven and LLWR sites are considered together as their effects are dominated by radioactivity in a common area of the Cumbrian coast

Table A4.3. Trends in total dose (mSv) from all sources^a

Site	2003	2004	2005	2006	2007	2008	2009
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Amersham		0.24	0.24	0.22	0.23	0.22	0.22
Berkeley and Oldbury		0.12	0.090	0.042	0.061	0.041	0.058
Bradwell		0.09	0.067	0.073	0.070	0.070	0.098
Capenhurst		0.080	0.080	0.085	0.12	0.17	0.19
Cardiff	0.038	0.023	0.023	0.011	0.008	0.007	0.006
Chapelcross		0.022	0.023	0.024	0.019	0.021	0.017
Derby							<0.005
Devonport		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dounreay	0.012	0.011	0.043	0.029	0.059	0.078	0.063
Dungeness		0.48	0.55	0.63	0.28	0.40	0.32
Faslane		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hartlepool	0.021	0.021	0.021	0.021	0.021	0.026	0.027
Harwell		0.017	0.022	0.026	0.022	0.020	0.023
Heysham		0.036	0.028	0.037	0.038	0.046	0.049
Hinkley Point		0.026	0.027	0.048	0.035	0.045	0.055
Hunterston		0.10	0.090	0.074	0.090	0.077	0.067
Rosyth		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sellafield, Whitehaven and LLWR	0.66	0.58	0.40	0.43	0.37	0.47	0.28
Sizewell		0.045	0.086	0.09	<0.005	0.031	0.026
Springfields		0.17	0.15	0.13	0.11	0.16	0.15
Torness		0.024	0.025	0.024	0.022	0.022	0.022
Trawsfynydd		0.032	0.021	0.028	0.018	0.031	0.018
Winfrith	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.010	0.011	0.011	0.011

^a Where no data is given, no assessment was undertaken due to a lack of suitable habit data at the time. Data in *italics* signify assessments performed to show trends in total dose over the five-year period from 2004 - 2008, using subsequently obtained habit data

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 2009 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 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.

External dose in the Ribble Estuary

Radionuclides are found in the Ribble Estuary in Lancashire from liquid waste discharges from Springfields and Sellafield. A study for the Environment Agency has begun to extend previous research and supplement the routine monitoring programme published in RIFE by offering detailed and focussed surveys of three field sites:

- (i) A boatyard where there are houseboat dwellers
- (ii) A salt marsh frequented by wildfowls and
- (iii) A tidal tributary used by pleasure craft

The main findings of the study are in preparation (Punt *et al.*, *in preparation*) but preliminary findings include:

- The current external gamma dose rates are dominated by caesium-137 discharges arising from the Sellafield site whilst the contribution from Springfields is minimal
- Large boat hulls resulted in a gamma dose rate reduction of up to 50% compared to that over intertidal sediment. There was little attenuation for small boat hulls.
- Houseboat dwellers in the Becconsall boatyard remain the most exposed people. They were estimated to receive around 70 μ Sv in 2008.
- Dose to wildfowls on the salt marshes are about half that received by houseboat dwellers, however more information is needed on the importance of dug-out hide pits where higher dose rates were measured

The full findings will be published and summarised in next year's RIFE report.

Table A5.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Freshwater concentration factors for phosphorus-32	SCO60083/SR	E	In press
Estimating external dose rates to people on houseboats	SCO60080	E	In press
Survey of gamma dose rates in air around the Esk Estuary	SCO60083/SR3	E	In press
Determining Capacities for Disposal of VLLW and LLW to Landfills	SC080027	E	In press
Soil and herbage survey	UKRSR01 and SCO00027	E, S	Dec-09
Transfer from seaweed to terrestrial foods	R04003	F	Nov-09
Measurement of radioactivity in canteen meals for Euratom (2005-2012)	R03025	F	Mar-13

E *Environment Agency*

F *Food Standards Agency*

S *Scotland and Northern Ireland Forum for Environmental Research or SEPA*

APPENDIX 6. Disposal of dredge material from Oldbury Power Station, South Gloucestershire

In England, the Marine Management Organisation (MMO) administers a range of statutory controls that apply to marine works on behalf of the Secretary of State for Environment, Food and Rural Affairs (Defra), this includes issuing licences under the Food and Environmental Protection Act (FEPA), 1985 (United Kingdom – Parliament, 1985) for the disposal of dredged material at sea. Licences for disposals made in Scottish waters and around the coast of Northern Ireland are the responsibility of the Scottish Government (Marine Scotland) and the Department of Environment (NIEA), respectively. As of 1 April 2010 licences for Welsh waters are the responsibility of the Welsh Assembly Government (WAG).

The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003). This has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2009, Magnox North Limited

lodged a FEPA licensing application to carry out a 3 months dredging program, involving the disposal at sea of 360 m³ of sediment from Oldbury Power Station. A specific assessment was conducted for the disposal of the dredge material (Leonard, 2009).

The sediments contain artificial radionuclides due to the combined effects of discharges from the site, other nuclear establishments discharging into the Bristol Channel and weapons testing (and possibly a small Sellafield derived component). Samples of the material were taken and analysed and the results are given in Table A6.1. The contributions from individual radionuclides to the total dose for individual crew members and individual members of the public are given in Figures A6.1 and A6.2, respectively. Under the London Convention, only materials with *de minimis* levels of radioactivity may be considered for dumping. Using the conservative generic radiological assessment procedure developed by the IAEA (International Atomic Energy Agency, 2003) to convert radionuclide concentrations in dumped material into radiation doses due to dumping, the total dose (from artificial and naturally-occurring radionuclides) to individual members of the crew and public were both less than 0.005 mSv per year and within the IAEA *de minimis* criteria of 0.010 mSv per year.

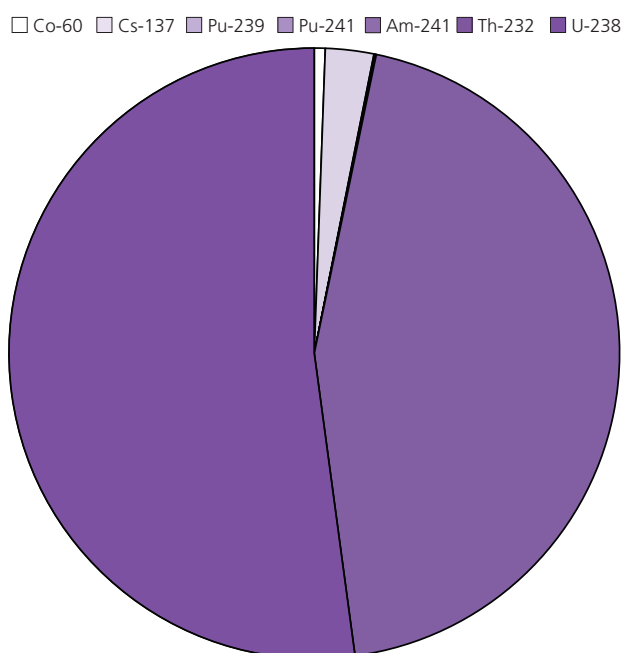


Figure A6.1. Radionuclide contribution to dose to individual crew members due to dredging at Oldbury power station

□ Co-60 □ Cs-137 □ Pu-239 □ Pu-241 □ Am-241 □ Th-232 □ U-238

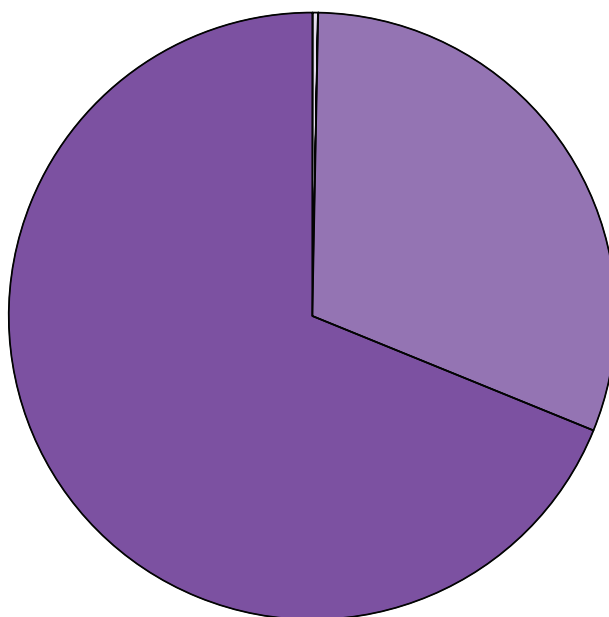


Figure A6.2. Radionuclide contribution to dose to individual members of the public due to dredging at Oldbury power station, 2009

Table A6.1. Concentrations of radionuclides in sediment dredged from Oldbury power station, 2009

Sample number	Mean radioactivity concentration (dry), Bq kg ⁻¹					
	⁶⁰ Co	¹³⁷ Cs	²²⁶ Ra (via ²¹⁴ Pb) ¹	²³² Th (via ²²⁸ Ac) ¹	²³⁸ U (via ²³⁴ Th) ¹	²⁴¹ Am
1	<0.25	12	17	19	30	<1.1
2	<0.28	8	13	15	19	<0.45
3	<0.27	15	24	26	37	<1.24
4	<0.40	6	15	16	19	<0.68
Mean*	0.3	10	17	19	26	1

¹ Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products

* Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)



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