RIFE - 17

Radioactivity in Food and the Environment, 2011

Environment Agency

Food Standards Agency
food.gov.uk

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

SEPA Scottish Environment Protection Agency

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October 2012

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

Cefas

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- in Northern Ireland,
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Preface

April 2011 marked the 25th anniversary of the Chernobyl accident which resulted in radioactivity being deposited over the UK. Over the past 25 years levels of radioactivity in the UK from the accident have fallen significantly. Results from a 2011 review have shown the risk to consumers from radioactivity in food is very low; consequently, all restrictions on movement of animals have been lifted.

In 2011, the major accident at the Fukushima Dai-ichi nuclear power station in Japan resulted in the release of radionuclides into the environment. Knowledge from dealing with the after-effects of the Chernobyl accident and experience gained from the UK governments' well established radiological monitoring programmes allowed the UK to respond appropriately and to offer advice and support to Japan, which is continuing.

As expected from such a significant accident, radioactive material was released into the atmosphere and with time this dispersed and spread across the globe. It was predicted that radioactivity levels in the UK would be very low and of no significant concern to health. The Environment Agency, the Northern Ireland Environment Agency and the Scottish Environment Protection Agency (SEPA) (collectively referred to as the environment agencies in this report) and the Food Standards Agency were able to detect the arrival in the UK of very low levels of radioactivity from Japan. The agencies focused their radiological programmes on direct monitoring of air, rain and food to check for radioactivity from the accident, showing the value of these programmes to respond to an accident. The Health Protection Agency made use of all the monitoring data to confirm that the health risks for the UK were negligible.

During 2011, the European Commission (EC) conducted a verification visit, as part of their on-going programme of inspections, of the environmental monitoring arrangements for Sellafield, and Lillyhall landfill sites. The EC team has concluded that the UK is fulfilling its monitoring obligations under Article 35 of the Euratom Treaty for these sites.

The continuation of our routine monitoring programmes allow us to demonstrate that radioactivity in food is well within safe levels, and the exposure of members of the public from authorised/permitted discharges and direct radiation around the 39 nuclear sites in the UK has remained within legal limits. It is important that the programmes remain fit for purpose and be flexible enough to adjust for new demands. To this end, in 2011, the Environment Agency, Food Standards Agency and SEPA published their Environmental Monitoring Guidance document for radioactivity. This sets out guidance on planning and implementing environmental radiological monitoring programmes as well as objectives and principles to consider when designing such programmes.

This report covers sampling and analysis conducted in 2011 and brings together the work of the environment agencies and the Food Standards Agency. These monitoring programmes are independent of, and also used as a check on, the site operators' programmes.

Technical summary

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

- Radiation exposures (doses) to people living around UK nuclear sites
- Radioactivity concentrations in samples collected around UK nuclear sites
- External dose rates as a result of exposure to radiation from sediments, etc.
- UK site incidents and non-routine surveys
- Radiation exposures and radioactivity concentrations at other locations remote from UK nuclear sites

Radiation exposure around UK 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 where appropriate. The assessments use radionuclide concentrations, dose rates and information on the habits of people living near the sites. Changes in the doses received by people can occur from year to year and 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, which is reported in habits surveys. The dose quantity presented in this summary is known as the *'total dose'* and is made up of contributions from all sources. Source specific dose assessments are also performed in some cases as a check on the *total dose* assessment method. *Total dose* is confirmed as a robust measure of exposure.

Figure S and Table S show the assessed *total doses* due to the effects of authorised/permitted waste discharges and direct radiation for those people most exposed to radiation near all major nuclear licensed sites in the UK. In 2011, radiation doses from authorised/permitted releases of radioactivity, to adults and children living around nuclear sites, remained well below the UK national and European limit of 1 millisievert (mSv, a measure of dose) per year (see Appendix 3 for explanation of reference to dose).

This year, those sites where the public received the highest doses were Amersham, Sellafield and Springfields with doses of 0.22 and 0.18 and 0.13 mSv, respectively. The dose received from Amersham was largely dominated by direct radiation from sources on the site. In comparison, the highest doses in 2010 were Capenhurst, Amersham and Sellafield. The decrease in the Capenhurst dose was due to a lower estimate of direct radiation from the site in 2011.

Permitted discharges were the source of most of the public dose at the Sellafield site. A small number of people in Cumbria who consumed samphire and seaweed (marine plants) represented those who received the highest dose of radiation there. Their dose was estimated to be 0.18 mSv in 2011, which was well within the EU and UK limit for members of the public of 1 mSv per year. This dose included 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 0.068 mSv to this dose in 2011, a reduction from the 0.14 mSv reported in 2010 (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 group representative of those most exposed changed from high rate consumers of molluscan shellfish in 2010 to those consuming locally harvested marine plants in 2011. However those eating marine plants also consumed fish and shellfish and the reduction in dose due to Sellafield discharges was largely caused by a reduction in the amount of molluscan shellfish consumed by those most exposed. Doses from technetium-99 have been falling for several years as a result of decreasing discharges from Sellafield. In 2011, technetium-99 in seafood contributed 0.002 mSv (about 2 per cent) to the 0.068 mSv dose. The effects of iodine-129 discharges are also determined. This radionuclide is estimated to have delivered a dose of 0.011 mSv in 2011, or about 16% of the dose due to Sellafield discharges. This estimate is based on results at the limit of detection of iodine-129 and is an overestimate of the dose actually received.

Most liquid radioactive discharges from Sellafield have decreased in recent years. Consequently, concentrations of most radionuclides in fish and shellfish have also reduced or were unchanged. The trend of generally reducing dose in recent years has also been affected by changes in consumption of local seafood.

As well as the radiation exposure from Sellafield discharges, the people who consumed seafood also received a dose of 0.11 mSv in 2011 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

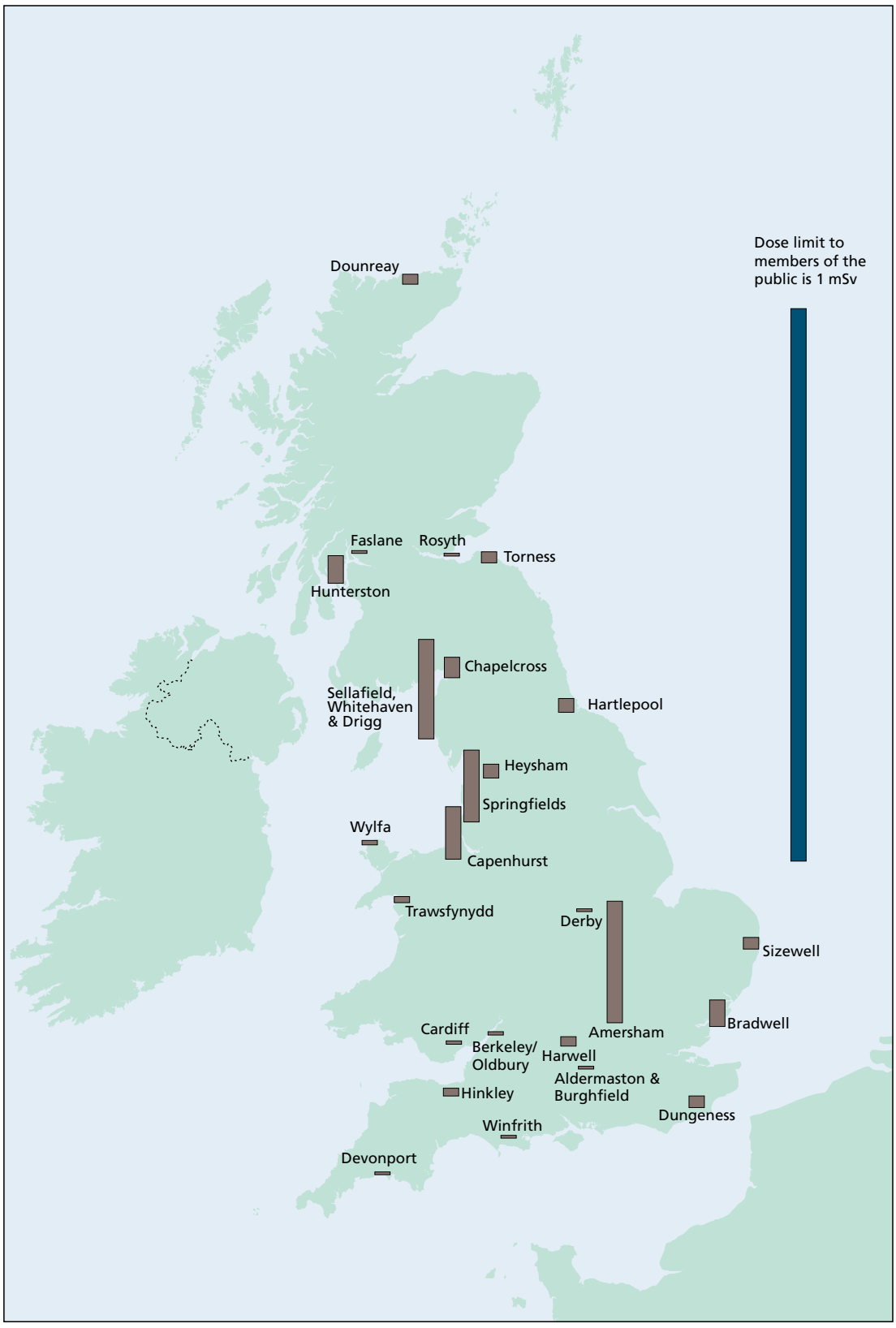

Figure S. Total radiation exposures in the UK due to radioactive waste discharges and direct radiation, 2011 (Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S. Radiation doses due to all sources at major UK sites, 2011[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.095	Direct radiation
Springfields	0.13	Gamma dose rate over sediment
Sellafield[d]	0.18	Crustaceans, fish, gamma dose rate over sediment, ^{210}Po
Research establishments		
Dounreay	0.018	Milk, ^{90}Sr, ^{106}Ru, ^{144}Ce, ^{241}Am
Harwell	0.017	Direct radiation
Winfrith	<0.005	Gamma dose rate over sediment
Nuclear power stations		
Berkeley and Oldbury	0.006	Gamma dose rate over sediment
Bradwell	0.048	Direct radiation
Chapelcross	0.037	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Dungeness	0.021	Direct radiation
Hartlepool	0.025	Direct radiation, gamma dose rate over sediment
Heysham	0.025	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}$Pu, ^{241}Am
Hinkley Point	0.014	Gamma dose rate over sediment
Hunterston	0.050	Direct radiation
Sizewell	0.021	Direct radiation
Torness	0.020	Direct radiation
Trawsfynydd	0.012	Exposure over sediment, fish, ^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am
Wylfa	0.008	Fish, gamma dose rate over sediment, ^{137}Cs
Defence establishment		
Aldermaston and Burghfield	<0.005	Milk, ^{3}H, ^{137}Cs
Derby	<0.005	Water, ^{60}Co
Devonport	<0.005	Fish, ^{131}I, ^{241}Am
Faslane	<0.005	Gamma dose rate over sediment
Rosyth	<0.005	Fish, ^{241}Am
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.006	Gamma dose rate over sediment
Industrial and landfill		
LLWR near Drigg[d]	0.18	Crustaceans, fish, gamma dose rate over sediment, ^{210}Po
Whitehaven[d]	0.18	Crustaceans, fish, gamma dose rate over sediment, ^{210}Po

[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 0.068 and 0.11 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 near Drigg site into the same area*

concentrations and the range of concentrations normally expected from natural background. 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 2011 of 0.11 mSv was higher than the dose of 0.047 mSv in 2010. The increase was largely due to (i) an increase in the polonium-210 concentration in fish in 2011 and (ii) an increase in the consumption rate of fish by the group representing those most exposed.

The highest dose at Sellafield was most affected by historic liquid discharges. The maximum dose at Sellafield for those people most affected by pathways related to gaseous discharge and direct radiation sources was 0.010 mSv in 2011 compared with 0.011 mSv in 2010. The people most exposed in 2010 and 2011 were high-rate infant consumers of milk.

The next highest dose due to waste discharges was received by people living on houseboats in the Ribble Estuary (Springfields). In 2011, 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 2010 was 0.17 mSv and the decrease was due to small decreases in dose rates near the boats. The dose to these people was the highest in the UK due to nuclear industry waste discharges.

In Scotland, the people who received the highest dose from authorised releases of radioactivity were those who lived near the Hunterston site. It is estimated that they received 0.050 mSv in 2011. Most of this dose was due to direct radiation from the site.

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 were produced until 2010. In 2011, the people most exposed received an estimated dose of 0.006 mSv. Their dose in 2010 was the same. The dose is now mostly due to external radiation that was not derived from operations at the Maynard Centre. Eating fish from the Severn Estuary that contained tritium and carbon-14 also made a small contribution to the dose. Doses at this site have been falling since 2000 in line with lower discharges.

Habits surveys near UK nuclear sites

In 2011, 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 2011, surveys were carried out at Aldermaston/Burghfield, Devonport, Heysham and Sellafield in England, and at Faslane and Torness in Scotland. The findings were used to confirm the adequacy of current monitoring programmes or strengthen and update them with a better representation of relevant pathways, and to improve the assessment of doses to members of the public near nuclear sites.

Radioactivity concentrations in samples collected around UK 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. This means that nuclear sites need action plans to achieve reductions in discharges. In 2011, the Environment Agency and SEPA issued new authorisations/permits, or varied existing ones, at eight sites (for defence sites at Barrow, for power stations: Dungeness A; Hunterston B and Torness, for the research establishments at Dounreay and Harwell, and for landfill sites: East Northants Resource Management Facility near Kings Cliffe and Waste Recycling Group (WRG) Limited, Lillyhall), resulting in one or more of: strengthened conditions, reduced limits or new routes for disposing of radioactive waste.

There were no major variations in environmental concentrations of radioactivity in 2011 compared to those in 2010. During the past decade, discharges from GE Healthcare at Cardiff have continued to decline. 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.

During 2011, discharges of technetium-99 from Sellafield continued to remain low, following the introduction of abatement technology in previous years. Discharges are expected to remain low in the future. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and in the North Sea. Concentrations of technetium-99 have shown a strong trend downward from their most recent peak in 2003, though concentrations in 2011 were similar to those in 2010. Technetium-99 has been found in seaweed, but monitoring has shown a low transfer from sea to land where seaweed has been used as a soil conditioner.

Marine sediment samples are a useful indicator of trends in the environment. People who spend time on beaches can be exposed to radiation through the radionuclide content of the sediments. Near Sellafield, the environmental concentrations of most radionuclides have declined substantially over the last 20 years. In previous years, concentrations of caesium-137, plutonium isotopes and americium-241 have increased in mud samples from the Ravenglass estuary near Sellafield. However, since 2006, these activity concentrations have been generally decreasing with time. There were small decreases in concentrations of plutonium isotopes and americium-241 in fish and shellfish samples from Cumbria in 2011.

On occasion, the effects of non-nuclear sites discharge are detected at low levels by the routine monitoring programme for nuclear sites. In 2011, iodine-131 was detected at several nuclear sites. The source of the iodine-131 is not known with certainty but a likely cause was the therapeutic use of this radionuclide in a local hospital. The concentrations were of low radiological significance.

Dose rates from around UK 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. Background levels are subtracted in dose assessments.

There were no major changes in external dose rates in intertidal areas in 2011 compared with 2010. 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

UK Nuclear site incidents and non-routine surveys

During 2011, as a result of an ongoing programme of monitoring by the operator, radioactive items were detected on beaches on the Cumbrian coastline, where 267 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 April 2011 (Environment Agency, 2011b). The Health Protection Agency (HPA) provided advice in March 2011 that the overall health risks for beach users from radioactive objects on beaches near Sellafield are very low and significantly lower than other risks that people accept when using the beaches (Brown and Etherington, 2011). Monitoring, removal and research into the origins, fate and effects of the particles by Sellafield Limited will continue.

At Chapelcross, a programme of work to reline and grout sections of the discharge pipeline has mitigated the potential release of limescale particles, with no particles being detected on the foreshore during 2011. At Dounreay, the comprehensive beach monitoring programme for fragments of irradiated nuclear fuel (particles) continued and further particles were recovered from local beaches. Offshore particles which could pose significant harm were recovered from the seabed, where fishing restrictions under the Food and Environment Protection Act (FEPA) 1985 are still in force.

'Special' (or *ad hoc*) sampling related to nuclear site operation was undertaken at two sites in 2011. At Chapelcross, rainwater was sampled and analysed on a weekly basis, and rabbits were sampled and analysed from around Dounreay. Further details of this work can be found in the relevant site text.

Radiation doses and levels at other locations

Additional monitoring was undertaken in the UK and surrounding seas to study the effects of (i) overseas incidents at Chernobyl in 1986 and at Fukushima Dai-ichi in 2011, (ii) non-nuclear sites and (iii) regional variation in levels of radioactivity across the UK.

Overseas incidents

The accident at Fukushima Dai-ichi nuclear power station in Japan in March 2011 resulted in significant quantities of radioactivity being released to air and sea. These began to circulate in the Northern Hemisphere atmosphere, reaching Western Europe towards the end of March that year.

In the UK, the situation was kept under review at the highest level in Government, which set up the Cabinet Office Briefing Room (COBR), meeting for the first time on 11 March 2011. COBR was supported by the Scientific Advisory Group in Emergencies (SAGE), which included experts from the Environment Agency and the Food Standards Agency. The main focus was to give UK citizens living in or visiting Japan advice on:

- Restrictions on access to contaminated areas;
- Restrictions on eating locally produced food;
- Keeping and disposing of contaminated items.

Actions taken in the UK included:

- Implementing EU controls on importing food from Japan
- Enhanced monitoring across the UK, measuring air, rain, grass and food to check for the effects of atmospheric transport and deposition from Japan.

The environment agencies and the Food Standards Agency increased the scrutiny of their environmental monitoring programmes and took additional samples. Elevated iodine-131 concentrations were detected at the end of March 2011 in the UK. The concentrations were extremely low and consistent with those found elsewhere in Europe. The very low levels detected in the UK environment were not radiologically significant and mean that there was minimal risk to public health in the UK from the release of radioactive material at the Fukushima Dai-ichi nuclear power plant.

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* *"Particle" is a term used in this report which encompasses discrete radioactive items which can range in size and origin. "Particles" include radioactive scale, fragments of irradiated nuclear fuel, incinerated waste materials and stones which have radioactive contamination on their surface. Particles are not physically the same at each of the sites mentioned, but can be compared according to the hazard posed.*

Controls on food imports took two forms. The European Commission (EC) implemented controls on the import of food and feed originating in or consigned from Japan. All food and feed imported from Japan had to be certified by the Japanese authorities. In addition, a percentage of Japanese imports into the EU were monitored at ports of entry. Some imports of seafood from other nations from the region where contamination might be expected in the western Pacific were also monitored. The results of monitoring Japanese imports to the UK have been published by the EC (http://ec.europa.eu/energy/nuclear/radiation_protection/fukushima_en.htm). None of the imports to the UK have contained activity exceeding the maximum permissible levels; most results have been below the limits of detection, with a few being around 10 Bq kg^{-1}. The public doses received due to the imports were of negligible radiological significance.

The environmental effects of the Chernobyl accident continued to be monitored in 2011. There were still restrictions on moving, selling and slaughtering sheep in some upland areas of the UK, but following a detailed appraisal of the possible exposures due to consumption of sheep meat, all restrictions were lifted by the Food Standards Agency in June 2012.

Non-nuclear sites

In the past, liquid slurry containing thorium and uranium was discharged into the Irish Sea from a phosphate plant near Whitehaven in Cumbria. 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 2011 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. 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, with about 60% from polonium-210.

Radioactive items containing radium-226 and associated daughter products have been detected at Dalgety Bay in Fife since at least 1990. Contamination has been associated with historic disposals of waste from past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959 and upon which large areas of the town of Dalgety Bay have been built. 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 by reclaiming land from the sea. Following years of erosion at the site the contamination is being exposed on, and adjacent to, the foreshore. Some of the incinerated material contained items such as dials and levers which had been painted with luminous paint containing radium-226.

In 2011, work to determine the primary source and extent of the contamination continued and SEPA began an investigation into the headland area of Dalgety Bay to determine whether it is a potential source of the particles that continue to repopulate the beach. Further monitoring of the beach was undertaken resulting in over 1000 particles being recovered from the beach including a number of high activity particles with activities of 76MBq (estimated), 10MBq, 2MBq, 1.8MBq and 1.3MBq. In order to provide SEPA with information on the potential hazards to the public at Dalgety Bay, SEPA commissioned work for characterisation of a sample of the particles recovered during 2011. This analysis involved the measuring of physical size, mass and activity of the selected particles. In addition, some were subject to a solubility analysis using simulated stomach acid and intestine solutions to inform on the potential ingestion hazard.

The finding of the increased number of particles coupled with the discovery of the high activity particles resulted in the erection of extra signage to inform the public and the demarcation of the section of the beach where the high activity particles were found. In addition, the Food Standards Agency in Scotland has placed a FEPA Order on Dalgety Bay prohibiting the collection of seafood from the area and SEPA has started a programme of shellfish monitoring. These public protection measures will remain in place until either remediation has been achieved or a full risk assessment can be conducted.

Further details of this work can be found in section 7.6 and on the Dalgety Bay web pages of the SEPA website. The work to characterise the extent of the contamination at Dalgety Bay is continuing and an update will be provided in next year's RIFE report.

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).

Regional monitoring

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 La Hague and other local sources were less than 1 per cent of the limit.

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.

Food imported into the UK may contain radioactive contamination. A monitoring system is in place to detect radioactivity in consignments. In 2011, the Food Standards Agency analysed a sample of wild mushrooms from Bulgaria that was to be imported into the UK. The concentration found was 4951 Bq kg^{-1} of caesium-137. This was above the maximum level permissible under EC regulations, which is 600 Bq kg^{-1}, and the Food Standards Agency recommended that the consignment should not be placed on the market and was unfit for human consumption.

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 governments' targets for improving the state of the marine environment.

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 agencies and the Food Standards Agency 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 (DECC), the Department for Environment, Food and Rural Affairs (Defra), the Manx Government and the Welsh Government. Overall, around 12,000 analyses and dose rate measurements were completed in 2011.

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 are supported by a number of research studies, investigating specific issues such as the measurement of radioactivity in canteen meals. 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

This section (i) describes the purpose and scope of the UK monitoring programmes for radioactivity in food and the environment, (ii) provides a summary of the key results in terms of radiation exposures at each major industrial site in 2011 and (iii) gives an overview of the main sources of radiation in a regulatory context.

Key points

- The RIFE report represents collaboration by the environment agencies and the Food Standards Agency across the UK, independent of industry
- 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
- Dose results are summarised for major industrial sites; all doses were below the legal limit in 2011

1.1 Purpose and scope of the monitoring programmes

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 carries out food, environmental and dose rate monitoring, working closely with the Food Standards Agency and the Food Standards Agency in Scotland on its programme, and in Northern Ireland this is carried out by the Northern Ireland Environment Agency. The Food Standards Agency (in 2011) continued to monitor some upland areas in England, Wales and Scotland for caesium-137, arising from the 1986 Chernobyl accident and all agencies contributed to the Government response to the Fukushima Dai-ichi accident in March 2011. Drinking water, air and rain are monitored on behalf of the Department of Energy and Climate Change, NIEA and the Scottish Government. The Food Standards Agency and SEPA also carry out nationwide monitoring of foodstuffs (including milk, animals, crops and canteen meals) that are remote from 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.

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 93) (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 within the vicinity of, 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 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, giving information on background concentrations of radionuclides; these data are reported to the European Commission. In 2011, programmes were extended as part of the UK governments' response to the accident at the Fukushima Dai-ichi power station in Japan. Food and environment samples from across the UK were analysed to check the effects of fallout from the long range transport of radioactivity from Japan. Guidance on planning and implementing routine environmental programmes has been published (Environment Agency, Food Standards Agency and Scottish Environment Protection Agency, 2010).

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 in a file 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, 2010b).

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 Limited (formerly Laboratory of the Government Chemist)
- Scientifics Limited (SL)
- Animal Health and Veterinary Laboratories Agency (AHVLA)
- Winfrith Environmental Level Laboratory (Amec NNC Limited)

1.2 Summary of doses

1.2.1 The assessment process

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 2011, using monitoring results for that year. The radioactivity concentrations and dose rates reported include the combined radiological impact 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 of assessment takes precedence since it is more complete. It considers the effects of discharges of radioactive waste and 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) working through their agency, the Office for Nuclear Regulation (ONR)*. Nuclear site operators provide estimates of direct radiation doses to HSE which are made available for use in these assessments (Table 1.1). The *total dose* assessments use recent habit survey data which has been profiled using an agreed method (Camplin *et al*., 2005).

The second type of assessment focuses on specific sources and their associated pathways. It serves as a check on the adequacy of the *total dose* method and is also compatible with the approach used prior to the introduction of *total dose* in 2004.

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

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.

1.2.2 *Total dose* results for 2011

The results of the assessment for each site are summarised in Table 1.2 (see also Figure S and Table S in the Technical Summary). 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 this case is presented in part C. The major contributions to dose are also presented. The use of radionuclide concentrations reported at the limits of detection provide an upper estimate of doses calculated for pathways based on these measurements. The full output from the assessment for each site is provided on the CD accompanying this report.

In all cases, doses estimated for 2011 were less than the limit of 1 mSv for members of the public. The people most affected from gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The people most affected from liquid discharges were generally adult consumers of seafood or occupants over contaminated substrates. The highest dose in 2011 from all sources was to local people living near the Amersham site; this dose was almost entirely due to direct radiation emanating from the site. The next highest doses

* *The Office for Nuclear Regulation was formed on 1 April 2011. It includes the functions previously undertaken by the Nuclear Installations Inspectorate.*

were due to seafood consumption and external exposure to radiation from muddy sediments (Sellafield and Springfields, respectively).

Permitted discharges were the source of most of the dose at the Sellafield site. The *total dose* from all sources at this site is combined with the effects of all local sources including specifically the effects of historic discharges of natural radionuclides from Whitehaven and the lesser effects of discharges from the Low Level Waste Repository (LLWR) near Drigg. The people most exposed to radiation were seafood consumers on the Cumbrian coastline. The next highest *total dose* was received by people living on houseboats in the Ribble estuary. Most of this exposure was due to external radiation from radionuclides from Sellafield deposited in intertidal sediments. The dose to houseboat occupants at Springfields was the highest in the UK due to nuclear industry waste discharges.

1.2.3 *Total dose* trends

A time-series of *total dose* from 2004 - 2011 is shown in Figure 1.1 (Table 1.3 gives numerical values). Many sites showed little by way of a trend in *total dose* over this period. Changes in direct radiation dominated the inter-annual variation at most of the power station sites, and small fluctuations in external dose rates had relatively large effects at some sites where high rates of intertidal occupancy were recorded. The effects of decreases in direct radiation were observed at Dungeness and Sizewell where cessation of power production by Magnox reactors was the cause. The most significant trend in *total dose* due to discharges of waste was for high-rate consumers of seafood on the Cumbrian coast near Sellafield, Whitehaven and Drigg. In this case the general reduction in *total dose* broadly followed a general downward trend in concentrations of naturally-occurring and artificial radionuclides from non-nuclear and nuclear sources, respectively. Year to year changes were also influenced by changes in consumption and occupancy characteristics of local people and the natural variability in radionuclide concentrations in food and the environment.

At Cardiff, there has been a downward trend in *total dose* which is partly due to reductions in discharges of tritium and carbon-14 to sea. The *total dose* observed at Dounreay in recent years has decreased from the peak value in 2008 due to changes in caesium-137 concentrations in game meat and the type of game meat sampled. The reduction in *total dose* at Heysham and Hinkley Point was largely due to findings from new habits surveys in 2011 and 2010 respectively.

1.2.4 Source specific dose results for 2011

The results of the source specific assessments for the main industrial sites in the UK are summarised in Table 1.4 and Figure 1.2. The focus for these assessments is the effect of gaseous or liquid waste discharges, unlike that for *total dose* which also includes all sources including the effect of direct radiation. The most significant exposures were found at Whitehaven and Sellafield and at Springfields. At Whitehaven and Sellafield the majority of the dose was from the legacy of historic discharges from Sellafield and from non-nuclear industrial operations resulting in technologically enhanced levels of natural radionuclides. The most important pathways and radionuclides at each site were similar to those found for *total dose* if the effect of direct radiation is taken into account. At Springfields the dose was also largely due to historic discharges from Sellafield.

The results confirm the adequacy of the *total dose* approach of assessment. Radiation doses to adults and children, calculated using the source specific method, were all found to be well below the national and European limit of 1 mSv per year.

1.2.5 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 a 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 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

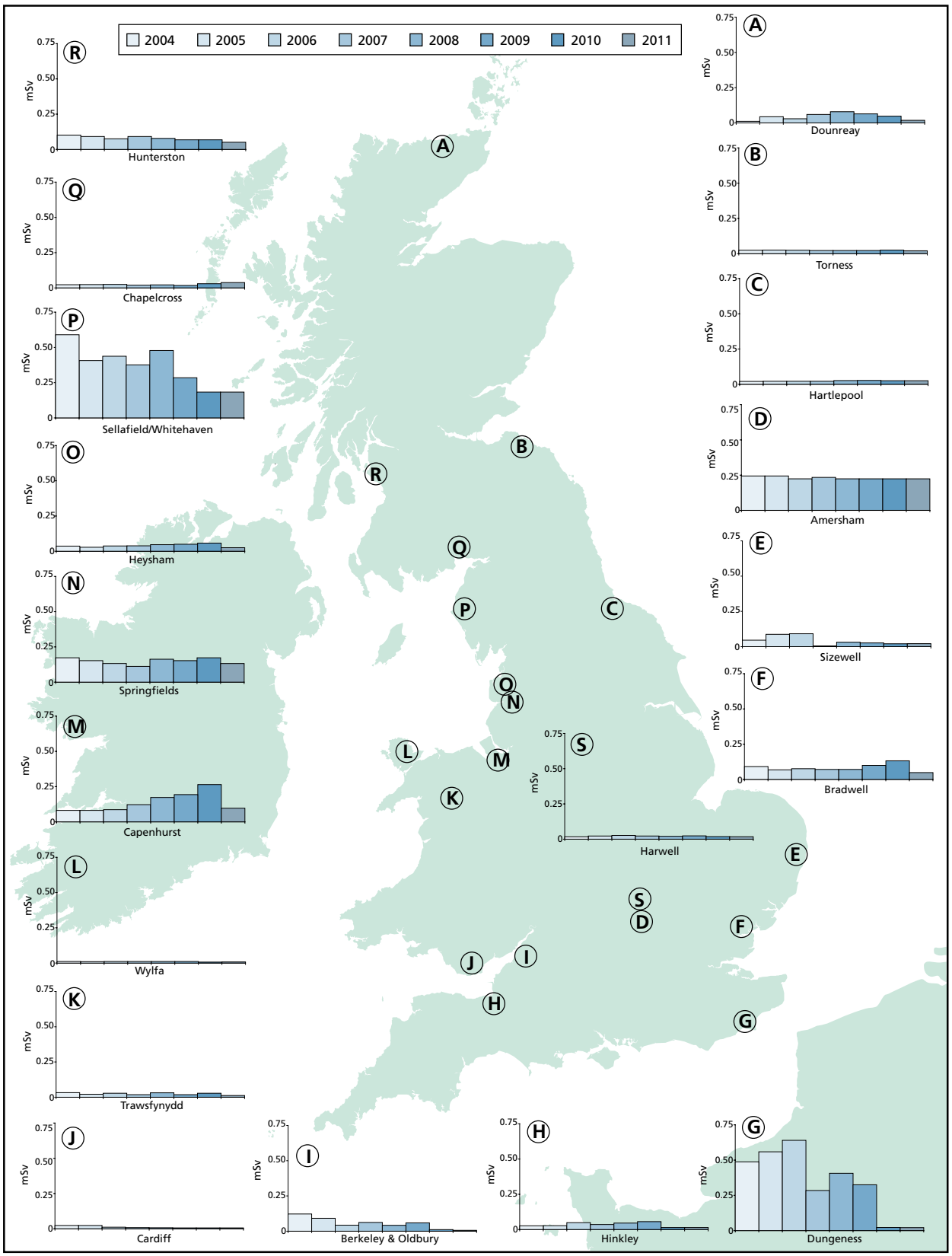


Figure 1.1. Total radiation exposures around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2011). (Exposures at Sellafield/Whitehaven receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)

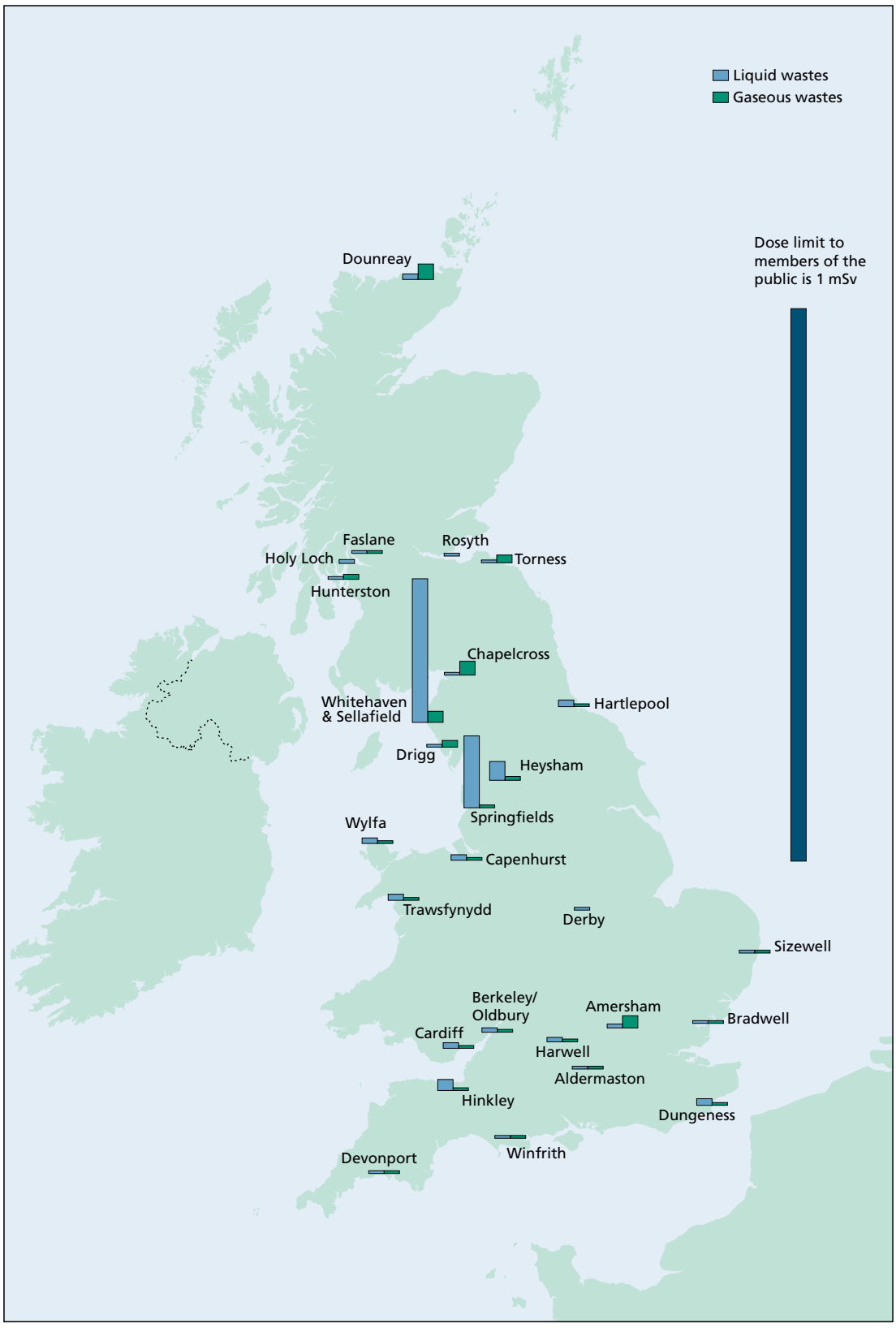


Figure 1.2. Individual radiation exposures to most exposed people in the UK, 2011 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

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 authorisations/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 authorisations/permits
- Stage 2 – determine which have a potential significant effect
- Stage 3 – appropriate assessment for those with significant effects
- Stage 4 – revision of authorisations/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 (in England and Wales). When a new authorisation/permit to discharge or dispose of radioactive waste is issued, or one is varied, the applicant is required to make an assessment of the potential impact of the 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 μGy h^{-1}.

The Environment Agency also assesses the impact of discharges at the permit limit using agreed data (Copplestone *et al*., 2001). When the predicted dose rate from an individual permit is greater than 1 μGy 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 μGy 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 μGy h^{-1}.

SEPA has carried out a Pressures and Impacts Assessment from radioactive substances on Scotland's water environment. The study 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. A report of the study is available from SEPA.

1.2.6 Food irradiation

Food irradiation is a processing technique where food is exposed to ionising radiation in a controlled manner. 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 imported plants or plant products of harmful organisms which may be harmful to domestic flora. 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).

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 each country 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 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/importers/irradiated

1.3 Sources of radiation exposure

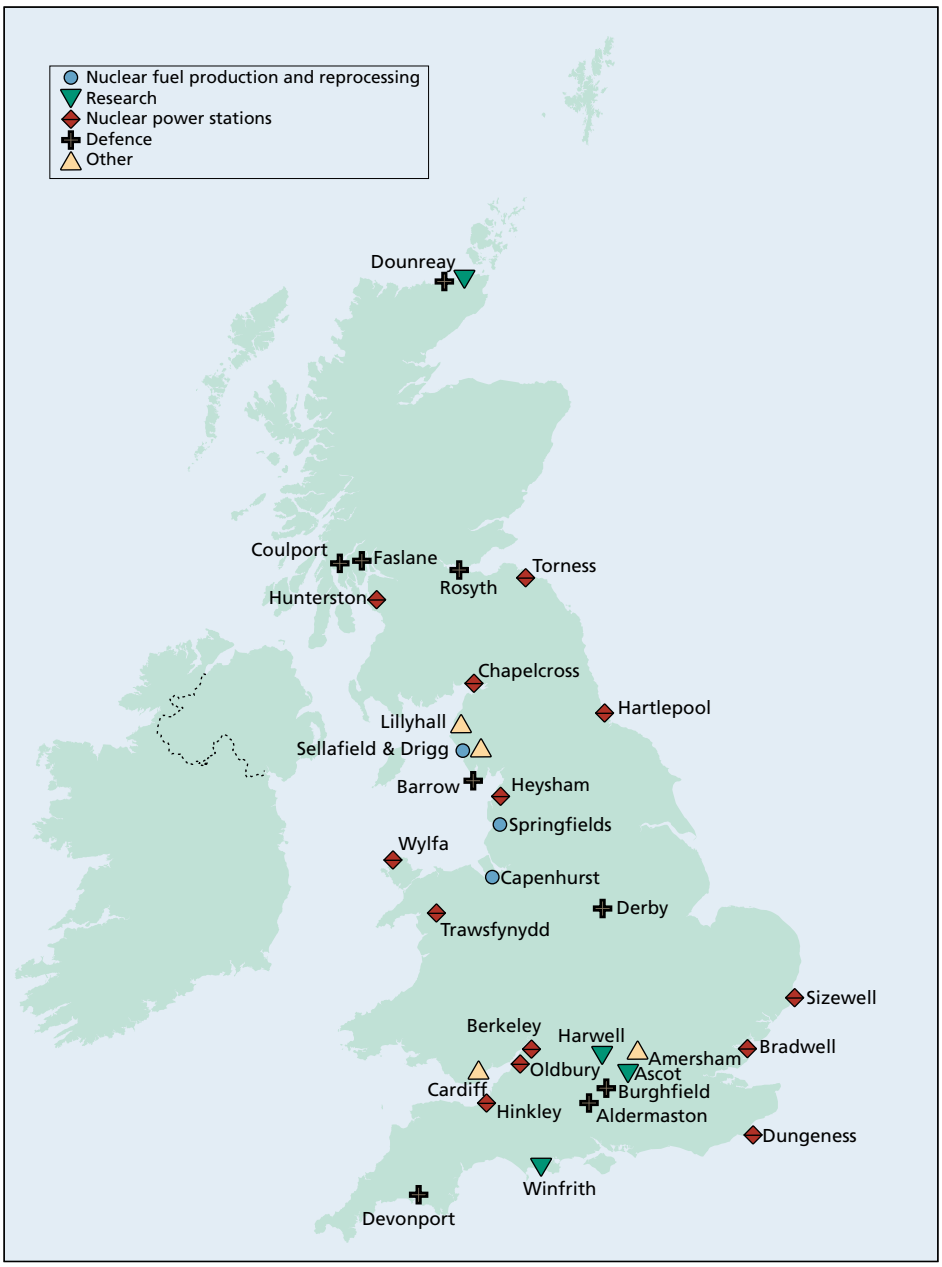
1.3.1 Radioactive waste disposal from nuclear sites

Nuclear licensed 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. Solid LLW from Dounreay will be transferred to the new Dounreay Low Level Waste Facility (due to be operational by 2014). These discharges and disposals are regulated by the environment agencies under RSA 93 or EPR 10*.

Figure 1.3 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 monitoring programmes reported here include studies at each of these sites. Discharges of radioactive waste from other sites

* *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. 'Authorisation' remains the relevant term for Scotland and Northern Ireland.*

Figure 1.3. Principal sources of radioactive waste disposal in the UK, 2011 (Showing main initial operation. Some operations are undergoing decommissioning)



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 monitoring programmes detect radioactivity in the environment as a result of these discharges. For example, iodine-131 from hospitals is occasionally detected in some river and 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 in England & Wales and so monitoring to protect public health is not usually carried out by all the environment agencies, although some routine monitoring programmes are undertaken. In Scotland, SEPA undertake routine sampling in the Firth of Clyde and at landfill sites to assess the impact of the non-nuclear industry on the environment. Additionally, SEPA periodically undertake intensive sampling at major sewage treatment plants to monitor the combined discharges from the non-nuclear industry.

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 2011. 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 2011 discharges and disposals were below the limits. The tables show the percentage of the limit actually discharged in 2011. 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 Available Techniques or Best Available Technology (BAT), under EPR 2010, to be used to further minimise discharges. The principles of Best Practicable Means are applied in Scotland.

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 2011.

Following a period of consultation (Department for Environment, Food and Rural Affairs, 2008), the Environment Agency and the Scottish Environment Protection Agency published guidance in May 2010 to nuclear operators on how they should assess discharges for reporting to regulators. The benefits of the guidance are:

- Operators can choose the most cost effective method (i.e. monitoring, calculation or estimation) of assessment at the appropriate level of quality
- More reliable reporting by accounting for results below the limit of detection
- Consistent regulatory approach across sites

The guidance is designed to support practicable implementation in the UK of parts of the European Commission's recommendation, 2004/2/Euratom, on standardised reporting of discharges.

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

This section gives information on the context of UK radioactive discharges as they relate to international agreements and the future 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 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 (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 (RSS) whose primary objective is to prevent marine pollution (OSPAR, 2003), as amended in 2010 (OSPAR, 2010a). 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, 2012). It also considers the relationship between OSPAR and its work on radioactivity and the initiative to determine Good Environmental Status (GES) as required by the Marine Strategy Framework Directive. 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, 2011a, b). The UK submission concerning the implementation of the principle of using Best Available Technology (BAT) has also been published (OSPAR, 2009a). Progress by Contracting Parties towards meeting the objectives in the Radioactive Substances Strategy has been reviewed (OSPAR, 2009b), as has the quality status of the Convention area (OSPAR, 2010b). The Quality Status Report considers radioactivity in food and the environment and refers to results of the monitoring programmes published in earlier issues of this report. 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. At the time of writing it is unclear whether the European Commission considers that radioactive substances are involved in the determination of GES. This is because the European Atomic Energy Community (Euratom) Treaty is seen to be the relevant regulatory instrument.

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 the national policy statement for nuclear power generation has been issued (Department of Energy and Climate Change, 20011b). 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 October 2010, DECC published for consultation revised draft National Policy Statements (NPS), for Nuclear Power Generation and other energy sources. The nuclear NPS listed eight sites assessed as potentially suitable for the development of new nuclear power stations and stated that any new nuclear power station would play a vitally important role in providing reliable electricity supplies and a secure and diverse energy mix as the UK makes the transition to a low carbon economy. The consultation of NPSs closed in January 2011. These were approved by Parliament on 18 July 2011 and designated under the Planning Act 2008 on 19 July 2011. 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 2011, the Health & Safety Executive (HSE) 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 commenced 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.

In December 2011, the Health and Safety Executive and the Environment Agency concluded their initial assessments, including consideration of the effects of the accident at the Fukushima Dai-ichi power station in Japan. The Environment Agency is content with the environmental aspects of both designs and has issued interim Statements of Design Acceptability (Environment Agency, 2011a). Similarly, the Health and Safety Executive issued an interim Design Acceptance Confirmation to the designers of each of the reactors (Office for Nuclear Regulation, 2011). The GDA process will continue before acceptance can be finalised with a focus on the UK-EPR design, because Westinghouse is not presently addressing the GDA issues for the AP1000 design. More details can be found at http://www.hse.gov.uk/newreactors/index.htm.

The Environment Agency has issued a Permit for the proposed Hinkley Point C development by EDF Energy and Centrica's joint venture company, NNB Generation Company Limited (NNB GenCo) to discharge (non-radioactive) waste water discharges for offsite construction (Environment Agency, 2012a). In addition, the Environment Agency is currently consulting on draft decisions for environmental permits for radioactive discharges relating to the operation of a nuclear power station at the Hinkley Point C site – 13 August to 9 November 2012. More information can be found at: www.environment-agency.gov.uk/hinkleypoint

1.3.3 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 has regularly issued reports, demonstrating compliance with the Convention and these are provided to the International Atomic Energy Agency (IAEA) as part of an international review process (for example, Department for Environment, Food and Rural Affairs, 2004a; 2005c and Department of Energy and Climate Change, 2008; 2010).

The current arrangements for managing civil sector nuclear clean up are founded in the Energy Act 2004, which 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 Limited (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 2011 (Nuclear Decommissioning Authority, 2011) and the plan for 2012/15 is available (Nuclear Decommissioning Authority, 2012). The NDA published an up-to-date inventory and forecast of radioactive wastes in the UK jointly with DECC in 2011 (Department of Energy and

Climate Change, 2011a). A recent report has considered the financial implications of nuclear decommissioning and waste management (MacKerron, 2012).

In 2007, the UK Government and Devolved Administrations issued a new UK-wide 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 volunteer and partnership approach to siting a facility, and communities were invited to discuss with Government the possibility of hosting a geological disposal facility at some point in the future. The UK Government and the Devolved Administrations of Northern Ireland, Scotland and Wales have published their response to CoRWMs report on national research and development for the long term management of higher activity radioactive waste (Department of Energy and Climate Change, Department of Environment (Northern Ireland), the Scottish Government and the Welsh Assembly Government, 2010). Independent scrutiny of the Government's long-term management, storage and disposal of radioactive waste will continue by CoRWM who have published their proposed work programme for 2012-2015 (Committee on Radioactive Waste Management, 2012).

An annual report has been issued by DECC summarising progress in implementing plans for geological disposal, including the setting up of a Geological Disposal Implementation Board (Department of Energy and Climate Change, 2011a). The Board enables key stakeholders including nuclear operators, local government representatives, regulators and non-government organisations to observe and provide input to the MRWS programme. DECC has issued two reports on the assessment and identification of candidate sites for disposal (Department of Energy and Climate Change, 2012a and b).

The Scottish Government has decided not to progress geological disposal as it does not consider that this is the right way forward for Scotland. For higher activity waste, the Scottish Government's policy is that the long-term management of such waste should be in near-surface facilities. Facilities should be located as near to the site as possible. Developers will need to demonstrate how the facilities will be monitored and how packages of waste could be retrieved (Scottish Government, 2011).

The Welsh 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 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. 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)).

1.3.4 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 2011 are presented in Section 9 and 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 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).

1.3.5 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 HPA has assessed incidents involving the transport of radioactive materials in the UK (Harvey, 2009). 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, 2012). 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 2011. Low concentrations of radionuclides were detected in the marine environment around the Channel Islands (Section 9) and these may be partly due to discharges from the nuclear fuel reprocessing plant at 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. The regime provides a system for identifying and remediating land, where contamination is causing people to be exposed to lasting exposure to radiation resulting from the after-effects of a radiological emergency, past practice or post work activity; and where intervention is liable to be justified. 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 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). Defra has consulted on proposals for revising Statutory Guidance on contaminated land, including the separation of guidance for radioactive and non-radioactive contamination into separate documents. No substantive changes are planned for the rules on radioactivity. The consultation closed in March 2011 and new Statutory Guidance has now been published (Department of Energy and Climate Change, 2012c). 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 ll 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. Revised Statutory Guidance was issued to SEPA in 2009. This guidance is broadly similar to that issued to the Environment Agency, apart from the fact that for the designation of radioactive contaminated land, clear dose criteria are set for homogeneous and hetrogeneous contamination and whether or not the probability of receiving the dose should be taken into account.

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). 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. The main conclusion was that aerial discharges do not make a significant contribution to levels in the marine environment. 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, the most recent report being published 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. To ensure protection of the public and environment, this RIFE report is directed at establishing the exposure of people who might receive the highest possible doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is the exposure of these people which forms the basis for comparisons with dose limits in EU and UK law.

Table 1.1. Individual radiation exposures - direct radiation pathway, 2011

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.095
Sellafield	0.002
Springfields	<0.022
Research establishments	
Dounreay	0.004
Harwell	0.016
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	Bgd[a]
Bradwell	0.048
Chapelcross	0.002
Dungeness	0.020[b]
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	0.010[c]
Hunterston	0.049[d]
Oldbury	Bgd[a]
Sizewell	<0.020[e]
Torness	<0.020
Trawsfynydd	0.009
Wylfa	Bgd[a]
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Devonport	Bgd[a]
Faslane	Bgd[a]
Rosyth	Bgd[a]
Radiochemical production	
Amersham	0.22
Cardiff	Bgd[a]
Industrial and landfill sites	
LLWR near Drigg	0.031

[a] *Doses not significantly different from natural background*
[b] *Datum for Dungeness B. Dungeness A (0.002) not used*
[c] *Datum for Hinkley B. Hinkley A (Bgd[a]) not used*
[d] *Datum for Hunterston A. Hunterston B (<0.020) not used*
[e] *Datum for Sizewell B. Sizewell A (Bgd[a]) not used*

Table 1.2. Total dose integrated across pathways, 2011

Site	Most exposed people[a]	Exposure, mSv	
		Total	Dominant contributions[b]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Infant milk consumers	<0.005	Milk, ^{3}H, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Infant milk consumers	<0.005	Milk, ^{14}C, ^{35}S
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.048	Direct radiation
Capenhurst	Local adult inhabitants (0 - 0.25km)	0.095	Direct radiation
Cardiff	Infant milk consumers	<0.005	Milk, ^{32}P, ^{35}S, ^{137}Cs
Chapelcross	Infant milk consumers	0.037	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Derby	Local adult inhabitants (0.25 - 0.5km)	<0.005	External and inhalation close to site
Devonport	Prenatal children of domestic fruit consumers	<0.005	Domestic fruit, green vegetables, ^{3}H
Dounreay	Infant milk consumers	0.018	Milk, ^{90}Sr, ^{106}Ru, ^{144}Ce, ^{241}Am
LLWR near Drigg	Local infant inhabitants (0.25 - 0.5km)	0.033	Direct radiation
Dungeness	Local adult inhabitants (0 - 0.25km)	0.021	Direct radiation
Faslane	Adult consumers of cattle meat	<0.005	Cattle meat, ^{241}Am
Hartlepool	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.017	Direct radiation
Heysham	Local adult inhabitants (0 - 0.25km)	0.022	Direct radiation
Hinkley Point	Prenatal children of local inhabitants (0.5 - 1km)	0.011	Direct radiation
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.050	Direct radiation
Rosyth[c]	-	-	
Sellafield and Whitehaven	Infant milk consumers	0.010	Milk, ^{60}Co, ^{90}Sr, ^{106}Ru. ^{137}Cs
Sizewell	Local adult inhabitants (0 - 0.25km)	0.021	Direct radiation
Springfields	Adult mushroom consumers	0.022	Direct radiation
Torness	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Trawsfynydd	Local infant inhabitants (0.25 - 0.5km)	0.011	Direct radiation, milk
Winfrith	Adult consumers of green vegetables	<0.005	Domestic fruit, gamma dose rate over sediment, honey, milk, ^{14}C, ^{137}Cs
Wylfa	Local infant inhabitants (0.25 - 0.5km)	<0.005	Milk, ^{14}C, ^{35}S, ^{137}Cs
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants over riverbank	<0.005	Exposure over riverbank
Amersham	Adult occupants over riverbank	0.007	Gamma dose rate over riverbank
Berkeley and Oldbury	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment
Bradwell	Adult occupants over sediment	<0.005	Exposure over sediments
Capenhurst	Occupants over riverbank aged 10y	0.008	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment
Chapelcross	Adult occupants over sediment	0.013	Gamma dose rate over sediment
Derby	Infant consumers of locally sourced water	<0.005	Water, ^{60}Co
Devonport	Adult fish consumers	<0.005	Fish, ^{131}I, ^{241}Am
Dounreay	Adult occupants over sediment	0.010	Gamma dose rate over sediment
Dungeness	Adult occupants over sediment	0.007	Direct radiation, gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Adult occupants over sea coal/sand	0.012	Gamma dose rate over sea coal/sand
Harwell	Adult occupants over riverbank	0.007	Gamma dose rate over riverbank
Heysham	Adult mollusc consumers	0.025	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Hunterston	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Rosyth	Adult fish consumers	<0.005	Fish, ^{241}Am
Sellafield, Whitehaven and LLWR[d]	Adult consumers of marine plants and algae	0.18[e]	Crustaceans, fish, gamma dose rate over sediment, ^{210}Po
Sizewell	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Adult fish consumers	0.006	Direct radiation, fish, ^{241}Am
Trawsfynydd	Adult fish consumers	0.012	Exposure over sediment, fish, ^{14}C ^{90}Sr, ^{137}Cs, ^{241}Am
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult consumers of marine plants and algae	0.008	Fish, gamma dose rate over sediment, ^{137}Cs

Table 1.2. continued

Site	Most exposed people[a]	Exposure, mSv	
		Total	Dominant contributions[b]
C All sources			
Aldermaston and Burghfield	Infant milk consumers	<0.005	Milk, ^{3}H, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.048	Direct radiation
Capenhurst	Local adult inhabitants (0 - 0.25km)	0.095	Direct radiation
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment
Chapelcross	Infant milk consumers	0.037	Milk, ^{14}C, ^{35}S, ^{90}Sr, ^{241}Am
Derby	Infant consumers of locally sourced water	<0.005	Water, ^{60}Co
Devonport	Adult fish consumers	<0.005	Fish, ^{131}I, ^{241}Am
Dounreay	Infant milk consumers	0.018	Milk, ^{90}Sr, ^{106}Ru, ^{144}Ce, ^{241}Am
Dungeness	Local adult inhabitants (0.5 - 1km)	0.021	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.025	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.017	Direct radiation
Heysham	Adult mollusc consumers	0.025	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.050	Direct radiation
Rosyth	Adult fish consumers	<0.005	Fish, ^{241}Am
Sellafield, Whitehaven and LLWR[d]	Adult consumers of marine plants and algae	0.18[e]	Crustaceans, fish, gamma dose rate over sediment, ^{210}Po
Sizewell	Local adult inhabitants (0 - 0.25km)	0.021	Direct radiation
Springfields	Adult occupants on houseboats	0.13	Gamma dose rate over sediment
Torness	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Trawsfynydd	Adult fish consumers	0.012	Exposure over sediment, fish, ^{14}C, ^{90}Sr, ^{137}Cs, ^{241}Am
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult consumers of marine plants and algae	0.008	Fish, gamma dose rate over sediment, ^{137}Cs

[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 and based on these measurements, an upper estimate of dose is calculated*

[c] *The effects of gaseous discharges and direct radiation are not assessed for this site*

[d] *Sellafield, Whitehaven and LLWR near Drigg sites are considered together as their effects are dominated by radioactivity in a common area of the Cumbrian coast*

[e] *The doses from man-made and naturally occurring radionuclides were 0.068 and 0.11 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 near Drigg site into the same area*

Table 1.3. Trends in total dose (mSv) from all sources[a]

Site	2003	2004	2005	2006	2007	2008	2009	2010	2011
Aldermaston and Burghfield	<0.005	<0.005	<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	0.22	0.22
Berkeley and Oldbury		*0.12*	*0.090*	*0.042*	0.061	0.041	0.058	0.011	0.006
Bradwell		*0.09*	*0.067*	*0.075*	0.070	0.070	0.098	0.13	0.048
Capenhurst		*0.080*	*0.080*	*0.085*	0.12	0.17	0.19	0.26	0.095
Cardiff	0.038	0.023	0.023	0.011	0.008	0.007	0.006	0.006	0.006
Chapelcross		*0.022*	0.023	0.024	0.019	0.021	0.017	0.029	0.037
Derby							<0.005	<0.005	<0.005
Devonport		<0.005	<0.005	<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	0.047	0.018
Dungeness		*0.48*	0.55	0.63	0.28	0.40	0.32	0.022	0.021
Faslane		*<0.005*	*<0.005*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hartlepool	0.021	0.020	0.021	0.021	0.021	0.026	0.027	0.025	0.025
Harwell		*0.017*	*0.022*	*0.026*	0.022	0.020	0.023	0.018	0.017
Heysham		*0.036*	*0.028*	0.037	0.038	0.046	0.049	0.057	0.025
Hinkley Point		*0.026*	*0.027*	0.048	0.035	0.045	0.055	0.014	0.014
Hunterston		0.10	0.090	0.074	0.090	0.077	0.067	0.067	0.050
Rosyth		*<0.005*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sellafield, Whitehaven and LLWR near Drigg	0.66	0.58	0.40	0.43	0.37	0.47	0.28	0.18	0.18
Sizewell		*0.045*	0.086	0.090	<0.005	0.031	0.026	0.020	0.021
Springfields		*0.17*	*0.15*	0.13	0.11	0.16	0.15	0.17	0.13
Torness		*0.024*	*0.025*	0.024	0.022	0.022	0.022	0.025	0.020
Trawsfynydd		*0.032*	0.021	0.028	0.018	0.031	0.018	0.028	0.012
Winfrith	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Wylfa		0.011	0.010	0.011	0.011	0.011	0.011	0.007	0.008

[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*

Table 1.4. Radiation doses due to discharges of radioactive waste in the United Kingdom, 2011

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[g]	L	0.010	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005[h]	^{234}U
Springfields	External (skin) to fishermen	L	0.069[f]	Beta
	Fish and shellfish consumption	L	0.017	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site	G	<0.005[h]	^{129}I $^{230/232}$Th
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	0.13	Ext
	External in intertidal areas (farmers and wildfowlers)	L	0.027	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2007-2011 surveys) (excluding naturally occurring radionuclides)[k]	L	0.15	Ext ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2007-2011 surveys) (including naturally occurring radionuclides)[l]	L	0.26	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2011 surveys) (excluding naturally occurring radionuclides)[k]	L	0.11	Ext ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.020	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.011	^{90}Sr
	External in intertidal areas (Ravenglass)[a]	L	0.038	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)	L	0.13	Ext
	External (skin) to bait diggers	L	0.055[f]	Beta
	Handling of fishing gear	L	0.072[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield[i]	L	0.009	^{99}Tc
Research establishments				
Culham	Water consumptionn	L	<0.005	
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.028	
Harwell	Fish consumption and external to anglers	L	0.008	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{222}Rn
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	G	<0.005	^{14}C ^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.008	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	^{14}C
Chapelcross	Wildfowl and fish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Crustacean consumption	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.025	^{14}C
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext ^{241}Am
	Occupancy of houseboats	L	0.012	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{14}C
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	0.009	Ext ^{241}Am
	Exposure over sand and sea coal	L	0.012	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.034	Ext ^{241}Am
	External in intertidal areas (turf cutters)	L	0.018	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.007	^{14}C
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.020	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{14}C
Hunterston	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.009	^{14}C ^{90}Sr

Table 1.4. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear power production *continued*				
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.006	^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.011	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{90}Sr
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005h	Ext ^{234}U
	Terrestrial foods, external and inhalation near site[i]	G	<0.005h	
Derby	Water consumption, fish consumption and external to anglers[n]	L	<0.005	Ext
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	^{14}C
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext
	Terrestrial food consumption	G	<0.005	^{137}Cs
Holy Loch	External in intertidal areas	L	0.007	Ext
Rosyth	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	0.007	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.022	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[o]	L	0.010	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.005	
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	
Industrial and landfill				
LLWR near Drigg	Terrestrial foods[i]	G	0.013	
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.11	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.26	^{210}Po ^{241}Am

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

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

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

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

[e] *The estimates for marine pathways include the effects of liquid discharges from 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*

2. Nuclear fuel production and reprocessing

Key points

- Doses, discharges, environmental concentrations and dose rates in 2011 were broadly similar to those in 2010

Capenhurst, Cheshire

- Public radiation doses from all sources decreased in 2011
- There were decreases in public radiation doses from liquid discharges due to lower gamma dose rates

Springfields, Lancashire

- Public radiation doses from all sources were lower in 2011 and less than 13 per cent of the dose limit. People living on houseboats received the highest exposure
- Gaseous discharges of uranium decreased and liquid discharges of technetium-99 increased
- Gamma dose rates were generally lower in the vicinity of the houseboats in 2011

Sellafield, Cumbria

- Public radiation doses from all sources (*total dose*) were less than 18 per cent of the public dose limit (as in 2010)
- The highest doses were from seafood affected by past phosphate processing at Whitehaven and by historic discharges from Sellafield
- There was a change in the people representative of those most exposed in 2011
- Radiation dose to seafood consumers from natural radionuclides was higher than in 2010, due to an increase in polonium-210 in fish from past phosphate processing at Whitehaven. The dose from Sellafield discharges reduced due to the revision in mollusc consumption rate
- Gaseous discharges were generally similar to 2010, except antimony-125 and plutonium radionuclides which decreased
- Liquid discharges of carbon-14 and iodine-129 were higher in 2011
- Concentrations and dose rates were generally similar to those in 2011. Plutonium radionuclides and americium-241 generally declined in shellfish
- Calder Hall defuelling commenced in 2011

Windscale, Cumbria

- Reactor decommissioning (Windscale Advanced Gas Cooled Reactor) was completed in 2011

This section considers the results of monitoring by the Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and the Scottish Environment Protection Agency of four sites in the UK associated with civil nuclear fuel production and reprocessing. These 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 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 Limited (NMP). The NDA's Capenhurst site was also included in the contract, but a contract has since been signed for the site to be leased long-term to Urenco and become part of the UUK licensed site. The Springfields site is leased long-term to Springfields Fuels Limited and have a contract with NDA to decommission legacy facilities on the site. The Windscale nuclear site, also owned by the NDA, is located on the Sellafield site and holds its own nuclear licence, which was transferred to Sellafield Limited in 2008. An integrated environment permit was also issued for the Windscale and Sellafield sites in 2008. Windscale is discussed in Section 2.4. The 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 2011, gaseous and liquid discharges were below permit limits for each of the sites (see Appendix 2). The medium-term trends in doses, discharges and environmental concentrations at these sites were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

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 uranic material storage facilities and activities associated with decommissioning redundant plant. The UUK site operates three plants producing enriched uranium for nuclear power stations. In 2010, the NDA and UUK signed a set of non-binding commercial principles to support a potential transfer of the NDA-owned Capenhurst site to UUK. A further agreement was signed in December 2011 confirming the future transfer of the NDA-owned site, enabling existing decommissioning and storage operations to transfer to UUK and the Capenhurst site to transition to a single licensee status. The most recent habits survey was conducted in 2008 (Tipple *et al.*, 2009).

Doses to the public

In 2011, the *total dose* from all pathways and sources is assessed to have been 0.095 mSv (Table 2.1), or less than 10 per cent of the dose limit. This was mostly due to direct radiation from the Capenhurst site. The dose assessment identifies local adults living near to the site as the most exposed age group. The decrease from 0.26 mSv in 2010 was due to a lower estimate of direct radiation from the site and included a change in the most exposed people (used for deriving the direct radiation value). The trend in *total dose* over the period 2004 – 2011 is given in Figure 1.1. Any changes in *total doses* with time were attributed to changes in the estimates of direct radiation from the site.

Source specific assessments indicated exposures for consumers of locally grown foods at high-rates, and for children playing in and around Rivacre Brook, were less than 0.095 mSv in 2011 (Table 2.1). As in 2010, the highest dose was 0.010 mSv in 2011 for 10 year old children (who play near the brook and inadvertently ingest water and sediment). The dose is 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 decrease in dose to 0.010 mSv from 0.012 mSv (in 2010) was due to lower gamma dose rates measured close to Rivacre Brook in 2011.

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. 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 2011 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 2002. 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.

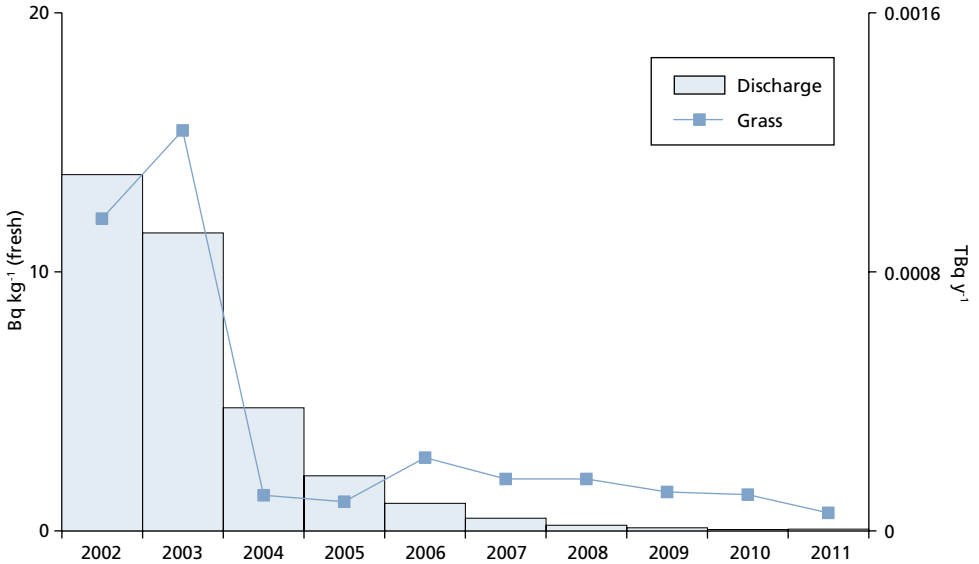


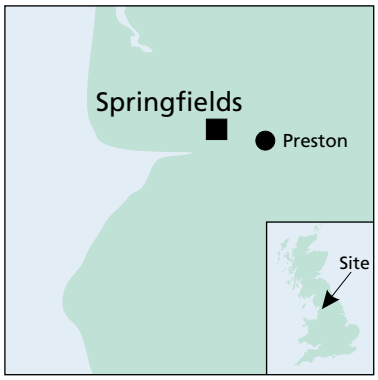
Figure 2.1. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2002-2011

Liquid waste discharges and aquatic monitoring

The permit held by Sellafield Limited for the Capenhurst site 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 2011, discharges from Capenhurst were similar to those in 2010.

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 2011 are given in Table 2.2(a) and (b). Concentrations of radionuclides and dose rates were very low and generally similar to those in 2010; although downstream of the Rivacre Brook (at the location where children play) dose rates were smaller in 2011. 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. As in 2009, measured dose rates were higher, relative to natural background, near to the discharge point. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides; these reflected the distant effects of discharges from Sellafield.

2.2 Springfields, Lancashire



The Springfields site at Salwick, near Preston, is operated by Springfields Fuels Limited (SFL), under the management of Westinghouse Electric UK Limited. The main commercial activity 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, under contract to the NDA, who retain responsibility for the historic nuclear liabilities on the site.

Monitoring around the site is carried out to check not only for uranium concentrations, but also for other radionuclides discharged in the past (such as actinide daughter products from past discharges when uranium ore concentrate was the main feed material) and for radionuclides discharged from Sellafield.

The most recent habits survey was undertaken in 2006 (Tipple *et al.*, 2007). In 2011, habits information, based on a five-year rolling average (2007 – 2011) was revised, but the resulting occupancy rate was unchanged for high-rate houseboat dwellers (see Appendix 1, Table X2.2). A study commissioned by the Environment Agency considered the exposures of houseboat owners and wildfowlers 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.*, 2011). Additional summary information is given in RIFE 16 (Appendix 4). The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.2.

Doses to the public

In 2011, the *total dose* from all pathways and sources is assessed to have been 0.13 mSv (Table 2.1), or 13 per cent of the dose limit. The people most affected were adult houseboat dwellers in the Becconsall boatyard, who were exposed to external radiation from activity in muddy sediments. As in recent years, gamma dose rate measurements were not taken aboard a houseboat in 2011. 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. The decrease from 0.17 mSv in 2010 was attributable to an overall decrease in gamma dose rates (measured at Becconsall) in 2011. *Total doses* over the period 2004 – 2011 are given in Figure 2.3. The data indicate that *total dose* initially decreased over time, although there was an increase in 2008 compared with 2007 (partly due to an increase from the revision of the occupancy rate). The trend at this site was primarily due to variations in gamma dose rates over sediment.

Source specific assessments indicated exposures for (i) consumers of locally grown food and of seafood, (ii) high-occupancy houseboat dwellers in the Ribble Estuary, (iii) children playing on the banks of the estuary, (iv) fishermen handling their gear, and (v) farmers and wildfowlers spending time on the banks of the estuary, were less than the *total dose* (Table 2.1).

In 2011, the dose to people who consume seafood at high-rates (including a contribution from external exposure) was 0.017 mSv, which was less than 2 per cent of the dose limit for members of the public of 1 mSv. Of this dose, 0.012 mSv was from external exposure and the remainder was from the consumption of fish and shellfish. The dose in 2010 was also 0.017 mSv. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site. The dose to wildfowlers and farmers from exposure over salt marsh was 0.027 mSv, which was less than 3 per cent of the dose limit for members of the public of 1 mSv.

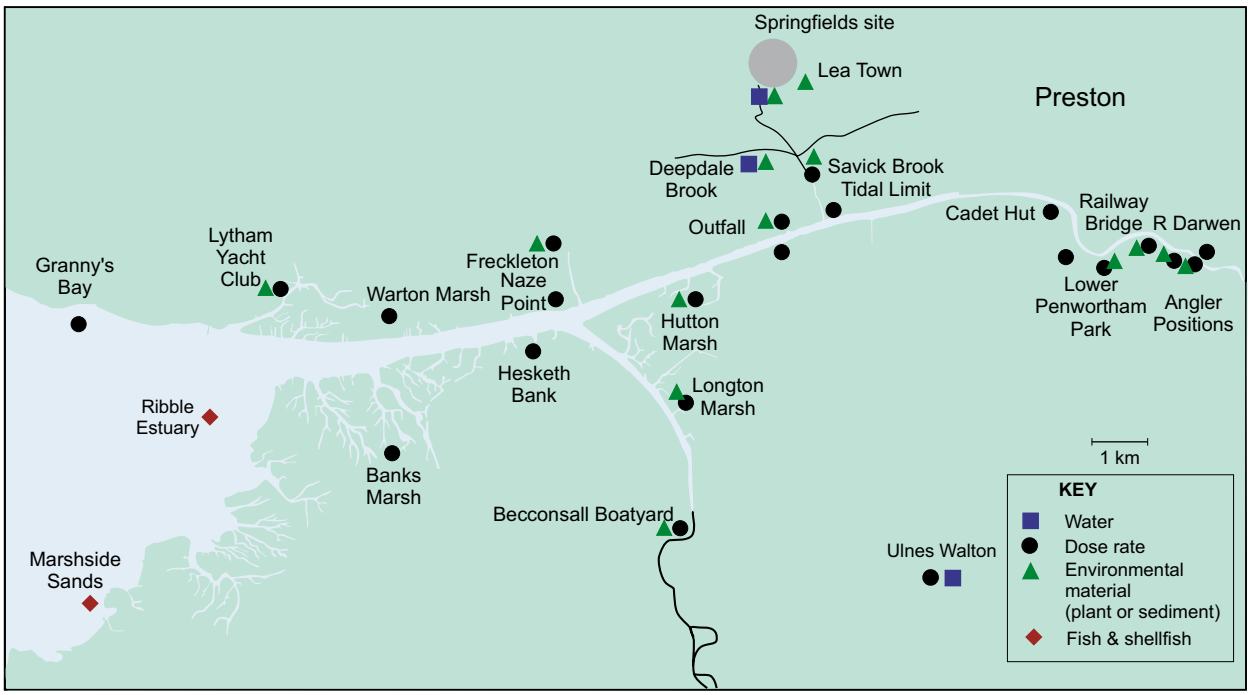


Figure 2.2. Monitoring locations at Springfields, 2011 (not including farms)

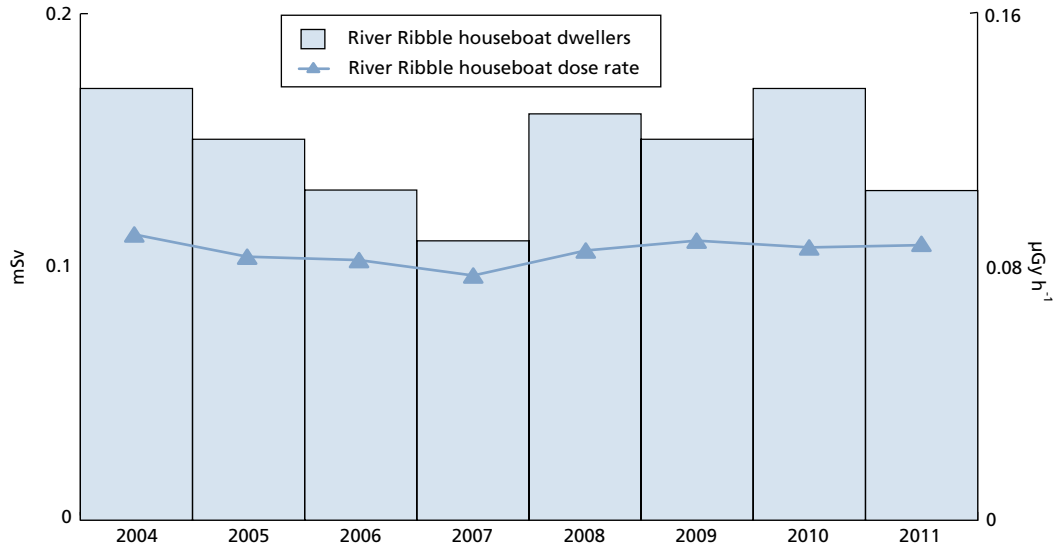


Figure 2.3. *Total dose* from all sources and dose rates at Springfields, 2004-2011

The decrease in dose from 0.032 mSv (in 2010) was due to a lower gamma dose rate measured at Longton Marsh in 2011.

It has been previously shown that assessed doses to the public from inhaling Ribble Estuarine sediment re-suspended in the air were much less than 0.001 mSv, and negligible in comparison with other exposure routes (Rollo *et al.*, 1994).

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. In 2011, Springfields Fuels Limited was granted a temporary variation to its permit, allowing the operator to discharge some gas containing krypton-85 to atmosphere. As krypton is an inert gas, the radiological consequences of the additional discharge will have been negligible. Discharges of uranium from the site decreased in 2011, in comparison to 2010, together with small decreases in tritium and carbon-14 releases from the research and development facilities.

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. Grass and soil samples were collected and analysed for isotopes of uranium. The concentrations of

radionuclides found in 2011 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 2011 were generally similar to those in recent years, including the short half-life beta-emitting radionuclides (mostly thorium-234) that have decreased following the end of the Uranium Ore Concentrate (UOC) purification process in 2006. Discharges of uranium increased in 2011 due to increased processing of legacy uranic residues. Technetium-99 discharges in liquid effluent also increased in 2011. The Ribble Estuary monitoring programme consisted of dose rate 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 2011 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 2011, thorium-234 concentrations in sediments (over the range of sampling sites) were generally smaller compared to 2010; the largest decreases were primarily at a few sites around Penwortham. Over a much longer timescale (1998 – 2011), these concentrations have declined due to reductions in discharges as shown by the trend of sediment concentrations at Lower Penwortham (Figure 2.4).

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.

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). In 2011, gamma dose rates in the estuary, excluding rates taken for houseboat assessments, were generally similar to those in 2010, but with some variations at some sites. Gamma dose rates measured at Becconsall were generally decreased in 2011. Beta dose rates on fishing nets also appeared enhanced above those expected due to natural background. Where comparisons can be made from similar ground types and locations, beta dose rates from sediments in 2011 were generally similar to those in recent years.

Solid waste disposals and related monitoring

The Springfields and Capenhurst permits allow disposal of solid LLW by controlled burial at Clifton Marsh landfill site, near

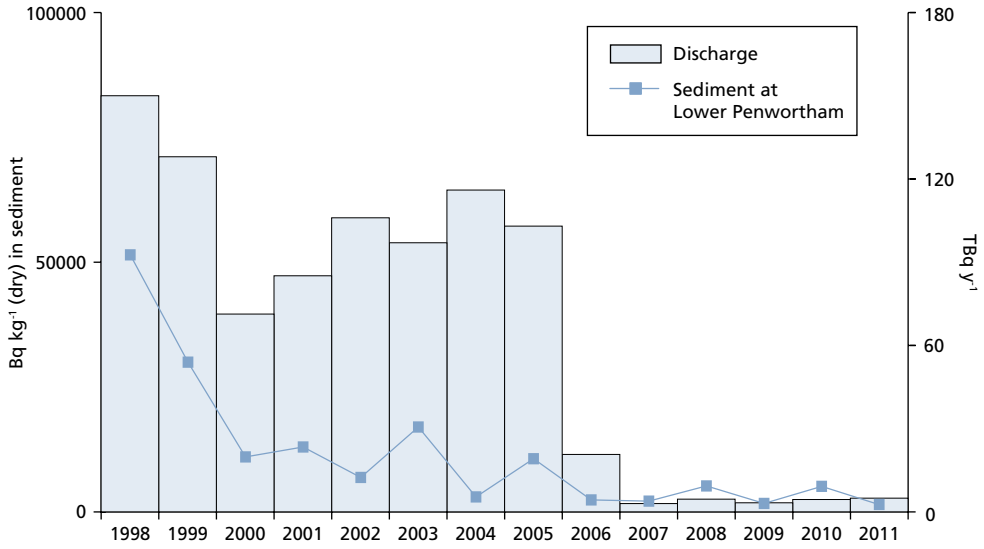


Figure 2.4. Total beta in liquid discharges from Springfields and concentrations in sediment at Lower Penwortham, 1998-2011

Preston in Lancashire. In June 2011, the Environment Agency conducted a public consultation, on an application made by Sita (Lancashire) Limited, to allow Clifton Marsh landfill to accept waste containing low levels of radioactivity from a range of sources. 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).

2.3 Sellafield, Cumbria

This site is operated by Sellafield Limited (formally called British Nuclear Group Sellafield Limited (BNGSL)), 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; and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in 2003 and is undergoing decommissioning. The Windscale site is located on the Sellafield site, and is discussed in Section 2.4.

The European Commission conducted a verification visit of the environmental monitoring arrangements for Sellafield, and Lillyhall landfill sites, from 23 - 25 August 2011. For Sellafield, this was a follow-up to a previous verification visit in 2010 which examined on-site monitoring arrangements. For the 2011 visit, the team examined air, rain, river water, dose rate and shellfish monitoring conducted by Sellafield Limited, the Environment Agency, the Food Standards Agency (and their contractors) and the independent monitoring by the Health Protection Agency around Sellafield. The plans for the radiological environmental monitoring at Lillyhall were also examined. The team also inspected the Sellafield Limited laboratory used for the environmental monitoring programme, which is also likely to be used for the Lillyhall monitoring programme. The European Commission team has concluded that the UK is fulfilling its monitoring obligations under Article 35 of the Euratom Treaty.

Sellafield Limited and the NDA have published their plans for decommissioning of the Sellafield site (http://www.sellafieldsites.com/publications/sellafieldplan/Sellafield_Plan.pdf). Sellafield Limited continues to prepare for retrievals of intermediate level waste from legacy facilities and to reduce environmental risk. Some of these projects have the potential to impact on discharges to the environment. For example, in 2011, the Liquor Activity Reduction (LAR) project reduced the risk posed by radioactive liquor in the Magnox Swarf Storage Silos by transferring quantities of the liquor to the Site Ion Exchange Plant (SIXEP). Work has also been carried out to remove sludge from the bottom of the Pile Fuel Storage Pond and to transfer fuel out of the pond. As part of this work measures are being introduced to further prevent and minimise discharges. For example, the introduction of a local effluent treatment plant at the Pile Fuel Storage Pond a few years ago and further optimisation of the SIXEP process. No significant impact on discharges to the environment has been observed so far but the impact may become more significant as bulk waste retrieval operations develop over the coming years.

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 (2,300 tonnes) from the heat exchangers, turbine halls and associated plants was completed in March 2010. Earlier work concerned with the asbestos removal from Calder Hall is described elsewhere (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a). The hazard reduction project to dispose of the remaining lagging material from the heat exchangers to the Lillyhall landfill site was completed in May 2011. In November 2011, a six year programme began to defuel spent fuel from the Calder Hall reactors.

In 2011, 530 tonnes of spent oxide fuel was reprocessed from THORP, compared with 302 tonnes in 2010. During 2011, the reprocessing of spent Magnox fuel resumed following an extended period of unplanned outage. The reprocessing of spent Magnox fuel continued during 2011, with a total of 454 tonnes of fuel reprocessed, compared with 317 tonnes in 2010.

Every five years, a habits 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). In the 2011 annual survey, changes were found in the amounts and mixes of species consumed (Clyne *et al.*, 2012). The consumption rate decreased for molluscs. However the percentage of winkles (relative to other molluscs) significantly increased and more winkles were consumed in 2011, compared to 2010. Crustacean consumption increased, whilst occupancy rates over sediments decreased in 2011. The revised habits data are given in detail in Appendix 1 (Table X2.2).

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 were

undertaken in 2007 and 2009 (Clyne *et al.*, 2008a; Clyne *et al.*, 2010a).

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 assessment of dose, the effects of gaseous discharges, the effects of liquid discharges and unusual pathways of exposure identified around the site.

2.3.1 Doses to the public

Total dose from all pathways and sources

The *total dose* from all pathways and sources is assessed using consumption and occupancy data from the full habits survey of 2008 and the yearly review in 2011. Calculations are performed for four age groups (adult, 10y, 1y and prenatal).

As in 2010, the highest *total dose* is assessed to have been 0.18 mSv in 2011 or 18 per cent of the dose limit to members of the public (Table 2.18). In 2011, the most exposed age group was represented by adults who consume high rates of locally harvested marine plants. This represents a change in the people representative of those most exposed, from high-rate consumers of molluscan shellfish in 2010. However, those eating marine plants also consumed fish and shellfish and it was their fish and shellfish consumption which largely determined the dose received.

In percentage terms, the most significant contributors to the *total dose* in 2011 were from the consumption of fish, crustaceans, external exposure over sediments and molluscs (55, 24, 12 and 9 per cent, respectively). The most important radionuclide was polonium-210 (60 per cent), with an increased contribution in comparison with 2010 (19 per cent). In 2011, the contributions to the *total dose* for americium-241 and plutonium-239+240 were 9 and 4 per cent, respectively and less than in 2010 (33 and 18 per cent, respectively).

Artificial radionuclides discharged by Sellafield (including external radiation) and historic discharges of naturally-occurring radionuclides from Whitehaven contributed 0.068 mSv and 0.11 mSv, respectively (values are rounded to two significant figures). In 2010, the contributions were 0.14 mSv and 0.047 mSv, respectively. In 2011, the contribution from the external radiation was approximately 0.022 mSv (< 0.009 mSv in 2010). Data for naturally-occurring radionuclides in fish and shellfish, and their variation in recent years, 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 included to determine their contribution to the *total dose*. These works were demolished in 2004 and the permit to discharge radioactive wastes was 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).

The contribution to the *total dose* of 0.068 mSv in 2011 from artificial radionuclides (including external radiation) was lower than in 2010 (0.14 mSv). In 2011, the contributing radionuclides were mostly americium-241 (23 per cent) and to a lesser extent iodine-129 (16 per cent) and plutonium-239+240 (11 per cent). The contribution to *total dose* from external exposure was 32 per cent (7 per cent in 2010). Although concentrations of americium-241 and plutonium radionuclides in mollusc samples (winkles only) were generally lower in 2011, the decrease in the contribution to the *total dose* from 2010 was mostly due to the reduction in the amount of mollusc consumption (from the revision of habits information in 2011) of the most exposed people.

The contribution to the *total dose* of 0.11 mSv in 2011 from naturally-occurring radionuclides was higher than in 2010 (0.047 mSv). In 2011, the contributing radionuclides were mostly polonium-210 (96 per cent), and to a lesser extent, lead-210 (3 per cent). An increase in the polonium-210 concentration in fish (dab), and to a much lesser extent an increase in the fish consumption rate (from the revision of habits information in 2011) of the most exposed people, contributed to a higher *total dose* in 2011. Polonium-210 concentrations (above expected background) in mollusc samples did not contribute to the *total dose* in 2011 (~ 0.007 mSv in 2010).

Contributions to the highest *total dose* each year from all sources, by specific radionuclides, are given in Figure 2.5 over the period 2003 – 2011. The trend of generally reducing dose broadly reflected a general reduction in concentrations in seafood of both naturally-occurring and artificial radionuclides from the non-nuclear and nuclear industries respectively. Inter-annual variations were more complex and governed by both natural variability in seafood concentrations and real changes in the consumption and occupancy characteristics of the local population.

The larger step changes (from 2004 to 2005 and from 2008 to 2009) were due to variations in naturally-occurring radionuclides (mainly polonium-210 and lead-210). The changes in *total dose* in the intervening years (from 2005 to 2007) were mainly a result of changes in seafood consumption rates. The decrease in 2010 was due to both reductions in naturally-occurring radionuclides concentrations (polonium-210) and consumption rates, whilst the variation in the radionuclide contributors in 2011 (from previous years) resulted from a change in the people representative of those most exposed (from consumers of molluscan shellfish to locally harvested marine plants). The largest proportion of the *total dose*, up till 2008 and again in 2011, was due to enhanced naturally-occurring radionuclides from the historic discharges at Whitehaven; with a smaller contribution from the historic discharges from Sellafield. From 2008 to 2010, the net result of progressive reductions of the naturally-occurring radionuclides contribution to the *total dose* has been a relative

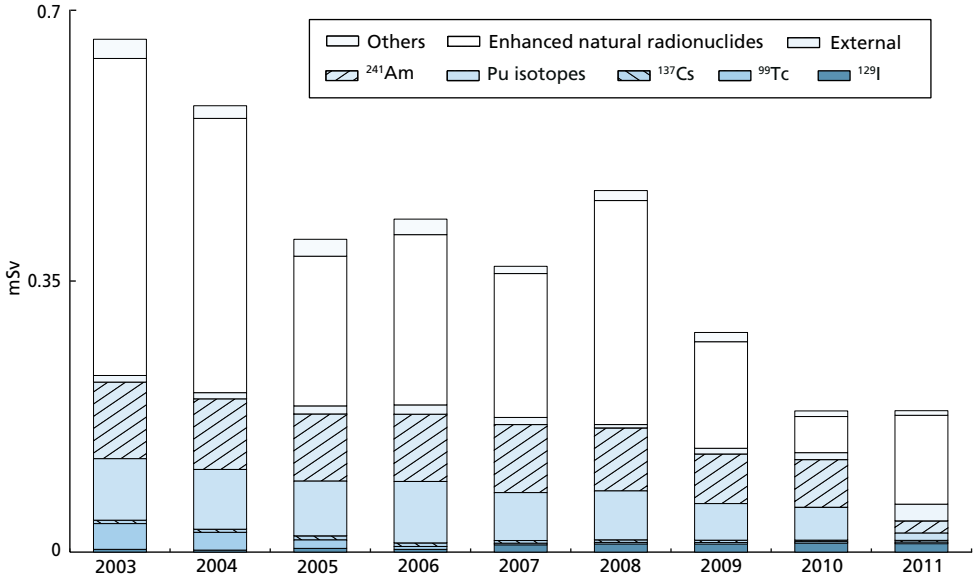


Figure 2.5. Contributions to *total dose* from all sources at Sellafield, 2003-2011

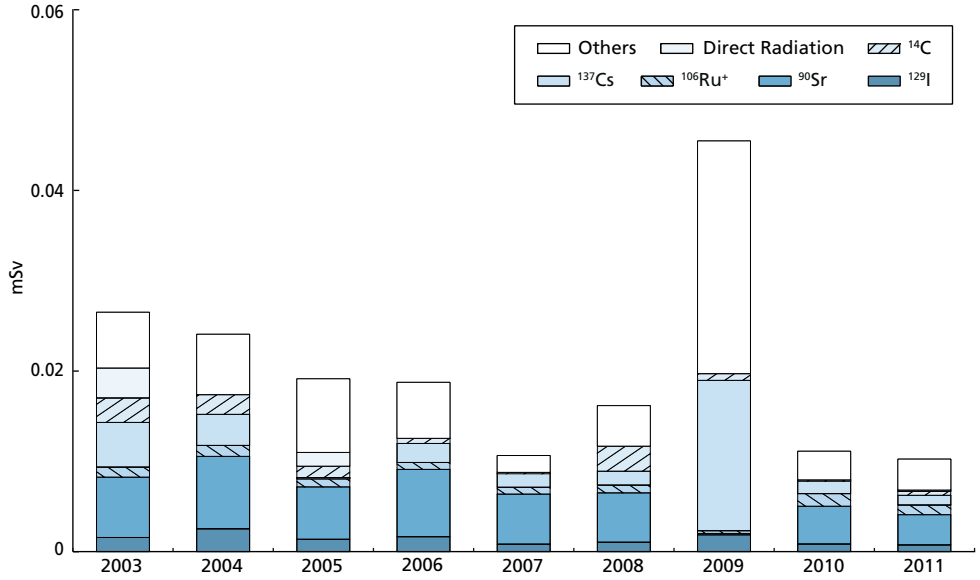


Figure 2.6. Contributions to *total dose* from gaseous discharge and direct radiation sources at Sellafield, 2003-2011 (+ based on limits of detection for concentrations in foods)

increase in the proportion from artificial radionuclides. The artificial radionuclides giving the largest contribution to the *total dose* were americium-241, iodine-129 (in 2011) and plutonium-239+240. Recent and current discharges of technetium-99 contributed approximately 2 per cent of the dose (from artificial radionuclides and external exposure), whilst iodine-129 contributed approximately 16 per cent, to the Sellafield seafood consumers in 2011.

Other age groups received less exposure than the adult *total dose* of 0.18 mSv in 2011 (1y: 0.047; 10y: 0.078; prenatal: 0.049, rounded to two significant figures). *Total doses* estimated for each age group 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.

Doses from gaseous discharges and direct radiation

In 2011, the dose to people receiving the highest *total dose* from the pathways predominantly relating to gaseous discharges and direct radiation was 0.010 mSv (Table 2.18). The most exposed age group were children (1y) who consumed milk at high-rates. This represents a small decrease from the *total dose* of 0.011 mSv in 2010 and was mostly due to a decrease in the maximum strontium-90 concentration in milk in 2011. The most significant contributors in 2011 to the *total dose* for children were from the consumption

of milk and potatoes (82 and 10 per cent, respectively), the most important radionuclides being strontium-90, cobalt-60, caesium-137 and ruthenium-106 (33, 17, 11 and 11 per cent, respectively). Other age groups received less exposure than the 1-year-old children *total dose* of 0.010 mSv in 2011 (adult: 0.006; 10y: 0.006; prenatal: < 0.005).

Contributions to the highest *total dose* each year, by specific radionuclides, are given in Figure 2.6 over the period 2003 – 2011. Up until 2007, the *total dose* was reducing each year because of the permanent shut down of Calder Hall power station on the Sellafield site which ended gaseous discharges of argon-41 and sulphur-35. In 2008, the assessment method included cobalt-60 results (below Limit of Detection (LoD)) because detectable activity was observed in other samples from the terrestrial environment. This increased the *total dose* over previous years. The relative increase and the change in the radionuclide contributors in 2009 (and not observed thereafter) resulted from the increase of total caesium in game and the change of the age group.

Doses from liquid discharges

The people receiving the highest *total dose* from the pathways predominantly relating to liquid discharges are given in Table 2.18. They are the same as those giving the maximum *total dose* for all sources and pathways.

Source specific doses

Important source specific assessments of exposures, as a result of 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 high-rate consumption of locally grown food (from atmospheric discharges), from 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 terrestrial food consumption

In 2011, 1-year old children who consumed milk at high-rates, and are exposed to external and inhalation pathways from gaseous discharges, received the highest dose of all for age groups, at 0.020 mSv (adult: 0.011; 10y: 0.014; prenatal: 0.009) or 2 per cent of the dose limit to members of the public (Table 2.18). The reason for the small decrease in dose from 0.022 mSv in 2010 is the same as that contributing to the maximum *total dose* from gaseous discharges and direct radiation.

Doses from seafood consumption

Two sets of habit data are used in these dose assessments. One is based on the habits seen in the area each year (2011 habits survey). The second is based on a five-year rolling average using habits data gathered from 2007 to 2011. Small changes were found in the amounts and mixes of species consumed. For molluscs, the consumption rate decreased for both the 2010 and the 2007 – 2011 data sets. Crustacean consumption increased for 2011, with much smaller increases in rates for 2007 – 2011. Occupancy rates over sediments decreased for 2011 and increased for 2007 – 2011. The revised habits data are given in detail in Appendix 1 (Table X2.2). 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 source specific doses to seafood consumers in 2011. The doses from artificial radionuclides to people, who consume a large amount of seafood, were 0.11 mSv and 0.16 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 2010 (0.16 mSv and 0.18 mSv, respectively). The reason for the decrease in doses in 2011 is the same as that contributing to maximum *total dose* from liquid discharges.

The dose to local people (who consume seafood at high annual rates) due to the enhancement of concentrations of naturally-occurring radionuclides from former non-nuclear industrial activity in the Sellafield area (using maximising assumptions for the dose coefficients and the five-year rolling average habits data) is estimated to have been 0.11 mSv in 2011. Most of this was due to polonium-210 (96 per cent), and lead-210 to a lesser extent (2 per cent). The reason for the increase in doses in 2011 (from 0.082 mSv in 2010) is the same as that contributing to maximum *total dose* from liquid discharges. 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 2011) was 0.13 mSv (Table 2.18).

Taking artificial and enhanced radionuclides together, the source specific doses were 0.23 and 0.26 mSv for annual and five-year rolling average habits data, respectively. These estimates are larger than the estimate of *total dose* from all sources of 0.18 mSv. The main reason for this is a difference in the approach to selecting consumption rates for seafood to represent the most exposed person. The source specific method pessimistically assumes that consumption of high

rates of fish, crustaceans and molluscs is additive whereas the *total dose* method takes more realistic consumption rate information from the local habits survey. The differences in dose are not unexpected, are well within the uncertainties in the assessments and confirm *total dose* as a robust measure of exposure.

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 are kept under review (Table 2.18). Where appropriate, the dose from consumption of seafood is summed with a contribution from external exposure over intertidal areas. The doses received by people in the wider communities were 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 2010 (Table 2.17). 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 2011.

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 0.011 mSv or approximately 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 2011 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, were received by people who live in houseboats in the Ribble Estuary in Lancashire. In 2011, 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 2011. 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 0.038 mSv. In 2010, this dose was 0.044 mSv. Overall, gamma dose rate measurements in 2011 were lower than in 2010 in the Ravenglass estuary. Nevertheless, the decrease in dose in 2011 was mostly attributed to sediment concentrations in the area, with a smaller contribution (0.007 mSv) from inhalation and ingestion of sediment.

In 2011, the estimated dose to wildfowlers along the Dumfries and Galloway coast, including their external dose from occupancy over salt marshes, was less than 0.005 mSv or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.18).

The doses to people in 2011 from a number of other activities are also estimated. Assessments are undertaken for typical residents using local intertidal areas for recreational purposes at 300 hours per year, and for the typical tourist visiting the coast of Cumbria at a beach occupancy of 30 hours per year. The use by residents for two different environments, at a number of locations at a distance from the Sellafield influence, are assessed: residents that visit and use beaches and residents that visit local muddy areas or salt marsh. Typical occupancy rates are assumed and appropriate gamma dose rates are used from Table 2.9. The activities for the typical tourist include 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 – 2.7, 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 (Table X2.2).

In 2011, the dose to people from recreational use of beaches varied from 0.008 to 0.011 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 0.014 mSv but were of a similar order of magnitude. In 2011, the maximum value of both ranges for these activities was less than in 2010, due to generally lower gamma dose rates measured in Cumbrian locations. 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.

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 (Table X2.2). In 2011, the skin doses to fishermen from handling their gear (including a component due to naturally-occurring radiation), and bait diggers and shellfish collectors from handling sediment, were 0.072 mSv and 0.055 mSv, respectively and both were less than 0.5 per cent of the appropriate annual dose limit of 50 mSv specifically for skin. 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 2011, their dose (including contributions from Chernobyl and weapon test fallout) was estimated to be 0.011 mSv, which was approximately 1 per cent of the dose limit for members of the public. The largest contributions of the dose were from strontium-90 in milk and ruthenium-106 in domestic fruit. The ruthenium-106 concentrations were below the LoD in all samples taken. This represents a decrease in the dose, in comparison to the value obtained in 2010 (0.038 mSv), but a similar dose to that in 2009 (0.012 mSv). The smaller doses were attributed the exclusion of high LoD values for both ruthenium-106 and cerium-144 in milk used in the 2010 assessment, which were larger than those values used in the 2011 and 2009 assessments. Therefore, as in previous years, sea-to-land transfer is not of radiological importance in the Ravenglass area.

Doses from seaweed and seawashed pasture

The dose to people in South Wales who consume laverbread (*Porphyra*) at high-rates was less than 0.005 mSv. Only small quantities of samphire, *Porphyra* and *Rhodymenia* (a red seaweed) are generally consumed, confirming this exposure pathway is of low radiological significance.

Seaweeds are sometimes used as fertilisers and soil conditioners. Assuming that high-rate vegetable consumers obtain all of their supplies from the monitored plots near Sellafield, the dose in 2011 was estimated to be 0.009 mSv. Although lower than the value in 2010 (0.012 mSv), the decrease in dose was mostly attributed to the unavailability of a domestic fruit sample (excluding the technetium-99 concentration in rhubarb) in 2011. Overall doses from this pathway remain similar, and minor variations from year to year are due to different foods being grown and sampled from the monitored plots. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales are expected to be much lower than near Sellafield.

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 to 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

2.3.2 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. Discharges to atmosphere during 2011 are summarised in Appendix 2 (Table A2.1). The permit limits gaseous discharges 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.

Discharges of gaseous wastes from Sellafield in 2011 were much less than the permit limits, and were generally similar to those in 2010. Discharges of antimony-125 and plutonium radionuclides slightly decreased in 2011, together with small increases in carbon-14, krypton-85 and iodine-129.

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 2011 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 2011 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 2010. Concentrations of radionuclides in meat and offal from cattle and sheep were low (many at, or below, the LoD), with only limited evidence of the effects of Sellafield's atmospheric discharges detected in data for tritium, carbon-14 and strontium-90 (values for iodine radionuclides were below the limit of detection). Plutonium concentrations in game when detectable were low and much lower than those found in seafood. A wide range of fruit and vegetables was sampled in 2011 and the activity concentrations were generally 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. Iodine-129 was positively detected in two samples (mushrooms and onions) in 2011, just above the LoD. Small enhancements (above expected background) in concentrations of carbon-14 were found in some food samples (including meat and offal) in 2010 (as in 2009). Concentrations of transuranic radionuclides, when detectable in these foods, were very low. In 2011, antimony-125 concentrations were below limits of detection in foods and soil, and just above the detection limit in grass, despite relatively enhanced discharges in recent years. 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 carbon-14 are relatively constant, and caesium-137 concentrations (and strontium-90 to a lesser extent) are declining overall.

2.3.3 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 2011 are summarised in Appendix 2 (Table A2.2). 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, SIXEP, Enhanced Actinide Removal Plant (EARP) and THORP). All of the discharges in 2011 were well below the limits in the permit. Discharges were generally similar to those in 2010, although carbon-14 and iodine-29 releases were increased in 2011. Overall, the discharges continue to reflect the varying amounts of fuel reprocessed in the THORP and Magnox reprocessing plant, and periods of planned and unplanned reprocessing plant shutdown that occur from year to year.

Discharges of technetium-99 were low and similar in 2011 to those in 2010. The long-term downward trend, from their peak of 192 TBq in 1995, has continued (Figure 2.8). 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, between 2003 and 2007, use of a chemical precipitant (Tetraphenylphosphonium Bromide) in the EARP to remove technetium-99 from the historic stock of MAC.

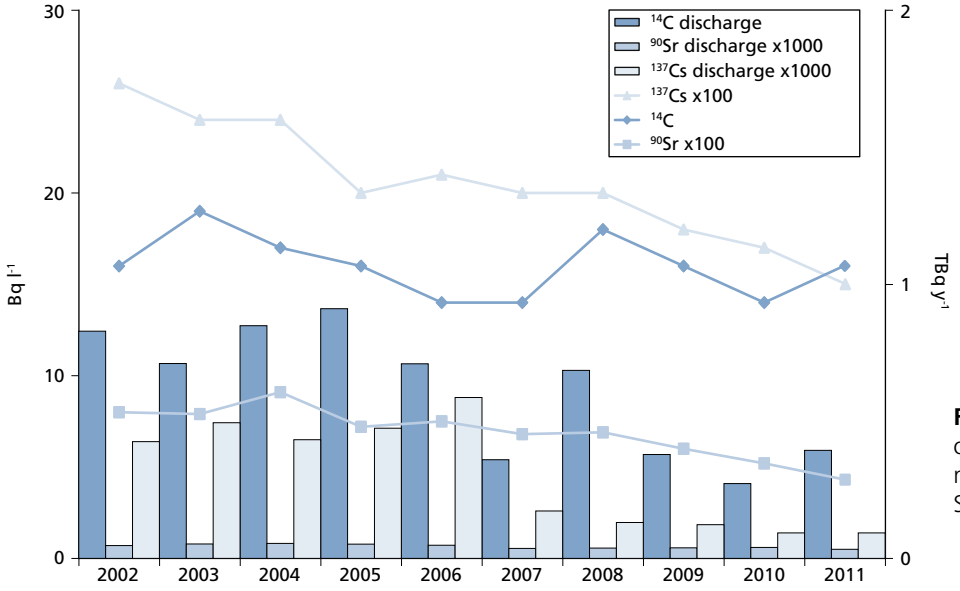


Figure 2.7. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2002-2011

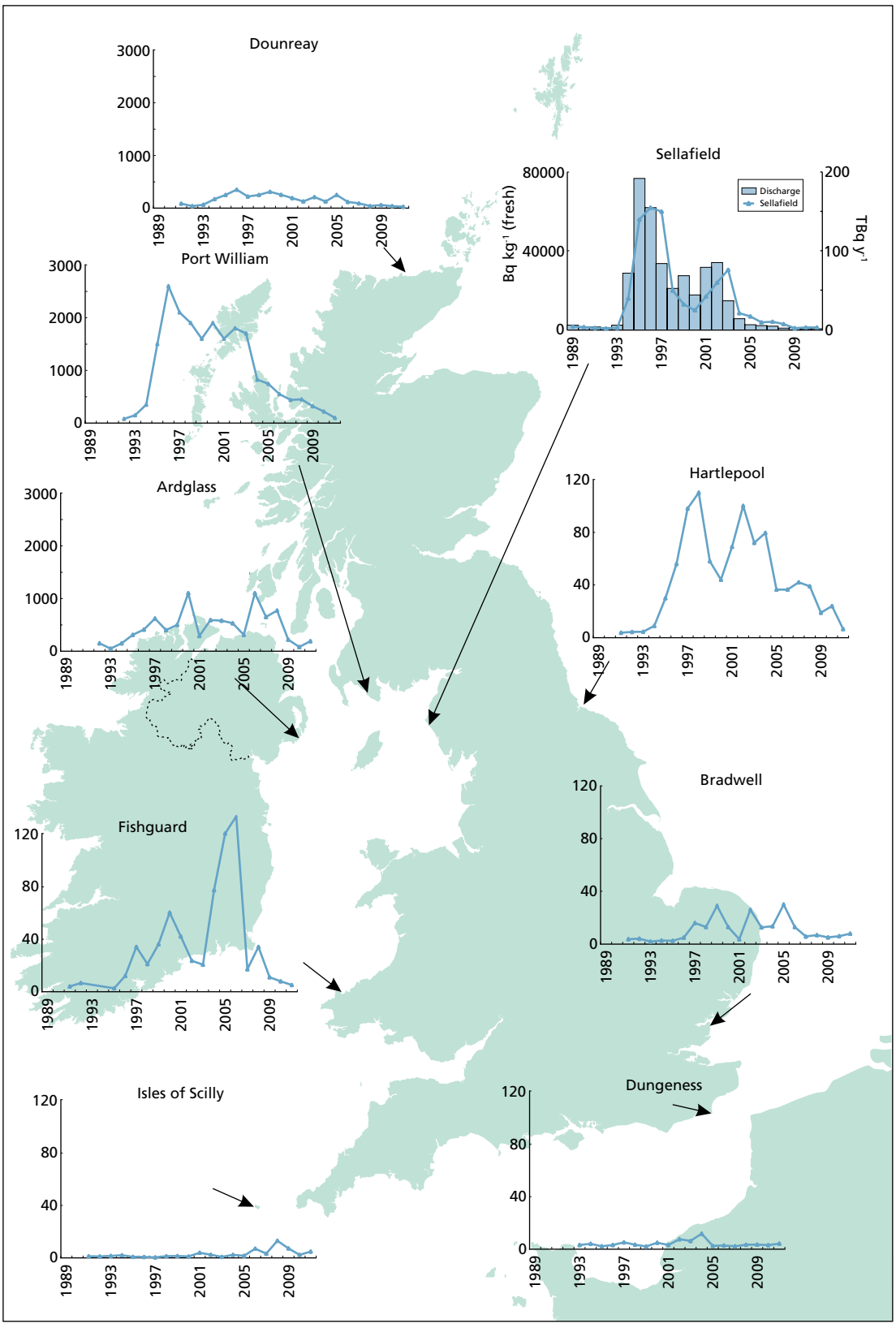


Figure 2.8. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2011

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2011. The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 2.9 and 2.10. The medium-term trends in discharges, environmental concentrations and dose were considered in a recent RIFE summary report, and overall showed 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, 2010b).

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

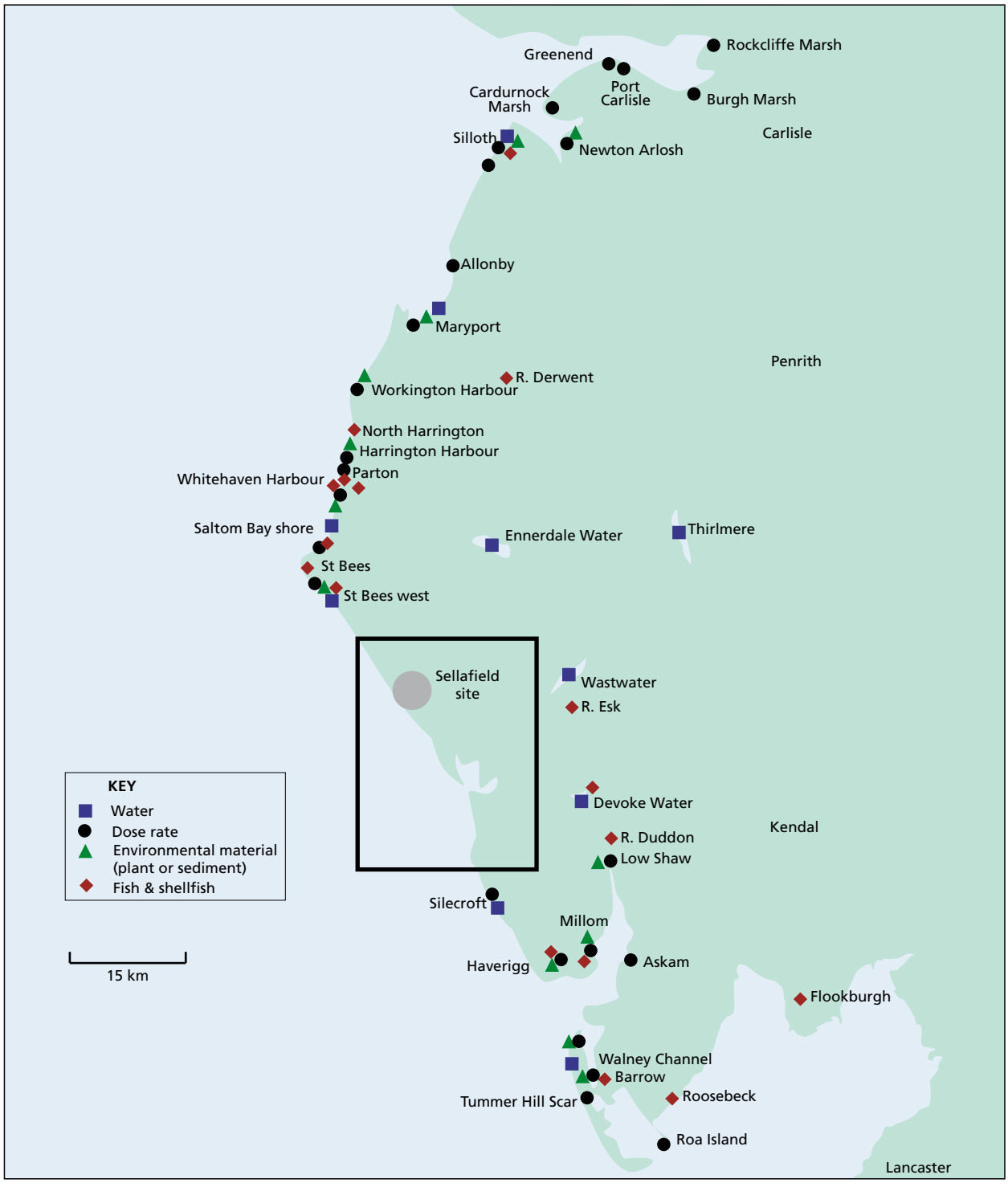


Figure 2.9. Monitoring locations in Cumbria, 2011 (not including farms)

Figure 2.10. Monitoring locations at Sellafield, 2011 (not including farms)

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 2.11 – 2.16. There was variability from year to year, particularly for the more mobile radionuclides. Liquid discharges of technetium-99 in 2011 were similar to those in 2010, these concentrations in fish and shellfish have continued to show a reduction from their most recent peak in 2003, but with a small increase in most recent years (Figure 2.13). For the transuranic elements (Figures 2.15 – 2.16), 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 mostly lower in 2011 compared to 2010.

Beta/gamma-emitting radionuclides detected in fish included: tritium, carbon-14, strontium-90 and caesium-137 (Table 2.5). Overall, concentrations of caesium-137 in fish species were generally similar to those in 2010. A relatively high concentration of caesium-137 (360 Bq kg^{-1}, in 2011) was again detected in brown trout from the River Calder (as in 2009), which flows through the Sellafield site, and significantly higher than the value in 2010 (33 Bq kg^{-1}). Activity concentrations in fish (and shellfish) generally reflected progressive dilution with increasing distance from Sellafield. However, the rate of decline of caesium-137 concentrations with distance was not as marked as was the case when significant reductions in discharges were achieved some years ago. There was therefore a greater contribution from historical sources.

Concentrations of caesium-137 in fish from the Baltic Sea originate from the Chernobyl accident. Caesium-137 in fish, known to have been caught in Icelandic waters, remained typical of those from weapons test fallout, at ~ 0.1 – 0.2 Bq kg^{-1} for caesium-137 in cod. Data for the Barents Sea were similar.

Other artificial beta/gamma-emitting radionuclides detected in fish included carbon-14 and tritium. With an expected carbon-14 concentration from natural sources ~ 25 Bq kg^{-1}, the data suggest a local enhancement of carbon-14 due to discharges from Sellafield. Tritium (total) gives the highest concentrations of radioactivity in marine fish of approximately 180 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 isotope of hydrogen and the low concentrations observed, the dose implication was very small. The concentrations of organically bound tritium (OBT) in environmental samples were 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 were of tritium, carbon-14, and technetium-99. Comparing 2011 and 2010 data across a wide range of sampling locations and shellfish species, technetium-99 concentrations were generally similar, but reduced in comparison to those in earlier years due to progressive reductions in discharges of this radionuclide over a longer time. Concentrations of other radionuclides in 2011 were broadly similar to 2010.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2011 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 2011 and 2010 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish were generally similar between the years. Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In comparison to 2010 data, the concentrations in shellfish were generally lower for plutonium radionuclides and americium-241 at most of the north-eastern Irish Sea locations in 2011 (including Tarn Bay, Nethertown, St Bees, Drigg and at the Sellafield Coastal Area). 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

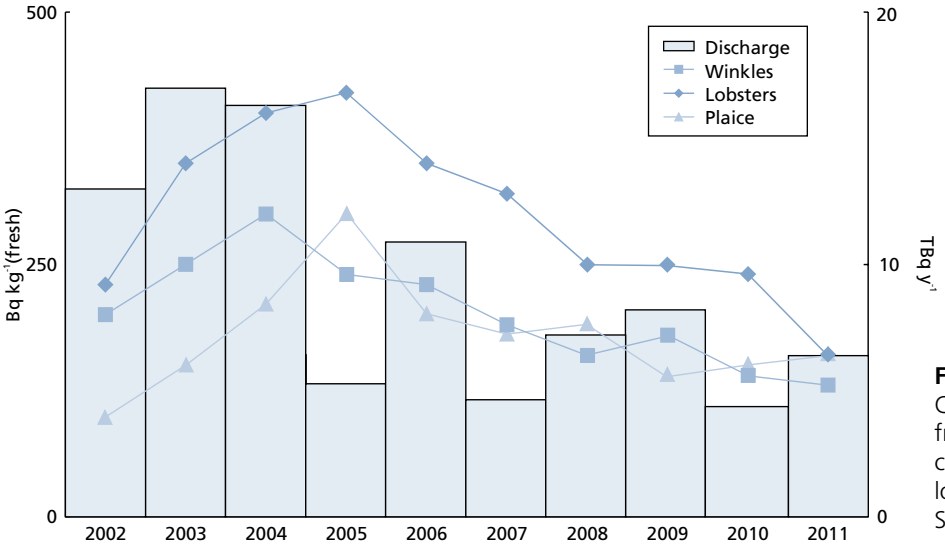


Figure 2.11.
Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

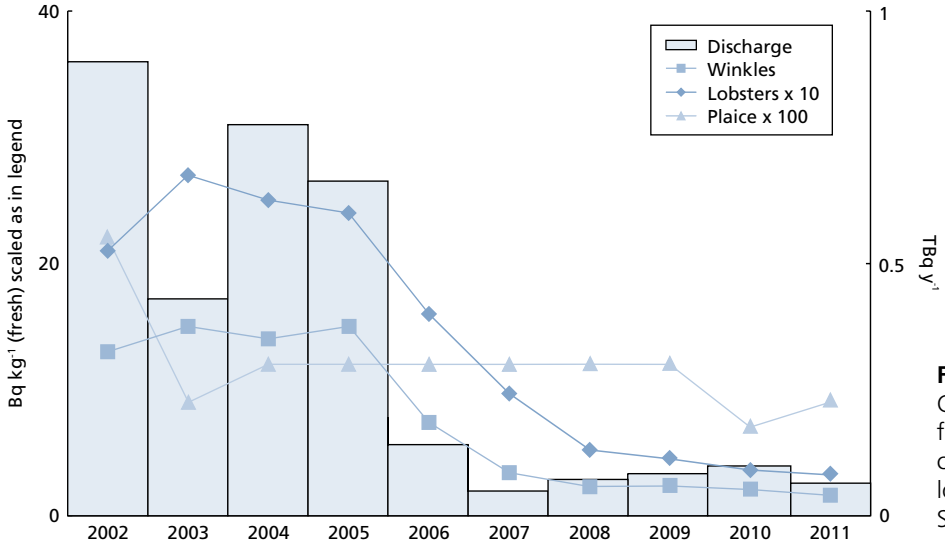


Figure 2.12.
Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

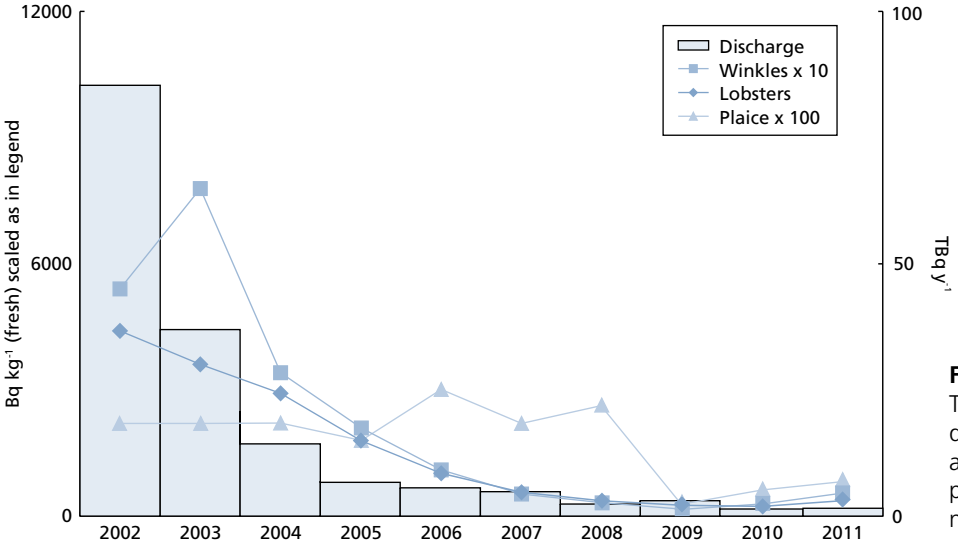


Figure 2.13.
Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

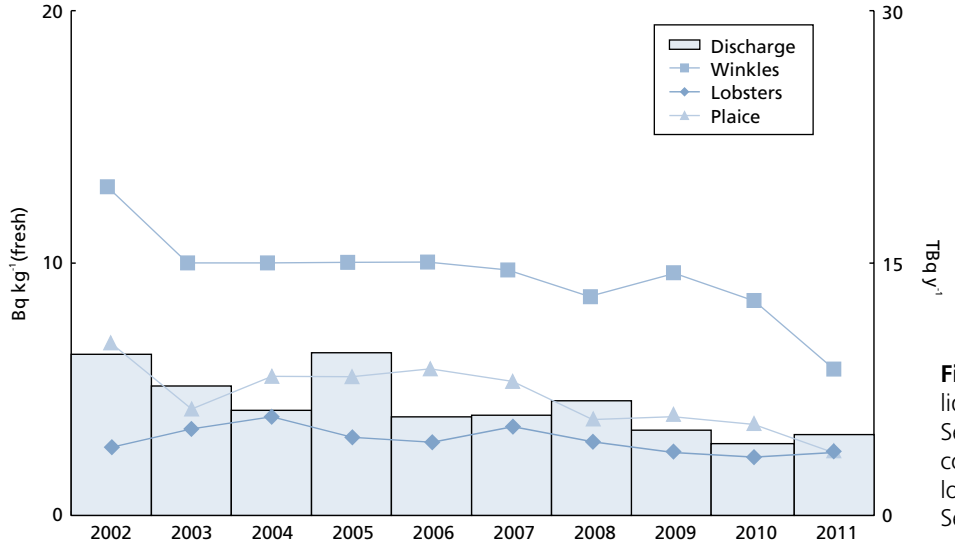


Figure 2.14. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

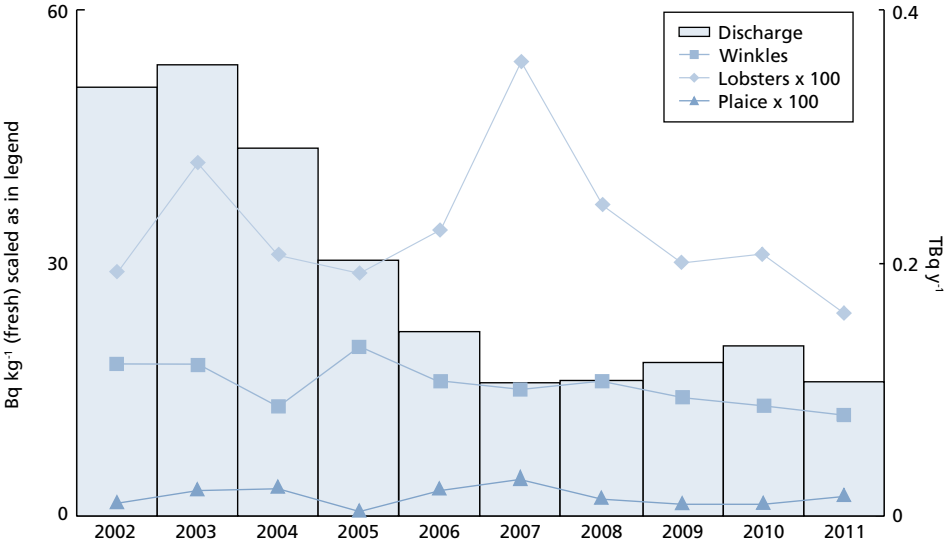


Figure 2.15. Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

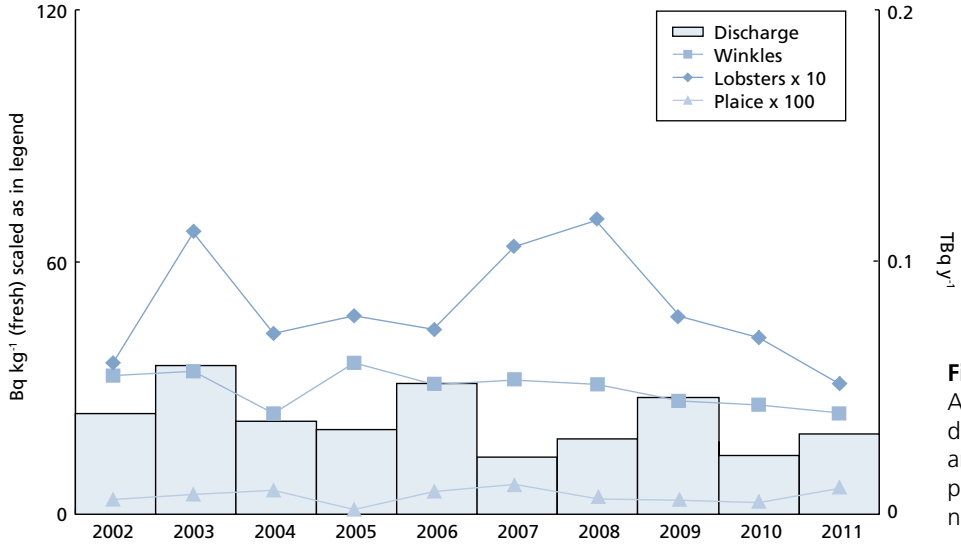


Figure 2.16. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2002-2011

exposure and in order to keep distributions of radioactivity under review. The results for 2011 are shown in Table 2.8. Radionuclides detected include 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 2011 were generally similar to those in recent years.

The trends over time (1987 – 2011) for concentrations in mud from Ravenglass with discharges from Sellafield are shown in Figures 2.17 – 2.20. 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 reduced in recent years, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 2.19). Over the last decade, caesium-137 and transuranic concentrations in sediments have remained relatively constant (Figures 2.17, 2.18 and 2.20). 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 small progressive increases in the concentrations in sediments (peaking over the period, ~2003 – 2006). This upward trend has not been continued, with the lowest concentrations of caesium-137 and plutonium isotopes reported in 2010. 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 2.14 – 2.16) 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 2.21. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations in 2011 at a given location were generally similar to those in 2010, and any fluctuations were most likely due to normal variability in the environment. In 2011, caesium-137 and americium-241 concentrations in sediments at Newton Arlosh decreased, contrary to the upward trend in most recent years. There was limited evidence to suggest small progressive increases in the concentrations in sediments at some locations at distance from Sellafield in most recent years, but these are still below peak values reported over the whole period of time (except at Carsliuth).

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 2011 were generally similar to those data in recent years. Any variations between years are likely to have been due to normal variability in the environment. Gamma dose rates measured on the banks of the River Calder, which flows through the Sellafield site, continued to show significant excess above natural background downstream of the site (of approximately 0.04 μGy h^{-1}). Although the dose rates are locally enhanced, occupancy by the public, mainly anglers, is low in this area (unlikely to be more than a few tens of hours per year). On this basis the resulting doses were much less than those at other intertidal areas as discussed earlier in this section.

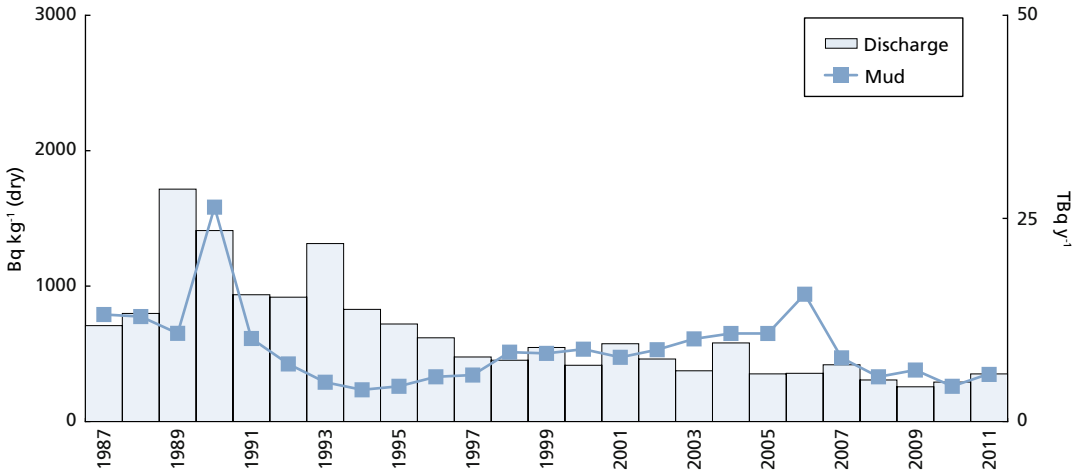


Figure 2.17. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1987-2011 (data prior to 1988 are from BNFL surveys)

Gamma dose rates above mud and salt marshes, from a range of coastal locations in the vicinity of Sellafield, are shown in Figure 2.22. 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. Close to Sellafield (at Carleton Marsh and Newbiggin), there was limited evidence to suggest that dose rates are slowly declining over the whole period. Locations that are further afield from Sellafield show dose rate values that only marginally exceeded 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 2.18). 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). 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.

The mean dose rate across all 576 locations was 0.14 µGy h^{-1}, with a range of 0.07 – 0.28 µGy h^{-1}. This indicates a significant decrease compared to the mean dose rate reported in 1989 (at similar locations) of 0.23 µGy h^{-1} (range 0.07 – 0.61 µGy h^{-1}).

The highest gamma dose rates measured in both surveys were from comparable locations within the estuary. The reduced dose rates in the 2007 survey were 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 has been published by the Environment Agency (Wood *et al*., 2011).

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 2011 are given in Table 2.10. Overall, measured dose rates were slightly decreased in comparison to rates in 2010, but generally increased 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 2011, 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. Overall in 2011, beta dose rates were higher at Tarn Bay and St Bees than in 2010.

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 2011, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

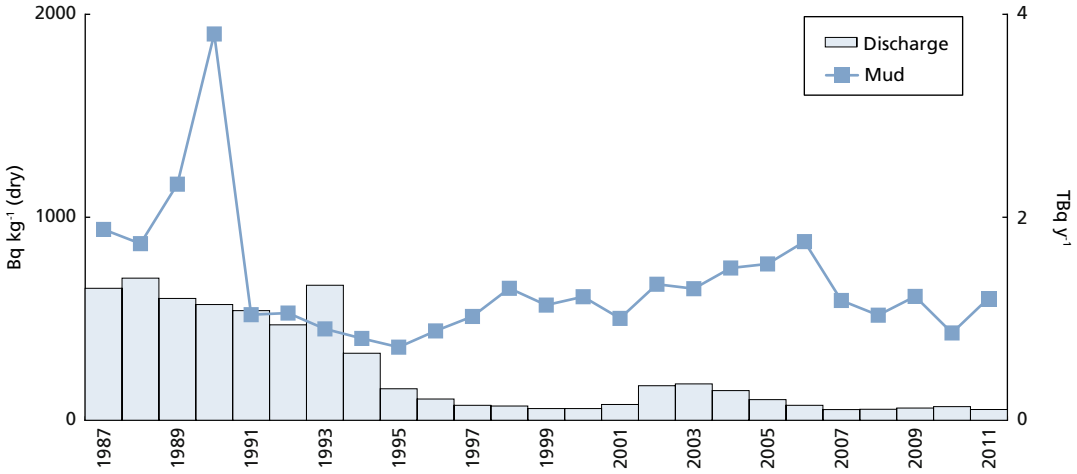


Figure 2.18. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass, 1987-2011 (data prior to 1988 are from BNFL surveys)

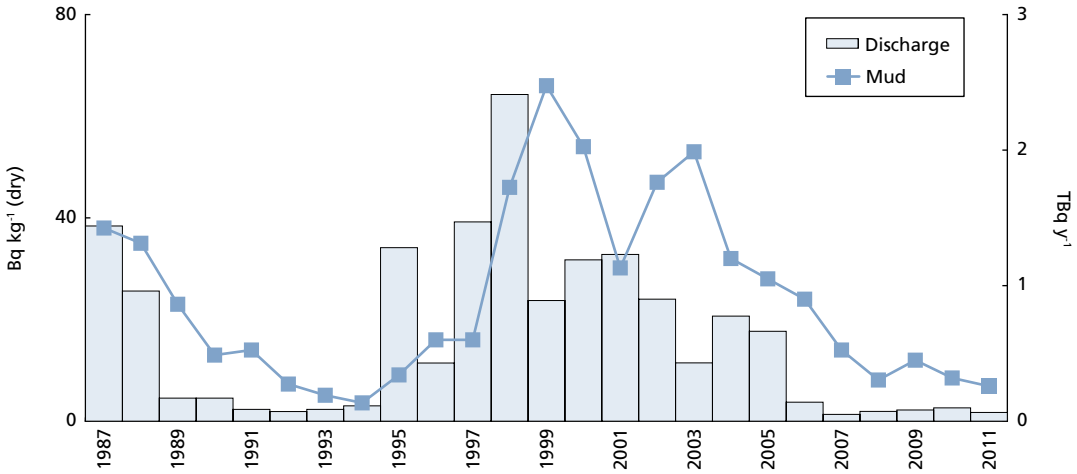


Figure 2.19. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1987-2011 (data prior to 1988 are from BNFL surveys)

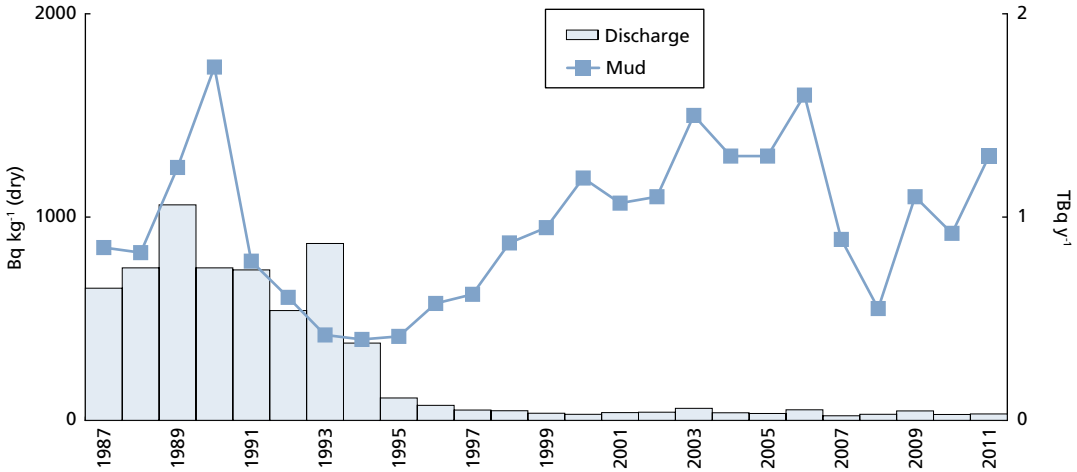


Figure 2.20. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1987-2011 (data prior to 1988 are from BNFL surveys)

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 was focused 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 and April 2011, the Environment Agency provided updates on further progress of the enhanced beach monitoring (Environment Agency, 2010b; 2011b). Earlier work up to 2010 was described elsewhere (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a).

Since vehicle-mounted beach survey work began in November 2006, and up to April 2012, over 1350 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 particles, 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 April 2012, the total number of finds that have been identified since 2006 comprised 1498 stones, pebbles and particles, with around 69 per cent being less than 2 mm in diameter. All have been removed from the beaches. The number of

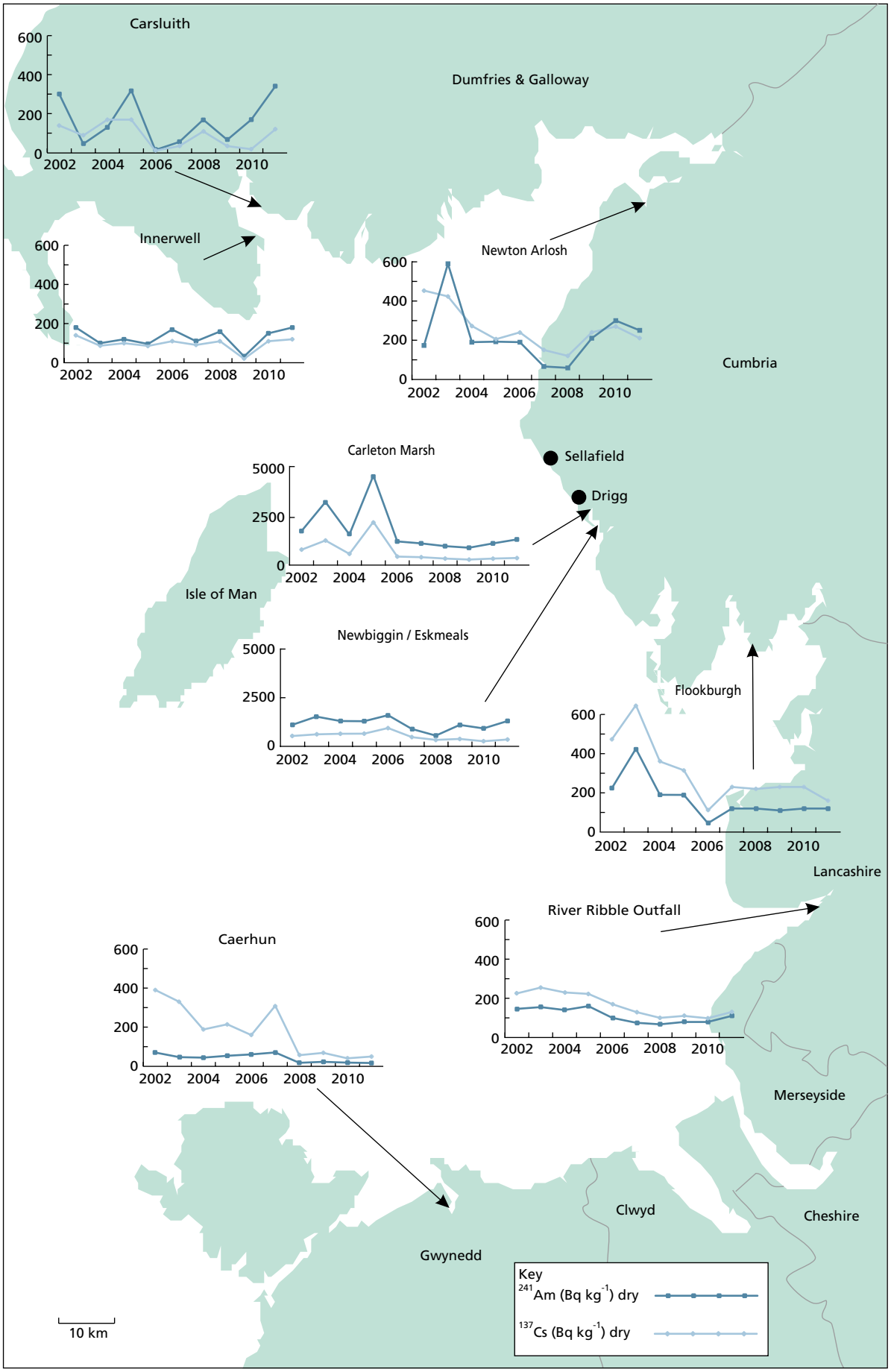


Figure 2.21. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2002-2011 (Note different scales used for Newbiggin and Carleton Marsh)

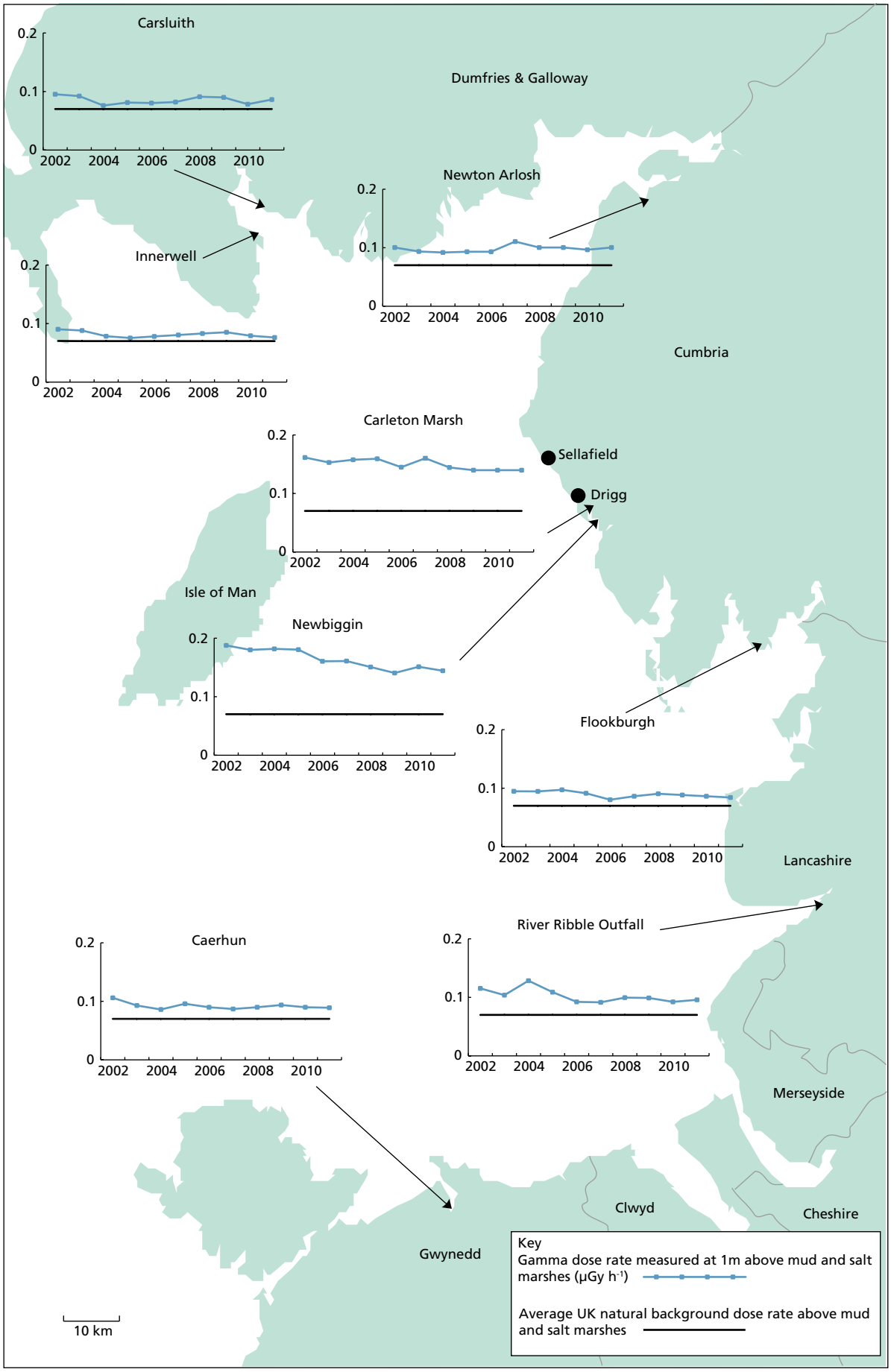


Figure 2.22. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2002-2011

radioactive finds identified in the period from 1st April 2011 to 1st April 2012 was 267. The majority of the finds (219) were concentrated on a 5 km stretch of beach running NW from the Sellafield site.

Monitoring along the Cumbrian coast will continue, with the current proposal being a further 150 Ha to be surveyed between April 2012 and March 2013, 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.

In August 2011, the Environment Agency conducted a trial programme of seabed sediment sampling along the west Cumbrian coastline in the vicinity of Sellafield. This programme was supported by on-vessel survey monitoring of the sediment to look for the presence of radioactive particles of the sort being detected and removed routinely from nearby beaches. The trial was successful in demonstrating the technique, and in retrieving samples, to allow sediment characteristics to be better understood. No active particles were found. The outputs from the exercise have been used to inform a further offshore sampling and monitoring exercise undertaken by Sellafield Limited in 2012.

In 2010, the Health Protection Agency (HPA) reported on a detailed assessment of risks, and restated the advice that it originally offered to the Environment Agency, in 2007 (Brown and Etherington, 2011). The report confirmed that no special precautionary actions were required to limit access to or use of the beaches. In relation to food safety, and following a previous assessment of the particles frequency and the activity concentrations, the Food Standards Agency's guidance to the Environment Agency supported HPA's advice. 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, 2011b). Further detail on the monitoring data compiled so far can be obtained from Sellafield Limited http://www.sellafieldsites.com/about-us/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 2011 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* are 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 2011, are shown in Figure 2.8. 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 were found near Sellafield were much less than those in the mid 1990s. In general, there was 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 broadly similar to those in 2010, and this included a specific location (Cemaes Bay, Wales) previously known to have had fluctuating levels over recent years. However in 2011, activity concentrations in seaweed (*Fucus* and *ascophyllum*) were higher at other locations (Carlingford Lough and Ardglass, Northern Ireland) compared with seaweed concentrations in previous 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 2011 are shown in Table 2.13. The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al.*, 2000). 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 showed enhanced concentrations of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Where comparisons can be made, technetium-99 concentrations in edible parts of the vegetables grown in these soils were similar to those

found in 2010. These activity concentrations in vegetables provide no evidence for significant uptake. Concentrations of gamma-emitting radionuclides in vegetables were small or below the LoD.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2011; 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 2011 are given in Table 2.12. In 2011, ruthenium-106 concentrations in *Porphyra* from the Cumbrian coast (St Bees) were at or below the LoD, and reduced in comparison with earlier years (due to the decreased discharges of this radionuclide in 2005 and 2006). Iodine-131 was also positively detected at low concentrations in two of the weekly collected Seascale *Porphyra* samples in 2011. 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 2011, activity concentrations in laverbread were 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 and Scottish Environment Protection Agency, 2007).

Monitoring of sea to land transfer

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

The results of measurements in 2011 are given in Table 2.14. In general, the data are similar to those for 2010 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. As in 2009, the evidence for sea to land transfer was very limited in 2011. Positively detected technetium-99 and iodine-129 concentrations were few, and measured just above the LoD. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. Where detectable, observed isotopic ratios of ^{238}Pu:$^{239+240}Pu$ concentrations were somewhat higher than 0.025, a value which might 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 previous years' monitoring have confirmed the findings of the 2003 study.

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 9.

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 2011 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. Unlike in 2010, there was some evidence of tritium at the outfall in 2011 (Table 2.15). However, the waters are not potable and any low concentrations observed previously are of no radiological significance. Table 2.15 also includes the results of monitoring from the Ehen Spit (Figure 2.10) 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 2011 with concentrations similar to those in recent years. The dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant (Environment Agency, 2002a).

2.3.4 Monitoring of unusual pathways

In 1998, high concentrations of caesium-137 (of up to 110,000 Bq kg^{-1}) were found in feral pigeons sampled in Seascale by the Ministry of Agriculture, Fisheries and Food (MAFF). Consumption of the breast meat of only 20 birds contaminated at the highest concentration would have given a dose of 1 mSv 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 2011 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon decreased in 2011 (0.29 Bq kg^{-1}), in comparison to the value reported in 2010 (16 Bq kg^{-1}). These total caesium concentrations have also had fluctuating levels in recent years prior to 2010. 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.

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 2011 are shown in Table 2.16, and were generally similar to those in previous years. In 2010, elevated concentrations (of stronium-90, caesium-137, americium-241 and plutonium radionuclides) in sediments were reported for one of the five Seascale road drains (Seascale SS 233). Investigations, including monitoring of additional Seascale road drains, were conducted in 2011 to confirm that the elevation had ceased or to inform appropriated action. The results indicate that the elevation (from 2010) was not sustained in 2011 and that results were mostly consistent with other road drains sampled. In 2011, one of the additionally monitored road drains (Seascale SS 206) also contained enhanced concentrations in sediments, but generally 60 per cent of the maximum values reported in 2010 (Seascale SS 233). The enhancements may have arisen from unusual weather conditions in that year, releasing radioactivity trapped within the drainage path. Generally, over a longer period, activity concentrations in road drains have fallen significantly since remedial measures to reduce contamination were taken.

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 permit. 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 but have recently been subject to deferrals in order to release resource for high hazard work. However, the reactor decommissioning of the Windscale Advanced Gas Cooled Reactor was completed in May 2011. Facilities which were undergoing decommissioning will be placed in a safe state until decommissioning work resumes. 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 were 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, 2011

Site	Exposed population[a]	Exposure, mSv per year						
		All pathways	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
Capenhurst								
***Total dose* - all sources**	**Local adult inhabitants (0-0.25km)**	**0.095**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.095**
Source specific doses	Infant consumers of locally grown food[d]	<0.005	-	<0.005	-	-	<0.005	-
	Children playing at Rivacre Brook[c,d]	0.010	-	-	0.010	<0.005	-	-
Springfields								
***Total dose* - all sources**	**Adult occupants on houseboats**	**0.13**	**-**	**-**	**0.13**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.017	0.005	-	0.012	-	-	-
	Houseboat occupants	0.13	-	-	0.13	-	-	-
	Fishermen handling nets or pots[b]	0.069	-	-	0.069	-	-	-
	Children playing at Lower Penwortham[c,d]	<0.005	-	-	<0.005	<0.005	-	-
	Farmers and wildfowlers	0.027	-	-	0.027	-	-	-
	Infant consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *Exposure to skin for comparison with the 50 mSv dose limit*

[c] *Children aged 10y*

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

Table 2.2(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{99}Tc	^{137}Cs	^{234}Th	^{234}U	^{235}U	^{238}U
Marine samples										
Dab	Liverpool Bay	1	<25							
Plaice	Liverpool Bay	1	<25							
Flounder	Mersey Estuary	2	<25							
Shrimps	Wirral	2	<25	<0.04	0.42	1.1	*			
Mussels	Liverpool Bay	2	<25							
Mussels	Mersey Estuary	2	<25							
Cockles	Dee Estuary	4		<0.12	2.8	1.5	15			
Sediment	Rivacre Brook	2[E]			110	2.0	63	98	3.5	45
Sediment	Rivacre Brook (1.5 km downstream)	2[E]			71	2.5	<16	31	<1.6	19
Sediment	Rossmore (3.1 km downstream)	2[E]			49	2.2	<14	30	<1.9	19
Sediment	Rivacre Brook (4.3 km downstream)	2[E]			18	<0.83	<12	14	<1.5	10
Freshwater	Rivacre Brook	2[E]	5.6		<0.10			0.033	<0.0065	<0.020
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<5.3		<0.085			0.018	<0.0045	<0.011
Freshwater	Rossmore (3.1 km downstream)	2[E]	<4.8		<0.090			0.017	<0.0050	0.012
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	<3.6		<0.095			0.018	<0.0040	0.011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu+	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Shrimps	Wirral	2				<0.03				
Cockles	Dee Estuary	4		0.13	0.79	2.1	*	*		
Sediment	Rivacre Brook	2[E]	<4.0						430	1300
Sediment	Rivacre Brook (1.5 km downstream)	2[E]	<4.0						200	670
Sediment	Rossmore (3.1 km downstream)	2[E]	<4.0						280	810
Sediment	Rivacre Brook (4.3 km downstream)	2[E]	<4.0						<100	650
Freshwater	Rivacre Brook	2[E]	<0.10						<0.12	0.26
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<0.10						<0.060	0.27
Freshwater	Rossmore (3.1 km downstream)	2[E]	<0.10						<0.045	0.17
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	<0.10						<0.060	0.22

Table 2.2(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H[c]	^{99}Tc	^{234}U	^{235}U	^{238}U
Terrestrial samples							
Milk		5	<3.0	<0.0065	<0.00074	<0.00048	<0.00054
Milk	max				0.0012	<0.00050	<0.00060
Gooseberries		1		<0.026	0.00080	<0.00050	0.0012
Lettuce		1			0.0051	<0.00030	0.0052
Potatoes		1		<0.022	0.0017	0.00040	<0.00060
Grass		4		0.018	0.017	<0.0012	0.017
Grass	max				0.041	0.0023	0.043
Grass/herbage	North of Ledsham	1[E]		<0.70	0.97	<0.39	0.78
Grass/herbage	South of Capenhurst	1[E]		<0.35	0.32	<0.15	0.37
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<0.60	<0.54	<0.23	<0.52
Grass/herbage	East of station	1[E]		<1.1	<1.2	<0.87	<0.46
Silage		2		0.018	0.030	0.00085	0.027
Silage	max			0.027	0.045	0.0010	0.043
Soil		1[#]			10	0.46	10
Soil	North of Ledsham	1[E]		<2.0	24	<1.6	25
Soil	South of Capenhurst	1[E]		<2.4	19	1.6	19
Soil	Off lane from Capenhurst to Dunkirk	1[E]		<2.0	19	<1.6	20
Soil	East of station	1[E]		<6.0	22	<1.5	22

* *Not detected by the method used*

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

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

[c] *In distillate fraction of sample*

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

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

[#] *Fresh concentrations*

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Grass and mud	1	0.099
Rivacre Brook Plant outlet	Grass	1	0.10
Rivacre Brook 1.5 km downstream	Grass and mud	1	0.080
Rivacre Brook 1.5 km downstream	Grass	1	0.085
Rossmore Road West 3.1 km downstream	Mud and stones	1	0.082
Rossmore Road West 3.1 km downstream	Grass and sand	1	0.082
Rivacre Brook 4.3 km downstream	Mud	1	0.080
Rivacre Brook 4.3 km downstream	Grass and vegetation	1	0.083

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{129}I	^{137}Cs
Marine samples										
Grey mullet	Ribble Estuary	2			<0.08			<0.22		2.9
Sole	Ribble Estuary	1			<0.06			<0.18		2.6
Bass	Ribble Estuary	1			<0.08			<0.20		5.8
Salmon	Ribble Estuary	1			<0.15			<0.39		0.10
Shrimps	Ribble Estuary	2		24	<0.07		0.29	<0.13		3.2
Cockles	Ribble Estuary	2			<0.11			<0.25		1.8
Mussels	Ribble Estuary	1			<0.07			<0.17		0.93
Wildfowl	Ribble Estuary	1	<25	27	<0.05	<0.065		<0.16	<1.6	1.0
Samphire	Marshside Sands	1			<0.08			<0.20		0.47
Sediment	River Ribble outfall	4[E]			<1.2					130
Sediment	Savick Brook	2[E]			<1.7					210
Sediment	Lea Gate	2[E]			<1.4					170
Sediment	Lower Penwortham Park	4[E]			<1.5					190
Sediment	Penwortham rail bridge	4[E]			<1.3					200
Sediment	Penwortham rail bridge - West bank	2[E]			<1.3					120
Sediment	Penwortham position 1	4[E]			<1.0					41
Sediment	Penwortham position 2	1[E]			<1.3					46
Sediment	Lytham Yacht Club	1[E]			<1.6					220
Sediment	Becconsall	4[E]			<1.3					150
Sediment	Freckleton	1[E]			<1.4					250
Sediment	Hutton Marsh	1[E]			<1.8					370
Sediment	Longton Marsh	1[E]			<1.5					110
Grass (washed)	Hutton Marsh	1[E]					<2.0			
Grass (unwashed)	Hutton Marsh	1[E]					<1.6			
Soil	Hutton Marsh	1[E]					62			

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{228}Th	^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np
Marine samples										
Shrimps	Ribble Estuary	2	0.011	0.0078	0.0054	*				0.00022
Cockles	Ribble Estuary	2	0.55	0.51	0.33	<4.5				
Mussels	Ribble Estuary	1	0.26	0.24	0.11	11				
Wildfowl	Ribble Estuary	1	0.0037	0.0045	0.0012	*				
Sediment	River Ribble outfall	4[E]	28	52	24	300	18	<1.7	17	
Sediment	Savick Brook	2[E]	39	79	31	760	30	2.1	29	
Sediment	Lea Gate	2[E]	30	74	25	1100	31	<2.8	27	
Sediment	Lower Penwortham Park	4[E]	33	110	30	620	30	<2.5	30	
Sediment	Penwortham rail bridge	4[E]	34	76	28	580	24	<1.6	24	
Sediment	Penwortham rail bridge - West bank	2[E]	23	52	22	400	22	<1.9	21	
Sediment	Penwortham position 1	4[E]	19	31	17	<83	17	<1.3	17	
Sediment	Penwortham position 2	1[E]	22	36	22	190	17	<2.6	15	
Sediment	Lytham Yacht Club	1[E]	32	66	31	200	24	1.6	24	
Sediment	Becconsall	4[E]	24	53	23	<190	19	<1.4	20	
Sediment	Freckleton	1[E]	37	82	33	520	19	1.5	19	
Sediment	Hutton Marsh	1[E]	54	180	46	78	20	<2.3	23	
Sediment	Longton Marsh	1[E]	43	84	39	<24	27	1.9	29	

Table 2.3(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Grey mullet	Ribble Estuary	2			<0.15				
Sole	Ribble Estuary	1			<0.18				
Bass	Ribble Estuary	1			<0.22				
Salmon	Ribble Estuary	1			<0.49				
Shrimps	Ribble Estuary	2	0.0025	0.013	0.027	*	*		
Cockles	Ribble Estuary	2	0.16	1.0	2.9	*	*		
Mussels	Ribble Estuary	1			0.70				
Wildfowl	Ribble Estuary	1	0.00072	0.0041	0.011	0.000065	*		
Samphire	Marshside Sands	1			<0.18				
Sediment	River Ribble outfall	4[E]			110			400	1000
Sediment	Savick Brook	2[E]			140			580	1700
Sediment	Lea Gate	2[E]			140			460	2100
Sediment	Lower Penwortham Park	4[E]			150			560	1600
Sediment	Penwortham rail bridge	4[E]			150			530	1300
Sediment	Penwortham rail bridge - West bank	2[E]			88			550	1300
Sediment	Penwortham position 1	4[E]			30			350	770
Sediment	Penwortham position 2	1[E]			36			360	840
Sediment	Lytham Yacht Club	1[E]			180			560	1300
Sediment	Becconsall	4[E]			110			500	920
Sediment	Freckleton	1[E]			200			660	1200
Sediment	Hutton Marsh	1[E]			240			810	1400
Sediment	Longton Marsh	1[E]			60			380	950

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{90}Sr	^{129}I	^{137}Cs	Total Cs
Terrestrial samples								
Apples		1	<4.0	13	0.027	0.022		0.082
Beetroot		1	<4.0	6.0	0.072	<0.027		0.038
Blackberries		1	<4.0	14	0.11	<0.028		0.12
Cabbage		1	<4.0	6.0	0.088	<0.022		0.13
Potatoes		1	<5.0	16	0.017	0.036		0.054
Rabbit		1	<6.0	27	0.0090	<0.038		0.029
Runner beans		1	<4.0	<3.0	0.091	<0.030		0.021
Sediment	Deepdale Brook	2[E]					<1.8	
Grass		1					0.60	

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		6				<0.00095	<0.00053	<0.00083
Milk	Max					0.0014	<0.00070	0.0013
Apples		1	0.0035	<0.00080		0.0013	<0.00040	<0.00050
Beetroot		1	0.0043	0.0023		0.0032	<0.00030	0.0033
Blackberries		1	0.0025	0.0031		0.0014	<0.00030	<0.00070
Cabbage		1	<0.0011	<0.0013		<0.00060	<0.00040	0.00080
Potatoes		1	0.0089	0.0040		0.0045	<0.00050	0.0038
Rabbit		1	0.0073	0.0034		0.00090	<0.00030	0.0012
Runner beans		1	0.0042	0.0028		0.0015	<0.00040	0.0017
Sediment	Deepdale Brook	2[E]			79	58	3.1	54
Grass		1				0.14	0.0052	0.085
Grass	Site fence	1[E]				1.3	<0.23	1.1
Grass	Opposite site entrance	1[E]				1.7	<0.13	1.7
Grass	Opposite windmill	1[E]				2.9	<0.30	3.2
Grass	Deepdale Brook	1[E]				3.7	<0.36	3.9
Grass	Lea Town	1[E]				0.72	<0.12	0.75
Grass	N of Lea Town	1[E]				3.2	<0.23	2.9
Silage		1				0.30	0.019	0.26
Soil		1[#]				33	1.4	33
Soil	Site fence	1[E]				100	4.5	93
Soil	Opposite site entrance	1[E]				94	5.0	89
Soil	Opposite windmill	1[E]				95	6.5	92
Soil	Deepdale Brook	1[E]				58	2.5	59
Soil	Lea Town	1[E]				29	1.9	29
Soil	N of Lea Town	1[E]				51	1.7	50
Freshwater	Deepdale Brook	4[E]				0.34	<0.016	0.32

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples								
Apples		1	<0.00010	<0.00020	<0.077	0.00030		
Beetroot		1	<0.00010	<0.00020	0.089	<0.00020		
Blackberries		1	<0.00040	<0.00060	<0.19	0.00080		
Cabbage		1	<0.00010	<0.00020	<0.075	0.00030		
Potatoes		1	<0.00010	<0.00020	<0.063	0.00040		
Rabbit		1	<0.00050	<0.0010	<0.14	0.00030		
Runner beans		1	<0.00010	0.00020	<0.059	0.00050		
Sediment	Deepdale Brook	2[E]					440	850
Grass		1				0.30		
Freshwater	Deepdale Brook	4[E]					0.70	0.66

* *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, 2011

Location	Material or ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Lytham Yacht Club	Grass	1	0.11
Warton Mud Marsh	Grass and salt marsh	2	0.12
Warton Mud Marsh	Grass and salt marsh[a]	2	0.13
Warton Salt Marsh	Grass and salt marsh	2	0.096
Freckleton	Grass and mud	1	0.10
Naze Point	Grass	2	0.11
Banks Marsh	Grass and salt marsh	1	0.11
Banks Marsh	Grass	1	0.11
Banks Marsh	Grass and salt marsh[a]	1	0.12
Banks Marsh	Grass[a]	1	0.10
Hesketh Bank	Grass	2	0.10
Becconsall Boatyard	Mud	1	0.083
Becconsall Boatyard	Salt marsh	1	0.092
Becconsall Boatyard	Grass and mud	2	0.085
Becconsall (vicinity of houseboats)	Asphalt	2	0.079
Longton Marsh	Grass and mud	1	0.12
Hutton Marsh	Grass and mud	1	0.13
River Ribble outfall	Mud	2	0.094
River Ribble outfall	Grass and mud	1	0.096
River Ribble outfall	Grass	1	0.090
Savick Brook, confluence with Ribble	Grass and mud	1	0.089
Savick Brook, confluence with Ribble	Grass	1	0.093
Savick Brook, tidal limit	Grass and mud	1	0.10
Savick Brook, tidal limit	Grass	1	0.10
Savick Brook, Lea Gate	Grass and mud	1	0.097
Savick Brook, Lea Gate	Grass	1	0.10
South bank opposite outfall	Grass	1	0.11
Penwortham Bridge cadet hut	Mud	2	0.090
Lower Penwortham Park	Grass	4	0.080
Lower Penwortham Railway Bridge	Mud	1	0.084
Lower Penwortham Railway Bridge	Mud and stones	3	0.082
River Darwen	Grass	4	0.082
Riverbank Angler location 1	Mud	1	0.080
Riverbank Angler location 1	Mud and sand	1	0.083
Riverbank Angler location 1	Grass and mud	1	0.073
Riverbank Angler location 1	Grass and sand	1	0.076
Riverbank Angler location 2	Mud and sand	1	0.083
Ulnes Walton, BNFL area survey	Grass	3	0.079
Mean beta dose rates			μSv h^{-1}
Lytham - Granny's Bay	Mud and sand	1	0.040
Ribble Estuary	Gill net	2	0.11
Ribble Estuary	Shrimp net	2	0.089
Banks Marsh	Grass and salt marsh	1	0.14
Banks Marsh	Grass	1	0.040
Warton Mud Marsh	Grass and salt marsh	2	0.060
Warton Salt Marsh	Grass and salt marsh	2	0.060

[a] *15cm above substrate*

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2011

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{131}I
Milk		16	<4.2	<4.2	16	<0.18	0.043	<0.0045	<1.1	<0.36	<0.0077	<0.0076
Milk	max		<4.8	<4.8	19	<0.20	0.12		<1.3	<0.40	<0.010	<0.011
Apples		2	<10	6.0	13	<0.25	0.17	<0.025	<1.3	<0.40	<0.023	
Apples	max		<12	7.0	14	<0.30	0.26			<0.50		
Barley		1		<7.0	83	<0.20	0.39		<1.1	<0.30	<0.046	
Beef kidney		1	<8.0	<8.0	20	<0.20	0.17	0.057	<1.4	<0.60		
Beef liver		1	<7.0	<7.0	19	<0.20	0.040	<0.024	<1.4	<0.20	<0.031	
Beef muscle		1	3.0	6.0	16	<0.10	<0.0060	<0.027	<1.0	<0.30	<0.045	
Blackberries		1	1.0	14	15	<0.20	0.81		<1.1	<0.30	<0.023	
Blackcurrants		1	<6.0	6.0	19	<0.10	0.14		<1.0	<0.20	<0.020	
Broccoli		1	<6.0	<6.0	11	<0.20	0.18		<1.3	<0.30	<0.025	
Cabbage		1	<7.0	<4.0	5.0	<0.20	0.11		<1.1	<0.40	<0.023	
Carrots		1	<4.0	<4.0	7.0	<0.20	0.15	<0.024	<1.2	<0.40	<0.036	
Cauliflower		1	<4.0	<4.0	<3.0	<0.10	0.083		<0.90	<0.30	<0.021	
Duck		1	<6.0	<6.0	59	<0.20	0.0080	<0.022	<1.3	<0.30	<0.031	
Eggs		1	<6.0	<6.0	31	<0.20	0.015		<1.4	<0.30	<0.024	
Elderberries		1	<7.0	<4.0	18	<0.20	0.45		<1.1	<0.40	<0.023	
French beans		1	<6.0	<4.0	13	<0.20	0.12		<1.2	<0.30	<0.026	
Honey		1		<7.0	99	<0.20	0.014		<1.4	<0.50	<0.014	
Leeks		1	<4.0	<4.0	14	<0.10	0.22		<0.80	<0.20	<0.027	
Mushrooms		1	<5.0	5.0	<5.0	<0.10	1.1		<1.1	<0.30	0.029	
Onions		1	<4.0	<4.0	6.0	<0.20	0.059		<1.0	<0.30	0.022	
Pheasants		1	<6.0	<6.0	58	<0.10	0.0080	<0.022	<1.6	<0.30	<0.046	
Potatoes		1	<6.0	<5.0	10	<0.30	0.046		<1.2	<0.30	<0.023	
Rabbit		1	<6.0	<6.0	27	<0.20	0.018	<0.023	<1.1	<0.40	<0.035	
Runner beans		1	<4.0	<4.0	8.0	<0.20	0.18		<1.0	<0.20	<0.022	
Sheep muscle		2	<5.0	<5.0	20	<0.20	0.014	<0.023	<1.1	<0.30	<0.046	
Sheep muscle	max				24		0.018			<0.40	<0.050	
Sheep offal		2	<8.0	<8.0	9.5	<0.20	0.19	0.068	<1.4	<0.50	<0.038	
Sheep offal	max			8.0	<10		0.22	0.077	<1.6		<0.039	
Strawberries		1	<7.0	5.0	10	<0.20	0.081		<1.1	<0.40	<0.024	
Swede		1	<4.0	<4.0	7.0	<0.20	0.18		<0.90	<0.40	<0.024	
Wheat		1		<7.0	110	<0.20	0.44		<1.3	<0.40	<0.036	
Wood pigeon muscle		2	<6.0	<6.0	32	<0.20	0.016		<1.1	<0.40	<0.037	
Wood pigeon muscle	max				37		0.018		<1.3	<0.50	<0.040	
Grass		5				<0.16		<0.039	<0.66	<0.36		
Grass	max					<0.20		0.053	<1.0	0.70		
Soil		3				<0.27			<1.1	<0.40		
Soil	max					0.40						

Table 2.4. continued

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{134}Cs	^{137}Cs	Total Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am
Milk		16	<0.19	<0.20	0.15				<0.00011	<0.00018	<0.034	<0.00012
Milk	max		<0.20	<0.28	0.30				<0.00013	<0.00018	<0.035	<0.00013
Apples		2			0.33				<0.00020	<0.00055	<0.059	0.0012
Apples	max				0.55				0.00020	0.00070	<0.078	0.0020
Barley		1			0.16				0.00020	0.0015	<0.094	0.0024
Beef kidney		1			0.83	0.0063	<0.0018	0.0048	<0.00010	0.00070	<0.12	0.00030
Beef liver		1			0.63				0.00040	0.0021	<0.056	0.0013
Beef muscle		1			0.91				<0.00020	0.00020	<0.058	0.00020
Blackberries		1			0.28				<0.00010	0.00090	<0.057	0.00050
Blackcurrants		1			0.12				<0.00010	0.00030	<0.037	0.00019
Broccoli		1			0.039				<0.00020	<0.00030	<0.069	0.00040
Cabbage		1			0.068				0.00010	<0.00030	<0.039	<0.00020
Carrots		1			0.12							
Cauliflower		1			0.069	0.0018	<0.00040	0.00070	<0.00020	<0.00020	<0.083	0.00050
Duck		1			0.36				<0.00010	<0.00030	<0.12	0.00040
Eggs		1			0.088				<0.00020	0.00010	<0.037	<0.00010
Elderberries		1			0.27				0.0012	0.0086	0.068	0.020
French beans		1			0.14				<0.00010	<0.00030	<0.068	0.00070
Honey		1			0.069				0.00010	<0.00020	<0.085	0.00090
Leeks		1			0.049	0.0088	<0.00040	0.010				
Mushrooms		1			0.26				0.0011	0.0042	<0.048	0.013
Onions		1			0.048							
Pheasants		1			0.16				0.00020	<0.00020	<0.12	0.00030
Potatoes		1			0.050							
Rabbit		1			1.4				<0.00020	<0.00040	<0.10	0.00050
Runner beans		1			0.12				<0.00020	0.00070	<0.074	0.0019
Sheep muscle		2			0.74				<0.00015	<0.00035	<0.084	<0.00020
Sheep muscle	max				0.91				<0.00020	<0.00040		
Sheep offal		2			0.41	0.0021	<0.00050	0.0014	<0.00030	0.0014	<0.089	0.0015
Sheep offal	max				0.44	0.0023	<0.00060	0.0016	0.00040	0.0016	<0.090	0.0017
Strawberries		1			0.041				0.00010	<0.00030	<0.061	0.00030
Swede		1			0.18							
Wheat		1			0.39				0.00040	0.0012	<0.089	0.0010
Wood pigeon muscle		2			0.26				<0.00025	<0.00040	<0.086	<0.00040
Wood pigeon muscle	max				0.29				<0.00030	<0.00050	<0.099	0.00060
Grass		5	<0.12	1.2								
Grass	max		<0.20	2.7								
Soil		3	<0.20	57								6.8
Soil	max			65		7.6	0.46	7.2				9.1

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

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

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

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Cumbria										
Maryport	Plaice	4				<0.06		<0.18	<0.19	
Parton	Cod	4				<0.09		<0.20	<0.19	
Whitehaven	Cod	4			90	<0.07	0.031	<0.15	<0.12	
Whitehaven	Plaice	4				<0.08	0.096	<0.20	<0.20	
Whitehaven	Skates / rays	4				<0.09		<0.26	<0.28	
Whitehaven	Sole	4				<0.11		<0.35	<0.39	
River Ehen	Salmon	1				<0.20		<0.37	<0.30	
Sellafield coastal area	Cod	8				<0.10		<0.23	<0.21	
Sellafield coastal area	Plaice	4	180	180		<0.13		<0.33	<0.32	
Sellafield coastal area	Bass	1				<0.13		<0.28	<0.25	
Sellafield coastal area	Grey mullet	1				<0.14		<0.32	<0.25	
Sellafield offshore area	Cod	1				<0.07	0.027	<0.15	<0.14	
Sellafield offshore area	Plaice[a]	2			160	<0.09	<0.18	<0.21	<0.21	8.2
Sellafield offshore area	Lesser spotted dogfish	2				<0.10		<0.23	<0.22	
Sellafield offshore area	Red gurnard	1			54	<0.19		<0.43	<0.34	5.1
River Esk	Salmon	1				<0.09		<0.19	<0.14	
River Esk	Sea trout	1				<0.21		<0.42	<0.31	
River Calder	Brown trout	1				<0.23		<1.2	<1.9	
River Calder	Sea trout	1				<0.30		<0.58	<0.46	
Ravenglass	Cod	6				<0.09		<0.22	<0.20	
Ravenglass	Plaice	3	83	110		<0.09		<0.29	<0.35	
Morecambe Bay (Flookburgh)	Flounder	4			92	<0.10		<0.40	<0.35	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.12		<0.35	<0.40	
Morecambe Bay (Morecambe)	Bass	2				<0.08		<0.35	<0.59	
Morecambe Bay (Morecambe)	Flounder	4	31	32		<0.11	0.033	<0.31	<0.34	1.5
Morecambe Bay (Sunderland Point)	Whitebait[b]	1				<0.10	<0.11	<0.36	<0.50	
Fleetwood	Plaice	3				<0.05		<0.24	<0.35	
Fleetwood	Cod	1				<0.05		<0.10	<0.09	
Fleetwood	Whiting	3			63	<0.10	<0.069	<0.26	<0.27	0.12
Fleetwood	Dab	1				<0.15		<0.47	<0.52	
Ribble Estuary	Grey mullet	2				<0.08		<0.26	<0.26	
Ribble Estuary	Sole	1				<0.06		<0.28	<0.41	
Ribble Estuary	Bass	1				<0.08		<0.36	<0.49	
Ribble Estuary	Salmon	1				<0.15		<0.35	<0.31	
Liverpool Bay	Plaice	1		<25						
Liverpool Bay	Dab	1		<25						
Mersey Estuary	Flounder	2		<25						
Scotland										
Shetland	Fish meal	1[S]				<0.36				
Shetland	Fish oil (herring)	1[S]				<0.26				
Shetland	Fish oil (salmon)	1[S]				<0.30				
Kirkcudbright	Plaice	4[S]			18	<0.10		<0.24	<0.24	0.76
Inner Solway	Flounder	1[S]			47	<0.10	<0.10	<0.22	<0.22	<0.43
Inner Solway	Salmon	1[S]		<5.0		<0.10		<0.29	<0.28	
Inner Solway	Sea trout	1[S]		<5.0		<0.10		<0.17	<0.19	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	Gross beta
Cumbria									
Maryport	Plaice	4	<0.57	<0.15	<0.06	2.8	<0.29	<0.13	
Parton	Cod	4	<0.76	<0.22	<0.09	5.1	<0.39	<0.20	
Whitehaven	Cod	4	<0.61	<0.17	<0.07	4.0	<0.36	<0.18	
Whitehaven	Plaice	4	<0.73	<0.19	<0.08	2.6	<0.36	<0.16	
Whitehaven	Skates / rays	4	<0.80	<0.23	<0.09	5.8	<0.42	<0.20	
Whitehaven	Sole	4	<1.1	<0.25	<0.11	2.8	<0.46	<0.20	
River Ehen	Salmon	1	<1.7	<0.38	<0.18	0.35	<0.59	<0.24	
Sellafield coastal area	Cod	8	<0.85	<0.24	<0.10	6.5	<0.42	<0.21	220
Sellafield coastal area	Plaice	4	<1.3	<0.33	<0.13	3.6	<0.56	<0.27	180
Sellafield coastal area	Bass	1	<1.2	<0.35	<0.12	11	<0.61	<0.31	
Sellafield coastal area	Grey mullet	1	<1.2	<0.36	<0.13	6.3	<0.65	<0.34	
Sellafield offshore area	Cod	1	<0.50	<0.13	<0.06	5.0	<0.17	<0.07	
Sellafield offshore area	Plaice[a]	2	<0.74	<0.21	<0.08	2.5	<0.39	<0.18	
Sellafield offshore area	Lesser spotted dogfish	2	<0.80	<0.22	<0.09	5.2	<0.38	<0.19	
Sellafield offshore area	Gurnard	1	<2.0	<0.47	<0.21	3.3	<0.93	<0.44	
River Esk	Salmon	1	<0.89	<0.24	<0.10	0.35	<0.54	<0.26	
River Esk	Sea trout	1	<2.0	<0.48	<0.22	16	<0.64	<0.29	
River Calder	Brown trout	1	<3.6	<1.3	<0.27	360	<1.7	<0.60	
River Calder	Sea trout	1	<2.6	<0.60	<0.28	7.7	<0.83	<0.38	
Ravenglass	Cod	6	<0.81	<0.23	<0.09	5.2	<0.42	<0.20	
Ravenglass	Plaice	3	<0.83	<0.22	<0.09	2.9	<0.43	<0.19	
Morecambe Bay (Flookburgh)	Flounder	4	<0.98	<0.26	<0.10	9.5	<0.49	<0.21	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<1.1	<0.26	<0.11	5.1	<0.47	<0.21	
Morecambe Bay (Morecambe)	Bass	2	<0.78	<0.20	<0.08	7.2	<0.44	<0.18	
Morecambe Bay (Morecambe)	Flounder	4	<0.97	<0.25	<0.11	6.8	<0.41	<0.18	
Morecambe Bay (Sunderland Point)	Whitebait[b]	1	<0.92	<0.23	<0.11	4.0	<0.38	<0.16	
Fleetwood	Plaice	3	<0.57	<0.14	<0.06	0.90	<0.30	<0.14	
Fleetwood	Cod	1	<0.34	<0.08	<0.04	3.1	<0.12	<0.05	
Fleetwood	Whiting	3	<0.93	<0.22	<0.10	2.0	<0.37	0.18	
Fleetwood	Dab	1	<1.5	<0.37	<0.16	1.2	<0.77	<0.33	
Ribble Estuary	Grey mullet	2	<0.86	<0.22	<0.09	2.9	<0.44	<0.19	
Ribble Estuary	Sole	1	<0.66	<0.18	<0.07	2.6	<0.46	<0.19	
Ribble Estuary	Bass	1	<0.80	<0.20	<0.08	5.8	<0.43	<0.20	
Ribble Estuary	Salmon	1	<1.6	<0.39	<0.17	0.10	<0.80	<0.40	
Scotland									
Shetland	Fish meal	1[S]	<6.4	<0.97	<0.42	0.42	<4.4	<0.76	
Shetland	Fish oil (herring)	1[S]	<5.1	<0.87	<0.35	<0.23	<4.1	<0.68	
Shetland	Fish oil (salmon)	1[S]	<6.0	<0.96	<0.40	<0.29	<4.3	<0.73	
Kirkcudbright	Plaice	4[S]	<0.69	<0.19	<0.11	<0.10	<0.37	<0.16	
Inner Solway	Flounder	1[S]	<0.70	<0.32	<0.10	12	<0.46	<0.20	
Inner Solway	Salmon	1[S]	<0.96	<0.26	<0.10	0.33	<0.55	<0.24	
Inner Solway	Sea trout	1[S]	<0.48	<0.15	<0.10	10	<0.30	<0.13	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Isle of Man										
Isle of Man	Cod	4				<0.06		<0.14	<0.12	
Isle of Man	Herring	1				<0.11		<0.24	<0.18	
Isle of Man	Mackerel	3				<0.08		<0.24	<0.24	
Wales										
North Anglesey	Skates/rays	1				<0.04		<0.14	<0.16	
North Anglesey	Lesser spotted dogfish	2				<0.16		<0.45	<0.47	
North Anglesey	Spurdog	1				<0.07		<0.29	<0.39	
North Anglesey	Plaice	2	<25	<25	23	<0.07		<0.15	<0.15	
North Anglesey	Bass	1				<0.13		<0.28	<0.21	
Northern Ireland										
North coast	Skates / rays	4^{N}				<0.14		<0.72	<0.49	
Ardglass	Herring	2^{N}				<0.09		<0.36	<0.46	
Kilkeel	Cod	4^{N}			33	<0.04		<0.17	<0.26	
Kilkeel	Plaice	3^{N}				<0.06		<0.28	<0.50	
Kilkeel	Skates / rays	4^{N}				<0.17		<0.89	<1.9	
Kilkeel	Witch	1^{N}				<0.19		<0.80	<1.2	
Kilkeel	Haddock	4^{N}				<0.07		<0.24	<0.37	
Glenarm	Rainbow trout	1				<0.08		<0.23	<0.22	<0.40
Further afield										
Baltic Sea	Cod	2				<0.08		<0.18	<0.16	
Baltic Sea	Herring	2				<0.10		<0.25	<0.24	
Barents Sea	Cod	2				<0.06		<0.21	<0.23	
Norwegian Sea	Cod	1				<0.05		*	*	
Norwegian Sea	Herring	1				<0.09		<1.7	*	
Norwegian Sea	Mackerel	1				<0.04		<0.76	*	
Norwegian Sea	Saithe	1				<0.06		<0.22	<0.30	
Norwegian processed	Cod	1			19	<0.06		<0.15	<0.13	
Iceland area	Haddock	1				<0.05		<0.57	*	
Skagerrak	Cod	2				<0.06		<0.21	<0.30	
Skagerrak	Herring	2				<0.09		<0.34	<0.43	
Mid North Sea	Cod	2			38	<0.07	0.023	<0.16	<0.14	
Mid North Sea	Plaice	2			28	<0.05	0.052	<0.15	<0.19	
Gt Yarmouth (retail shop)	Cod	2				<0.05		<0.09	<0.07	
Gt Yarmouth (retail shop)	Plaice	2				<0.04		<0.09	<0.07	
Southern North Sea	Cod	2				<0.04	<0.050	<0.09	<0.07	
Southern North Sea	Plaice	1				<0.12	<0.049	<0.37	<0.43	
Southern North Sea	Sole	1				<0.06		<0.10	<0.08	
Southern North Sea	Herring	1				<0.05		<0.14	<0.12	
English Channel-East	Plaice	2				<0.05		<0.18	<0.23	
English Channel-East	Whiting	1				<0.05		<0.15	<0.17	
English Channel-East	Pout whiting	1				<0.06		<0.22	<0.26	
English Channel-West	Mackerel	2				<0.10		<0.32	<0.38	
English Channel-West	Plaice	2			38	<0.04		<0.16	<0.21	
English Channel-West	Whiting	2				<0.08		<0.24	<0.31	
Celtic Sea	Haddock	1				<0.12		<0.43	<0.55	
Celtic Sea	Plaice	1				<0.07		<0.15	<0.11	
Celtic Sea	Whiting	1			14	<0.05	<0.047	<0.07	<0.04	
Celtic Sea	Dab	1				<0.10		<0.34	<0.43	
Northern Irish Sea	Dab	1				<0.14		<0.56	<0.73	
Northern Irish Sea	Lesser spotted dogfish	1				<0.19		<0.57	<0.70	
Northern Irish Sea	Skates / rays	1				<0.14		<0.58	<0.80	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu
Isle of Man								
Isle of Man	Cod	4	<0.52	<0.13	<0.06	1.7	<0.23	<0.11
Isle of Man	Herring	1	<1.1	<0.29	<0.11	0.38	<0.63	<0.30
Isle of Man	Mackerel	3	<0.77	<0.18	<0.08	0.63	<0.31	<0.14
Wales								
North Anglesey	Skates/rays	1	<0.39	<0.09	<0.04	0.69	<0.18	<0.08
North Anglesey	Lesser spotted dogfish	2	<1.6	<0.36	<0.17	1.0	<0.66	<0.28
North Anglesey	Spurdog	1	<0.78	<0.19	<0.08	1.8	<0.41	<0.19
North Anglesey	Plaice	2	<0.59	<0.15	<0.07	0.88	<0.24	<0.11
North Anglesey	Bass	1	<1.3	<0.30	<0.13	4.1	<0.60	<0.29
Northern Ireland								
North coast	Skates / rays	4[N]	<1.4	<0.30	<0.14	2.0	<0.53	<0.20
Ardglass	Herring	2[N]	<0.89	<0.22	<0.09	0.64	<0.47	<0.20
Kilkeel	Cod	4[N]	<0.40	<0.09	<0.04	0.61	<0.20	<0.08
Kilkeel	Plaice	3[N]	<0.59	<0.13	<0.06	0.42	<0.26	<0.11
Kilkeel	Skates / rays	4[N]	<1.8	<0.35	<0.17	1.2	<0.62	<0.23
Kilkeel	Witch	1[N]	<1.9	<0.38	<0.18	0.98	<0.63	<0.24
Kilkeel	Haddock	4[N]	<0.61	<0.14	<0.06	0.52	<0.29	<0.13
Glenarm	Rainbow trout	1	<0.61	<0.13	<0.07	0.14	<0.20	<0.08
Further afield								
Baltic Sea	Cod	2	<0.69	<0.20	<0.07	6.3	<0.35	<0.17
Baltic Sea	Herring	2	<0.91	0.23	<0.10	4.0	<0.42	<0.20
Barents Sea	Cod	2	<0.59	<0.15	<0.07	0.13	<0.31	<0.15
Norwegian Sea	Cod	1	<0.74	<0.12	<0.07	0.22	<0.36	<0.09
Norwegian Sea	Herring	1	<1.0	<0.20	<0.10	<0.08	<0.58	<0.21
Norwegian Sea	Mackerel	1	<0.50	<0.09	<0.05	0.14	<0.25	<0.08
Norwegian Sea	Saithe	1	<0.59	<0.14	<0.07	0.19	<0.25	<0.11
Norwegian processed	Cod	1	<0.56	<0.14	<0.07	0.12	<0.28	<0.15
Iceland area	Haddock	1	<0.57	<0.12	<0.06	0.06	<0.31	<0.12
Skagerrak	Cod	2	<0.48	<0.11	<0.06	0.16	<0.19	<0.08
Skagerrak	Herring	2	<0.89	<0.21	<0.10	<0.22	<0.40	<0.19
Mid North Sea	Cod	2	<0.56	<0.15	<0.07	0.29	<0.29	<0.15
Mid North Sea	Plaice	2	<0.42	<0.09	<0.05	<0.05	<0.16	<0.07
Gt Yarmouth (retail shop)	Cod	2	<0.45	<0.12	<0.05	0.11	<0.23	<0.12
Gt Yarmouth (retail shop)	Plaice	2	<0.39	<0.10	<0.04	<0.04	<0.17	<0.08
Southern North Sea	Cod	2	<0.34	<0.09	<0.04	0.22	<0.16	<0.07
Southern North Sea	Plaice	1	<1.2	<0.25	<0.12	0.13	<0.41	<0.16
Southern North Sea	Sole	1	<0.38	<0.09	<0.05	0.18	<0.12	<0.06
Southern North Sea	Herring	1	<0.53	<0.13	<0.06	0.25	<0.30	<0.14
English Channel-East	Plaice	2	<0.53	<0.11	<0.06	<0.07	<0.23	<0.09
English Channel-East	Whiting	1	<0.36	<0.08	<0.04	0.16	<0.12	<0.05
English Channel-East	Pout whiting	1	<0.59	<0.14	<0.06	0.06	<0.30	<0.15
English Channel-West	Mackerel	2	<0.95	<0.21	<0.10	<0.14	<0.36	<0.16
English Channel-West	Plaice	2	<0.41	<0.10	<0.04	0.07	<0.19	<0.08
English Channel-West	Whiting	2	<0.70	<0.15	<0.07	0.22	<0.26	<0.11
Celtic Sea	Haddock	1	<1.2	<0.24	<0.12	0.24	<0.46	<0.17
Celtic Sea	Plaice	1	<0.59	<0.14	<0.07	<0.07	<0.23	<0.11
Celtic Sea	Whiting	1	<0.31	<0.07	<0.04	0.30	<0.10	<0.05
Celtic Sea	Dab	1	<1.0	<0.21	<0.10	0.31	<0.40	<0.16
Northern Irish Sea	Dab	1	<1.6	<0.35	<0.15	0.96	<0.79	<0.33
Northern Irish Sea	Lesser spotted dogfish	1	<1.8	<0.37	<0.19	1.0	<0.59	<0.25
Northern Irish Sea	Skates / rays	1	<1.6	<0.35	<0.15	1.3	<0.81	<0.32

* *Not detected by the method used*
[a] *The concentrations of ^{129}I and ^{147}Pm were <1.6 and <0.069 Bq kg^{-1} respectively*
[b] *The concentration of ^{108m}Ag was 0.21 Bq kg^{-1}*
[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, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria											
Silloth	Shrimps	4				<0.17		<0.47	<0.53		<1.6
Silloth	Winkles	4		<25		<0.45		<0.40	<0.45		<1.4
Parton	Crabs	4				0.33		<0.15	<0.14		<0.57
Parton	Lobsters	4				<0.12		<0.16	<0.17		<0.61
Parton	Winkles	4				0.70		<0.18	<0.16		<1.3
Whitehaven	*Nephrops*	4			79	<0.09	0.081	<0.34	<0.54	31	<0.83
Whitehaven	Cockles	2				<0.08		<0.20	<0.17		<0.83
Whitehaven	Mussels	2				<0.05	<0.053	<0.13	<0.12		<0.52
Whitehaven outer harbour	Mussels	2				0.50		<0.22	<0.23		<1.1
Saltom Bay	Winkles	4				0.62		<0.22	<0.18		<1.2
St Bees	Winkles[a]	4			93	1.4	2.1	<0.37	<0.43	20	<4.1
St Bees	Mussels	4				0.77		<0.29	<0.34		<4.2
St Bees	Limpets	4				0.52		<0.30	<0.27		<3.8
Nethertown	Winkles	12	<25	48	140	1.6	1.8	<0.22	<0.18	55	7.4
Nethertown	Mussels	4	47	55	200	1.2		<0.32	<0.30	53	7.0
Sellafield coastal area	Crabs[b]	8			130	0.51	0.16	<0.19	<0.22	11	<1.2
Sellafield coastal area	Lobsters	8			180	0.33	0.086	<0.20	<0.22	400	<0.75
Sellafield coastal area[c]	Winkles	8			130	1.4	1.2	<0.24	<0.21	44	<6.1
Sellafield coastal area[c]	Mussels	4				0.59	0.86	<0.23	<0.20		<1.9
Sellafield coastal area[c]	Limpets	4			94	0.46	3.0	<0.22	<0.19	73	<1.8
Whitriggs	Prawns	1				<0.22		<0.90	<1.4		<2.1
Drigg	Winkles	4			150	1.7		<0.24	<0.20	57	6.0
Ravenglass	Crabs	4				0.21	0.13	<0.22	<0.27	3.9	<0.65
Ravenglass	Lobsters	6				<0.15	0.060	<0.22	<0.25	160	<0.64
Ravenglass	Winkles	2				0.85		<0.35	<0.32		<3.1
Ravenglass	Cockles	4			170	2.1	1.1	<0.20	<0.19	5.3	4.1
Ravenglass	Mussels	4		53		0.93		<0.16	<0.15	77	4.1
Tarn Bay	Winkles	4				1.1		<0.21	<0.18		2.9
Haverigg	Winkles	2				0.41		<0.23	<0.20		<0.95
Millom	Mussels	4				0.21		<0.14	<0.12		<1.2
Barrow	Crabs	1				0.08		<0.19	<0.25		<0.48
Barrow	Lobsters	4				<0.08		<0.25	<0.37	140	<0.60
Roosebeck	Pacific oysters	2				<0.04		<0.08	<0.05		<0.36
Morecambe Bay (Flookburgh)	Shrimps	4			93	<0.11		<0.25	<0.24	0.27	<0.91
Morecambe Bay (Flookburgh)	Cockles	4			49	0.19	0.22	<0.31	<0.60	2.4	<0.57
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2				<0.05		<0.10	<0.07		<0.41
Morecambe Bay (Morecambe)	Mussels	4	46	<42	62	<0.08		<0.13	<0.10	16	<0.59
Red Nab Point	Winkles	4				<0.13		<0.16	<0.14		<0.64
Morecambe Bay (Middleton Sands)	Cockles	2				0.26		<0.93	<0.04		<1.2
Knott End	Mussels	2				<0.18		<0.27	<0.24		<1.2
Fleetwood	Whelks	1				<0.07		<0.19	<0.18		<0.61
Ribble Estuary	Shrimps	2			24	<0.07		<0.13	<0.11	0.29	<0.51
Ribble Estuary	Mussels	1				<0.07		<0.16	<0.14		<0.61
Ribble Estuary	Cockles	2				<0.11		<0.24	<0.20		<1.0
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<25							
Dee Estuary	Cockles	4				<0.12		<0.34	<0.34	2.8	<1.2
Wirral	Shrimps	2		<25		<0.04		<0.08	<0.07	0.42	<0.33

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{155}Eu	Gross beta
Cumbria										
Silloth	Shrimps	4	<0.29	<0.37	<0.17	2.8	<0.54		<0.22	
Silloth	Winkles	4	<0.25	<0.44	<0.15	5.6	<0.63		<0.29	
Parton	Crabs	4	<0.11	<0.24	<0.06	1.4	<0.24		<0.11	
Parton	Lobsters	4	<0.13	<0.18	<0.07	1.4	<0.24		<0.11	
Parton	Winkles	4	<0.15	0.63	<0.08	6.2	<0.28		<0.14	
Whitehaven	*Nephrops*	4	<0.17	<0.21	<0.09	3.0	<0.38		<0.16	180
Whitehaven	Cockles	2	<0.14	<0.19	<0.09	<0.10	<0.38		<0.17	
Whitehaven	Mussels	2	<0.10	<0.13	<0.06	<0.05	<0.24		<0.12	
Whitehaven outer harbour	Mussels	2	<0.14	0.86	<0.08	1.5	<0.32		<0.15	
Saltom Bay	Winkles	4	<0.20	<0.70	<0.10	3.8	<0.48		<0.26	
St Bees	Winkles[a]	4	<0.24	1.3	<0.13	6.0	<0.54	0.39	<0.23	
St Bees	Mussels	4	<0.18	1.2	<0.10	2.5	<0.48		<0.21	
St Bees	Limpets	4	<0.22	2.0	<0.12	4.8	<0.57		<0.29	
Nethertown	Winkles	12	<0.23	1.4	<0.11	5.8	<0.44	0.60	<0.22	280
Nethertown	Mussels	4	<0.23	2.1	<0.13	2.5	<0.69		<0.32	200
Sellafield coastal area	Crabs[b]	8	<0.13	<0.27	<0.07	1.5	<0.30	0.084	<0.13	150
Sellafield coastal area	Lobsters	8	<0.21	<0.27	<0.07	2.5	<0.29	0.12	<0.13	480
Sellafield coastal area[c]	Winkles	8	<0.25	1.3	<0.12	4.4	<0.49	0.32	<0.24	
Sellafield coastal area[c]	Mussels	4	<0.16	1.1	<0.11	2.9	<0.43		<0.22	
Sellafield coastal area[c]	Limpets	4	<0.19	1.8	<0.11	2.7	<0.48		<0.24	
Whitriggs	Prawns	1	<0.39	<0.44	<0.21	2.3	<0.71		<0.28	
Drigg	Winkles	4	<0.24	1.6	<0.10	3.7	<0.43	0.40	<0.22	270
Ravenglass	Crabs	4	<0.13	<0.17	<0.07	1.1	<0.28		<0.12	130
Ravenglass	Lobsters	6	<0.14	<0.17	<0.07	1.6	<0.27		<0.12	300
Ravenglass	Winkles	2	<0.27	1.2	<0.15	5.7	<0.71		<0.37	
Ravenglass	Cockles	4	<0.15	0.55	<0.09	3.5	<0.32		<0.15	150
Ravenglass	Mussels	4	<0.12	1.2	<0.07	1.4	<0.25		<0.11	
Tarn Bay	Winkles	4	<0.20	0.79	<0.10	3.3	<0.37		<0.18	
Haverigg	Winkles	2	<0.17	0.59	<0.10	3.2	<0.44		<0.21	
Millom	Mussels	4	<0.10	<0.29	<0.06	1.2	<0.26		<0.13	
Barrow	Crabs	1	<0.09	<0.12	<0.05	0.78	<0.21		<0.08	
Barrow	Lobsters	4	<0.13	<0.15	<0.06	1.4	<0.27		<0.12	220
Roosebeck	Pacific oysters	2	<0.07	<0.10	<0.04	1.1	<0.17		<0.09	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.19	<0.25	<0.10	3.8	<0.43		<0.21	
Morecambe Bay (Flookburgh)	Cockles	4	<0.12	<0.16	<0.06	2.8	<0.24		<0.10	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Shrimps	2	<0.08	<0.11	<0.05	3.4	<0.17		<0.08	
Morecambe Bay (Morecambe)	Mussels	4	<0.09	<0.22	<0.06	2.0	<0.26		<0.14	
Red Nab Point	Winkles	4	<0.12	<0.30	<0.08	4.8	<0.28		<0.14	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.22	<0.28	<0.12	2.3	<0.47		<0.18	
Knott End	Mussels	2	<0.20	<0.39	<0.12	1.8	<0.41		<0.17	
Fleetwood	Whelks	1	<0.13	<0.15	<0.07	0.23	<0.31		<0.16	
Ribble Estuary	Shrimps	2	<0.12	<0.13	<0.06	3.2	<0.17		<0.08	
Ribble Estuary	Mussels	1	<0.12	<0.17	<0.07	0.93	<0.31		<0.16	
Ribble Estuary	Cockles	2	<0.17	<0.25	<0.11	1.8	<0.42		<0.20	
Liverpool Bay	Mussels	2								
Mersey Estuary	Mussels	2								
Dee Estuary	Cockles	4	<0.21	<0.28	<0.13	1.5	<0.48		<0.21	
Wirral	Shrimps	2	<0.07	<0.08	<0.04	1.1	<0.11		<0.05	

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland										
Lewis	Mussels	1[S]			<0.10		<0.33	<0.34		<0.93
Skye	Lobsters	1[S]			<0.10		<0.17	<0.14	17	<0.60
Skye	Mussels	1[S]			<0.10		<0.16	<0.26		<0.31
Islay	Crabs	1[S]			<0.10		<0.27	<0.17		<0.82
Islay	Scallops	1[S]			<0.10		<0.10	<0.10		<0.17
Kirkcudbright	Scallops	3[S]			<0.10		<0.22	<0.20	0.57	<0.64
Kirkcudbright	Queens	4[S]			<0.10		<0.21	<0.23	0.59	<0.65
Kirkcudbright	Limpets	1[S]			<0.10		<0.46	<0.68		<0.94
Southerness	Winkles	4[S]	<5.0		<0.32	0.29	<0.20	<0.19	48	<0.67
North Solway coast	Crabs	4[S]		75	<0.13	<0.10	<0.21	<0.21	4.2	<0.64
North Solway coast	Lobsters	4[S]		99	<0.10	<0.10	<0.21	<0.20	69	<0.67
North Solway coast	Winkles	4[S]			<0.13	0.18	<0.26	<0.26	32	<0.81
North Solway coast	Cockles	1[S]			0.34		<0.26	<0.26		<0.77
North Solway coast	Mussels	4[S]	<4.9	56	<0.12	0.42	<0.19	<0.17	13	<0.59
Inner Solway	Shrimps	2[S]	<5.5		<0.10	<0.10	<0.20	<0.19	0.70	<0.55
Isle of Man										
Isle of Man	Lobsters	4			<0.06		<0.24	<0.49	18	<0.56
Isle of Man	Scallops	4			<0.07		<0.16	<0.14		<0.63
Wales										
Conwy	Mussels	2		49	<0.04		<0.13	<0.16		<0.34
North Anglesey	Crabs	2			<0.05		<0.26	<0.40	0.66	<0.56
North Anglesey	Lobsters	2			<0.04		<0.18	<0.16	26	<0.44
Northern Ireland										
Ballycastle	Lobsters	1[N]			<0.12		<0.51	<0.71	23	<1.3
County Down	Scallops	2[N]			<0.05		<0.14	<0.14		<0.44
Kilkeel	Crabs	2[N]			<0.05		<0.24	<0.44		<0.49
Kilkeel	Lobsters	2[N]			<0.05		<0.17	<0.21	21	<0.44
Kilkeel	*Nephrops*	4[N]			<0.11		<0.49	<0.85	6.4	<1.1
Minerstown	Winkles	3[N]			<0.09		<0.26	<0.30		<0.89
Minerstown	Toothed winkles	1[N]			<0.06		<0.24	<0.28		<0.63
Carlingford Lough	Mussels	1[N]			<0.11		*	*	8.0	<1.8
Further afield										
Cromer	Crabs	1			<0.05		<0.14	<0.14		<0.48
Southern North Sea	Cockles	1			<0.03		<0.06	<0.05		<0.24
Southern North Sea	Mussels	2			<0.09		<0.33	<0.44	1.2	<0.91
Southern North Sea	Cockles[d]	1			<0.05		<0.08	<0.05	<0.22	<0.48
Southern North Sea	Mussels[d]	1			<0.04		<0.06	<0.03		<0.32
English Channel-East	Queens	1		35	<0.10		<0.43	<0.56		<1.1
English Channel-East	Scallops	1			<0.06		<0.13	<0.11		<0.46
English Channel-West	Crabs	2		46	<0.05		<0.32	<0.58		<0.56
English Channel-West	Lobsters	2			<0.05		<0.22	<0.33	0.45	<0.51
English Channel-West	Scallops	2		35	<0.07		<0.19	<0.20		<0.64
Northern Irish Sea	Crabs	1			<0.21		<0.74	<0.91		<1.9
Northern Irish Sea	Octopuses	1			<0.04		<0.09	<0.09		<0.27

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	Gross beta
Scotland									
Lewis	Mussels	1[S]	<0.11	<0.27	<0.10	<0.10	<0.61	<0.24	
Skye	Lobsters	1[S]	<0.10	<0.18	<0.10	<0.10	<0.39	<0.16	
Skye	Mussels	1[S]	<0.10	<0.10	<0.10	<0.10	<0.19	<0.10	
Islay	Crabs	1[S]	<0.10	<0.22	<0.10	<0.10	<0.44	<0.19	
Islay	Scallops	1[S]	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Kirkcudbright	Scallops	3[S]	<0.10	<0.17	<0.10	<0.10	<0.37	<0.15	
Kirkcudbright	Queens	4[S]	<0.10	<0.19	<0.10	<0.14	<0.39	<0.17	
Kirkcudbright	Limpets	1[S]	<0.15	0.44	<0.10	4.3	<0.65	<0.24	
Southerness	Winkles	4[S]	<0.12	<0.29	<0.10	1.3	<0.42	<0.18	
North Solway coast	Crabs	4[S]	<0.11	<0.18	<0.10	0.83	<0.37	<0.16	
North Solway coast	Lobsters	4[S]	<0.11	<0.20	<0.10	1.5	<0.43	<0.18	
North Solway coast	Winkles	4[S]	<0.14	<0.28	<0.12	0.95	<0.46	<0.20	
North Solway coast	Cockles	1[S]	<0.15	<0.17	<0.10	2.3	<0.52	<0.22	
North Solway coast	Mussels	4[S]	<0.11	<0.19	<0.10	2.1	<0.36	<0.16	
Inner Solway	Shrimps	2[S]	<0.10	<0.17	<0.10	2.9	<0.34	<0.14	
Isle of Man									
Isle of Man	Lobsters	4	<0.12	<0.13	<0.06	0.24	<0.25	<0.12	140
Isle of Man	Scallops	4	<0.12	<0.16	<0.07	0.27	<0.29	<0.14	
Wales									
Conwy	Mussels	2	<0.07	<0.08	<0.04	0.26	<0.16	<0.07	
North Anglesey	Crabs	2	<0.11	<0.13	<0.06	0.28	<0.31	<0.12	
North Anglesey	Lobsters	2	<0.09	<0.11	<0.05	0.42	<0.24	<0.10	130
Northern Ireland									
Ballycastle	Lobsters	1[N]	<0.23	<0.28	<0.13	0.15	<0.47	<0.17	
County Down	Scallops	2[N]	<0.09	<0.11	<0.05	0.29	<0.23	<0.10	
Kilkeel	Crabs	2[N]	<0.10	<0.11	<0.05	0.18	<0.21	<0.08	
Kilkeel	Lobsters	2[N]	<0.09	<0.10	<0.05	0.15	<0.19	<0.08	
Kilkeel	*Nephrops*	4[N]	<0.21	<0.23	<0.11	0.55	<0.43	<0.17	
Minerstown	Winkles	3[N]	<0.16	<0.22	<0.09	0.17	<0.43	<0.20	
Minerstown	Toothed winkles	1[N]	<0.13	<0.18	<0.06	0.58	<0.35	<0.16	
Carlingford Lough	Mussels	1[N]	<0.37	<0.31	<0.14	0.42	<1.0	<0.26	
Further afield									
Cromer	Crabs	1	<0.09	<0.12	<0.05	<0.05	<0.23	<0.10	
Southern North Sea	Cockles	1	<0.05	<0.06	<0.03	0.08	<0.08	<0.04	
Southern North Sea	Mussels	2	<0.16	<0.19	<0.09	<0.09	<0.33	<0.14	
Southern North Sea	Cockles[d]	1	<0.08	<0.13	<0.05	0.07	<0.25	<0.14	
Southern North Sea	Mussels[d]	1	<0.07	<0.08	<0.04	<0.04	<0.11	<0.05	21
English Channel-East	Queens	1	<0.19	<0.25	<0.10	<0.09	<0.55	<0.23	
English Channel-East	Scallops	1	<0.10	<0.12	<0.06	<0.05	<0.25	<0.13	
English Channel-West	Crabs	2	<0.12	<0.12	<0.06	<0.05	<0.25	<0.09	
English Channel-West	Lobsters	2	<0.11	<0.12	<0.06	<0.05	<0.22	<0.09	
English Channel-West	Scallops	2	<0.13	<0.16	<0.07	<0.06	<0.32	<0.17	
Northern Irish Sea	Crabs	1	<0.33	<0.39	<0.19	1.0	<0.62	<0.26	
Northern Irish Sea	Octopuses	1	<0.06	<0.06	<0.03	0.34	<0.09	<0.04	

* *Not detected by the method used*
[a] *The concentration of ^{129}I was <2.0 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <1.6 Bq kg^{-1}*
[c] *Samples collected by Consumer 971*
[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, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cumbria									
Silloth	Shrimps	1		0.0036	0.022	<1.0	0.041	*	0.000068
Silloth	Winkles	1		1.0	5.7		11	*	0.014
Maryport	Plaice	4					<0.11		
Parton	Cod	4					<0.20		
Parton	Crabs	4					1.2		
Parton	Lobsters	4					4.4		
Parton	Winkles	1		1.4	7.6	50	15	*	0.015
Whitehaven	Cod	1		0.00050	0.0028		0.0077	0.000045	*
Whitehaven	Plaice	1		0.0013	0.0075		0.027	*	*
Whitehaven	Skates / rays	1		0.00013	0.00062		0.0014	*	*
Whitehaven	Sole	1		0.00017	0.00099		0.0015	*	*
Whitehaven	*Nephrops*	1		0.049	0.32		1.3	*	*
Whitehaven	Cockles	1		0.0045	0.031		0.029	0.000083	0.000078
Whitehaven	Mussels	1		0.00013	0.0015	<0.77	0.0040	0.000023	0.000016
Whitehaven outer harbour	Mussels	2					8.3		
Saltom Bay	Winkles	4					12		
St Bees	Winkles	1	0.017	1.7	9.5	120	19	*	0.017
St Bees	Mussels	2		1.0	5.3	39	12	*	0.019
St Bees	Limpets	1		1.5	8.4		17	*	0.011
Nethertown	Winkles	4	0.033	2.3	12	120	24	*	<0.030
Nethertown	Mussels	4		1.1	5.7		14	*	0.025
River Ehen	Salmon	1					<0.13		
Sellafield coastal area	Cod	2		0.00081	0.0046		0.0068	<0.00013	*
Sellafield coastal area	Plaice	1		0.0019	0.0099		0.021	*	0.000030
Sellafield coastal area	Bass	1					<0.37		
Sellafield coastal area	Grey mullet	1					<0.40		
Sellafield coastal area	Crabs	2	0.0018	0.068	0.35	2.1	1.6	<0.00095	0.0043
Sellafield coastal area	Lobsters	2	0.0097	0.055	0.24	2.0	3.1	*	0.0057
Sellafield coastal area[a]	Winkles	2	0.012	1.4	7.0	46	14	*	0.021
Sellafield coastal area[a]	Mussels	1		1.1	5.7	39	12	0.016	0.011
Sellafield coastal area[a]	Limpets	1		1.4	7.0	49	15	0.027	0.015
Sellafield offshore area	Cod	1		0.00061	0.0033		0.015	*	*
Sellafield offshore area	Plaice	1	0.00017	0.0041	0.023		0.061	0.000078	0.000074
Sellafield offshore area	Lesser spotted dogfish	2					<0.20		
Sellafield offshore area	Red gurnard	1					<0.41		
River Esk	Salmon	1					<0.26		
River Esk	Sea trout	1					<0.16		
River Calder	Brown trout	1					<0.31		
River Calder	Sea trout	1					<0.20		
Whitriggs	Prawns	1					<0.15		
Drigg	Winkles	1	0.015	1.6	8.4	56	16	*	0.019
Ravenglass	Cod	1		0.00044	0.0023		0.0044	*	*
Ravenglass	Plaice	1		0.0030	0.016		0.032	*	*
Ravenglass	Crabs	1		0.039	0.20	1.2	1.0	*	0.0015
Ravenglass	Lobsters	1		0.036	0.17	1.3	3.5	*	0.0016
Ravenglass	Winkles	2					19		
Ravenglass	Cockles	1		1.4	7.4	50	23	*	0.014
Ravenglass	Mussels	1		0.95	4.5	35	11	*	0.020
Tarn Bay	Winkles	1		0.80	4.3	28	9.1	0.030	0.011
Haverigg	Winkles	2					7.7		
Millom	Mussels	1		0.25	1.4		3.4	*	0.0058
Barrow	Crabs	1		0.025	0.14		0.65	0.00037	0.00074
Barrow	Lobsters	4					1.1		
Roosebeck	Pacific oysters	1		0.067	0.40		0.38	*	*
Morecambe Bay (Flookburgh)	Flounder	1		0.00029	0.0020		0.0038	0.00015	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0064	0.041	<0.75	0.072	0.00017	*
Morecambe Bay (Flookburgh)	Cockles	1		0.25	1.5	17	4.7	*	0.0050

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4					<0.17		
Morecambe Bay (Morecambe)	Bass	2					<0.14		
Morecambe Bay (Morecambe)	Flounder	4					<0.12		
Morecambe Bay (Morecambe)	Shrimps	2					<0.05		
Morecambe Bay (Morecambe)	Mussels	1		0.22	1.3		2.6	0.011	*
Red Nab Point	Winkles	1		0.38	2.2		4.1	*	0.0057
Morecambe Bay (Middleton Sands)	Cockles	1		0.25	1.6		4.5	*	0.0035
Morecambe Bay (Sunderland Point)	Whitebait	1		0.029	0.16	1.1	0.27	*	0.00015
Knott End	Mussels	1		0.23	1.4		2.6	0.0077	0.0022
Fleetwood	Plaice	1		0.00014	0.00079		0.0015	*	*
Fleetwood	Cod	1					<0.03		
Fleetwood	Whiting	1		0.00021	0.0014		0.0043	*	*
Fleetwood	Dab	1					<0.30		
Fleetwood	Whelks	1					<0.20		
Ribble Estuary	Grey mullet	2					<0.15		
Ribble Estuary	Sole	1					<0.18		
Ribble Estuary	Bass	2					<0.22		
Ribble Estuary	Salmon	1					<0.49		
Ribble Estuary	Shrimps	1	0.00022	0.0025	0.013		0.027	*	*
Ribble Estuary	Mussels	1					0.70		
Ribble Estuary	Cockles	1		0.16	1.0		2.9	*	*
Wirral	Shrimps	2					<0.03		
Dee Estuary	Cockles	1		0.13	0.79		2.1	*	*
Scotland									
Shetland	Fish meal	1[S]		0.0061	0.015		0.029		
Shetland	Fish oil (Herring)	1[S]		<0.0086	0.015		0.038		
Shetland	Fish oil (Salmon)	1[S]		<0.0097	<0.0097		<0.060		
West of Scotland	Mackerel	1[S]		<0.0075	0.031		0.068		
Lewis	Mussels	1[S]					<0.13		
Skye	Lobsters	1[S]					<0.11		
Skye	Mussels	1[S]					<0.10		
Islay	Crabs	1[S]					<0.12		
Islay	Scallops	1[S]					<0.10		
Kirkcudbright	Plaice	1[S]		<0.00043	0.00047		0.0031		
Kirkcudbright	Scallops	1[S]		0.0065	0.040		0.017		
Kirkcudbright	Queens	1[S]		0.0022	0.015		0.0093		
Kirkcudbright	Limpets	1[S]					9.4		
Southerness	Winkles	1[S]		0.99	5.1	24	4.1		
North Solway coast	Crabs	1[S]		0.020	0.12	<0.85	0.64		
North Solway coast	Lobsters	1[S]		0.025	0.15	<0.53	0.90		
North Solway coast	Winkles	1[S]		0.30	1.9		3.3		
North Solway coast	Cockles	1[S]		0.47	2.7		10		
North Solway coast	Mussels	1[S]		0.55	3.1	16	6.5		
Inner Solway	Flounder	1[S]		0.019	0.035		0.074		
Inner Solway	Salmon	1[S]					<0.16		
Inner Solway	Sea trout	1[S]					0.13		
Inner Solway	Shrimps	1[S]		0.0053	0.022		0.045		
Isle of Man									
Isle of Man	Cod	1		0.00021	0.0011		0.0021	*	0.000012
Isle of Man	Herring	1		0.00012	0.00075		0.0011	*	*
Isle of Man	Mackerel	3					<0.08		
Isle of Man	Lobsters	4					<0.12		
Isle of Man	Scallops	1		0.024	0.15		0.041	*	*

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Wales							
Conwy	Mussels	1	0.027	0.16	0.26	*	0.00021
North Anglesey	Skates/rays	1			<0.04		
North Anglesey	Lesser spotted dogfish	2			<0.21		
North Anglesey	Spurdog	1	0.00014	0.00073	0.0022	*	*
North Anglesey	Plaice	2			<0.07		
North Anglesey	Bass	1			<0.27		
North Anglesey	Crabs	1	0.0016	0.011	0.049	*	0.000063
North Anglesey	Lobsters	2			<0.12		
Northern Ireland							
North coast	Skates / rays	4[N]			<0.10		
Ballycastle	Lobsters	1[N]			0.29		
County Down	Scallops	2[N]			<0.11		
Ardglass	Herring	2[N]			<0.14		
Kilkeel	Cod	4[N]			<0.06		
Kilkeel	Plaice	3[N]			<0.07		
Kilkeel	Skates / rays	4[N]			<0.12		
Kilkeel	Witch	1[N]			<0.13		
Kilkeel	Haddock	4[N]			<0.13		
Kilkeel	Crabs	2[N]			0.15		
Kilkeel	Lobsters	2[N]			<0.05		
Kilkeel	*Nephrops*	1[N]	0.0022	0.013	0.034	0.000046	0.000052
Minerstown	Winkles	1[N]	0.035	0.21	0.15	*	0.00017
Minerstown	Toothed winkles	1[N]			0.29		
Carlingford Lough	Mussels	1[N]			<0.22		
Glenarm	Rainbow trout	1			<0.05		
Further afield		2					
Baltic Sea	Cod	2			<0.17		
Baltic Sea	Herring	2			<0.16		
Barents Sea	Cod	2			<0.18		
Norwegian Sea	Cod	1			<0.05		
Norwegian Sea	Herring	1			<0.22		
Norwegian Sea	Mackerel	1			<0.04		
Norwegian Sea	Saithe	1			<0.07		
Norwegian processed	Cod	1	<0.000034	0.000051	0.000053	*	*
Iceland area	Haddock	1			<0.14		
Skagerrak	Cod	2			<0.05		
Skagerrak	Herring	2			<0.16		
Mid North Sea	Cod	2			<0.18		
Mid North Sea	Plaice	2			<0.04		
Cromer	Crabs	1			<0.05		
Gt Yarmouth (retail shop)	Cod	2			<0.14		
Gt Yarmouth (retail shop)	Plaice	2			<0.04		
Southern North Sea	Cod	2			<0.05		
Southern North Sea	Plaice	1			<0.08		
Southern North Sea	Sole	1			<0.03		
Southern North Sea	Herring	1			<0.14		
Southern North Sea	Cockles	1	0.0018	0.012	0.0086	*	*
Southern North Sea	Mussels	1	0.0023	0.014	0.0093	0.00016	*
Southern North Sea	Cockles[b]	1	0.00064	0.0049	0.0049	*	0.00014
Southern North Sea	Mussels[b]	1	0.00014	0.0012	0.00065	*	0.000010
English Channel-East	Plaice	2			<0.05		
English Channel-East	Whiting	1			<0.03		
English Channel-East	Pout whiting	1			<0.17		
English Channel-East	Queens	1			<0.20		
English Channel-East	Scallops	1	0.00034	0.0018	0.00056	0.000051	0.000049

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
English Channel-West	Mackerel	2			<0.09		
English Channel-West	Plaice	2			<0.04		
English Channel-West	Whiting	2			<0.06		
English Channel-West	Crabs	1	0.000036	0.00063	0.00079	0.000068	0.000044
English Channel-West	Lobsters	2			<0.05		
English Channel-West	Scallops	1	0.00054	0.0043	0.0036	*	0.000027
Celtic Sea	Haddock	1			<0.09		
Celtic Sea	Plaice	1			<0.06		
Celtic Sea	Whiting	1			<0.03		
Celtic Sea	Dab	1			<0.08		
Northern Irish Sea	Dab	1			<0.29		
Northern Irish Sea	Lesser spotted dogfish	1			<0.13		
Northern Irish Sea	Skates / rays	1			<0.30		
Northern Irish Sea	Crabs	1			0.87		
Northern Irish Sea	Octopuses	1			0.03		

* *Not detected by the method used*
[a] *Samples collected by consumer 971*
[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, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria											
Newton Arlosh	Sediment	4	<1.1		<2.1	<0.65	<6.8	<3.7	<0.83	210	<3.6
Maryport Outer Harbour	Sediment	2	1.2	<26	<1.2	<0.29	<2.8	<1.4	<0.33	68	<1.6
Workington Harbour	Sediment	2	<0.45		<1.3	<0.42	<3.0	<1.6	<0.40	43	<2.0
Harrington Harbour	Sediment	2	<0.51		<1.2	<0.31	<2.8	<1.4	<0.31	140	<2.0
Whitehaven Outer Harbour	Sediment	4	<1.2	<3.9	<0.92	<0.28	<2.7	<1.5	<0.31	100	<1.7
St Bees beach	Sediment	4	<1.3		<1.4	<0.32	<3.5	<1.9	<0.40	60	<1.9
Sellafield beach, S of former pipeline	Sediment	2	<1.1		<1.4	<0.43	<4.5	<2.5	<0.52	42	<2.3
River Calder - downstream	Sediment	2	<0.74		<1.8	<0.49	<5.0	<2.8	<0.60	54	<2.6
River Calder - upstream	Sediment	2	<0.89		<1.9	<0.61	<5.5	<2.9	<0.75	50	<3.1
Seascale beach	Sediment	4	<0.93		<1.0	<0.35	<3.1	<1.7	<0.39	31	<1.8
Ravenglass - Carleton Marsh	Sediment	4	6.0		<2.1	<0.71	<27	<4.7	<0.91	360	<4.1
River Mite Estuary (erosional)	Sediment	4	<3.1	51	<2.0	<0.59	<11	<3.6	<0.72	370	<3.6
Ravenglass - Raven Villa	Sediment	4	2.1		<1.5	<0.47	<5.6	<3.0	<0.55	180	<2.8
Newbiggin (Eskmeals)	Sediment	4	6.9	68	<2.2	<0.68	<12	<5.2	<0.79	350	<3.4
Haverigg	Sediment	2	<1.6		<1.7	<0.54	<5.3	<2.9	<0.64	65	<2.8
Millom	Sediment	2	<1.1		<1.8	<0.59	<5.5	<3.0	<0.67	87	<2.8
Low Shaw	Sediment	2	<0.67		<1.5	<0.49	<4.6	<2.5	<0.56	60	<2.3
Walney Channel - N of discharge point	Sediment	2	<1.0		<1.9	<0.62	<5.7	<3.0	<0.72	92	<2.9
Walney Channel - S of discharge point	Sediment	2	<0.77		<1.6	<0.53	<4.9	<2.7	<0.63	50	<2.5
Sand Gate Marsh	Sediment	4	<0.45		<1.0	<0.32	<3.0	<1.6	<0.37	66	<1.7
Kents Bank	Sediment	4	<0.63		<1.5	<0.44	<4.8	<2.6	<0.56	160	<2.8
Lancashire											
Morecambe	Sediment	2	<0.30							3.5	
Half Moon Bay	Sediment	2	<0.43							56	
Red Nab Point	Sediment	2	<0.36							39	
Potts Corner	Sediment	2	<0.30							17	
Sunderland Point	Sediment	4	<0.73		<2.4	<0.56	<5.4	<2.8	<0.69	55	<3.2
Conder Green	Sediment	4	<0.75		<2.4	<0.58	<5.5	<2.9	<0.72	70	<3.2
Hambleton	Sediment	4	<1.0		<2.7	<0.65	<7.0	<3.6	<0.82	250	<4.0
Skippool Creek	Sediment	4	<1.1		<3.6	<0.77	<9.1	<4.4	<1.0	230	<4.9
Fleetwood	Sediment	4	<0.57		<2.0	<0.45	<4.3	<2.2	<0.56	11	<2.5
Blackpool	Sediment	4	<0.49		<1.8	<0.37	<3.8	<2.0	<0.47	2.7	<2.1
Crossens Marsh	Sediment	4	<1.5		<6.0	<1.1	<12	<6.1	<1.4	220	<5.9
Ainsdale	Sediment	4	<0.50		<2.0	<0.39	<4.1	<2.1	<0.49	4.4	<2.2
Rock Ferry	Sediment	4	<1.1		<4.6	<0.76	<8.2	<4.2	<0.99	120	<4.4
New Brighton	Sediment	4	<0.71		<3.1	<0.51	<5.5	<2.8	<0.64	3.9	<2.8
Scotland											
Campbeltown	Sediment	1[S]	<0.10		<0.15	<0.15	<0.55	<0.18	<0.10	6.5	<0.59
Garlieston	Sediment	1[S]	0.26		<0.11	<0.18	<0.61	0.36	<0.10	29	<0.41
Innerwell	Sediment	1[S]	1.3		<0.23	<0.31	1.4	1.5	<0.13	120	<1.1
Carsluith	Sediment	1[S]	1.2		<0.15	<0.17	0.91	1.1	<0.12	120	<0.86
Skyreburn	Sediment	1[S]	<0.10		<0.21	<0.25	<0.81	<0.25	<0.11	26	<0.72
Kirkcudbright	Sediment	1[S]	0.80		<0.31	<0.17	<1.0	1.0	<0.14	65	<1.1
Rascarrel Bay	Sediment	1[S]	0.17		<0.20	<0.30	<0.83	<0.30	<0.13	38	<0.82
Palnackie Harbour	Sediment	1[S]	0.93		<0.28	<0.29	<0.74	1.2	<0.13	120	<0.91
Gardenburn	Sediment	1[S]	1.0		0.22	<0.27	1.6	1.1	<0.11	120	<0.89
Kippford Slipway	Sediment	1[S]	1.8		<0.22	<0.28	3.2	2.0	<0.12	190	<0.94
Kippford Merse	Sediment	1[S]	1.8		<0.20	<0.16	2.9	2.1	<0.12	180	<0.92
Southerness	Sediment	1[S]	0.14		<0.12	<0.17	<0.57	0.27	<0.10	16	<0.53
Kirkconnel Merse	Sediment	1[S]	0.36		<0.29	<0.30	<1.2	0.56	<0.13	210	<1.1

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Cumbria										
Newton Arlosh	Sediment	4	<2.3	<1.6				250	530	880
Maryport Outer Harbour	Sediment	2	<0.97	<0.66	16	88	650	160	420	740
Workington Harbour	Sediment	2	<1.1	<0.82				23	530	830
Harrington Harbour	Sediment	2	<0.84	<0.78				61	470	870
Whitehaven Outer Harbour	Sediment	4	<1.0	<0.71	22	120	700	240	510	650
St Bees beach	Sediment	4	<1.1	<0.81				160	320	390
Sellafield beach, S of former pipeline	Sediment	2	<1.7	<1.0				150	220	410
River Calder - downstream	Sediment	2	<1.9	<1.2				52	<160	510
River Calder - upstream	Sediment	2	<2.1	<1.4					330	1300
Seascale beach	Sediment	4	<1.2	<0.79				140	250	450
Ravenglass - Carleton Marsh	Sediment	4	4.1	<1.9				1300	2100	1400
River Mite Estuary (erosional)	Sediment	4	3.9	<1.6	100	600	3800	1300	1800	1400
Ravenglass - Raven Villa	Sediment	4	<2.1	<1.3				610	1100	920
Newbiggin (Eskmeals)	Sediment	4	4.3	<2.9	110	600	4200	1300	1700	1200
Haverigg	Sediment	2	<1.8	<1.2				250	520	630
Millom	Sediment	2	<2.0	<1.2				210	570	740
Low Shaw	Sediment	2	<1.7	<1.1				100	170	500
Walney Channel - N of discharge point	Sediment	2	<1.9	<1.3				190	500	770
Walney Channel - S of discharge point	Sediment	2	<1.7	<1.1				96	220	590
Sand Gate Marsh	Sediment	4	<1.1	<0.75				55	<210	510
Kents Bank	Sediment	4	<1.6	<1.2				120	270	700
Lancashire										
Morecambe	Sediment	2						1.7		
Half Moon Bay	Sediment	2			1.2	8.1		68		
Red Nab Point	Sediment	2						46		
Potts Corner	Sediment	2						12		
Sunderland Point	Sediment	4	<1.7	<1.3				61	230	730
Conder Green	Sediment	4	<1.8	<1.3				76	360	630
Hambleton	Sediment	4	<2.0	<1.7				240	550	1200
Skippool Creek	Sediment	4	<2.7	<2.1				220	530	980
Fleetwood	Sediment	4	<1.4	<1.1				14	<120	420
Blackpool	Sediment	4	<1.3	<0.91				3.7	<98	240
Crossens Marsh	Sediment	4	<3.6	<2.4				190	490	1200
Ainsdale	Sediment	4	<1.3	<0.92				3.4	<95	250
Rock Ferry	Sediment	4	<2.5	<1.8				79	290	880
New Brighton	Sediment	4	<1.7	<1.2				3.7	<100	270
Scotland										
Campbeltown	Sediment	1^{S}	<0.15	0.81				0.95		
Garlieston	Sediment	1^{S}	<0.10	0.43	4.0	24		39		
Innerwell	Sediment	1^{S}	0.54	1.3				180		
Carsluith	Sediment	1^{S}	0.79	1.1	34	200		340	75	230
Skyreburn	Sediment	1^{S}	<0.17	0.62				12		
Kirkcudbright	Sediment	1^{S}	<0.17	1.8	9.2	50		100		
Rascarrel Bay	Sediment	1^{S}	<0.22	<0.49	1.2	5.3		13		
Palnackie Harbour	Sediment	1^{S}	<0.22	<0.45	18	110		180		
Gardenburn	Sediment	1^{S}	0.51	1.1	15	89		180		
Kippford Slipway	Sediment	1^{S}	1.0	0.98	25	150		280		
Kippford Merse	Sediment	1^{S}	0.94	1.2	32	170		310		
Southerness	Sediment	1^{S}	<0.13	0.29	2.6	17		27		
Kirkconnel Merse	Sediment	1^{S}	0.33	1.1	12	75		120	210	720

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man										
Ramsey	Sediment	1	<0.34	<0.84	<0.28	<2.1	<1.1	<0.32	6.6	<1.4
Wales										
Rhyl	Sediment	2	<1.3	<4.8	<0.95	<10	<4.9	<1.2	69	<5.0
Llandudno	Sediment	2	<0.48	<1.4	<0.39	<3.7	<2.0	<0.45	2.7	<2.3
Caerhun	Sediment	2	<0.94	<2.6	<0.71	<7.0	<3.5	<0.83	50	<3.2
Llanfairfechan	Sediment	2	<0.66	<1.9	<0.50	<4.6	<2.4	<0.58	16	<2.4
Northern Ireland										
Carrichue	Mud	1^{N}	<0.54	<2.4	<3.1	<5.6	<1.3	<0.70	2.3	<2.9
Carrichue	Mud, sand and stones	1^{N}	<0.33	<1.6	<1.8	<3.9	<0.99	<0.46	1.0	<3.1
Portrush	Sand	2^{N}	<0.37	<2.2	<3.7	<4.1	<1.0	<0.46	0.60	<2.7
Oldmill Bay	Mud	2^{N}	<0.67	<2.6	<3.1	<6.4	<1.7	<0.86	30	<3.6
Ballymacormick	Mud	2^{N}	<0.43	<3.1	<5.5	<5.1	<1.3	<0.60	15	<3.4
Strangford Lough - Nicky's Point	Mud	2^{N}	<0.45	<2.9	<5.2	<5.2	<1.3	<0.63	21	<4.0
Dundrum Bay	Mud	2^{N}	<0.54	<3.7	<2.1	<6.7	<1.7	<0.82	25	<4.8
Carlingford Lough	Mud	2^{N}	<0.68	<4.1	<7.4	<7.9	<2.3	<1.0	53	<5.3

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Isle of Man											
Ramsey	Sediment	1	<0.80	<0.60			1.6			<100	460
Wales											
Rhyl	Sediment	2	<3.0	<2.1			41			440	870
Llandudno	Sediment	2	<1.2	<1.0			<1.3			120	340
Caerhun	Sediment	2	<2.4	<1.4			17			250	650
Llanfairfechan	Sediment	2	<1.6	<1.0			11			340	510
Northern Ireland											
Carrichue	Mud	1^{N}	<1.4	<1.3	0.071	0.55	0.91	*	0.00083		
Carrichue	Mud, sand and stones	1^{N}	<1.1	<1.3			<1.7				
Portrush	Sand	2^{N}	<1.1	<1.1			<1.1				
Oldmill Bay	Mud	2^{N}	<2.1	<1.6			10				
Ballymacormick	Mud	2^{N}	<1.4	<1.4			12				
Strangford Lough - Nicky's Point	Mud	2^{N}	<1.4	<1.8			6.9				
Dundrum Bay	Mud	2^{N}	<1.7	<2.2			<6.4				
Carlingford Lough	Mud	2^{N}	<2.1	<2.4	2.1	13	9.0	*	*		

* *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, 2011

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Grass and salt marsh	1	0.088
Rockcliffe Marsh	Grass	1	0.081
Burgh Marsh	Grass and salt marsh	1	0.084
Burgh Marsh	Grass	1	0.076
Port Carlisle 1	Mud	3	0.090
Port Carlisle 1	Mud and salt marsh	1	0.090
Port Carlisle 2	Salt marsh	1	0.077
Port Carlisle 2	Grass	3	0.090
Greenend 1	Mud	3	0.090
Greenend 1	Mud and stones	1	0.089
Greenend 2	Grass and salt marsh	1	0.094
Greenend 2	Grass	3	0.089
Cardurnock Marsh	Grass	4	0.080
Newton Arlosh	Grass	4	0.10
Silloth harbour	Mud and stones	2	0.10
Silloth harbour	Mud and pebbles	1	0.092
Silloth harbour	Sand and stones	1	0.11
Silloth silt pond	Grass	4	0.082
Allonby	Sand	3	0.083
Allonby	Sand and stones	1	0.10
Maryport harbour	Mud and sand	1	0.088
Maryport harbour	Sand	1	0.088
Workington harbour	Pebbles and stones	2	0.11
Harrington harbour	Pebbles and sand	2	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	2	0.088
Whitehaven - outer harbour	Pebbles and sand	2	0.10
St Bees	Sand	3	0.076
St Bees	Pebbles and sand	1	0.085
Nethertown beach	Pebbles and stones	1	0.14
Nethertown beach	Stones	1	0.12
Braystones	Sand and stones	1	0.11
Braystones	Pebbles	1	0.12
Sellafield dunes	Grass	2	0.11
North of former pipeline on foreshore	Sand	2	0.085
South of former pipeline on foreshore	Sand	2	0.079
River Calder downstream of factory sewer	Grass	2	0.090
River Calder upstream of factory sewer	Grass	2	0.11
Seascale beach	Sand	2	0.081
Seascale beach	Sand and stones	1	0.083
Seascale beach	Sand and pebbles	1	0.078
Seascale	Grass	4	0.086

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Grass	4	0.14
Ravenglass - River Mite estuary (erosional)	Grass	4	0.16
Ravenglass - Raven Villa	Mud and salt marsh	3	0.15
Ravenglass - Raven Villa	Grass and salt marsh	1	0.15
Ravenglass - boat area	Mud and sand	1	0.11
Ravenglass - boat area	Mud and pebbles	1	0.11
Ravenglass - boat area	Sand and pebbles	1	0.11
Ravenglass - boat area	Sand and stones	1	0.12
Ravenglass - ford	Mud	3	0.11
Ravenglass - ford	Mud and sand	1	0.11
Muncaster Bridge	Grass	4	0.12
Ravenglass - salmon garth	Mud	1	0.10
Ravenglass - salmon garth	Mud and sand	1	0.12
Ravenglass - salmon garth	Mud and pebbles	1	0.11
Ravenglass - salmon garth	Sand	1	0.13
Ravenglass - Eskmeals Nature Reserve	Mud and salt marsh	4	0.12
Newbiggin/Eskmeals viaduct	Mud	1	0.11
Newbiggin/Eskmeals viaduct	Mud and salt marsh	3	0.11
Newbiggin/Eskmeals Bridge	Salt marsh	3	0.14
Newbiggin/Eskmeals Bridge	Grass and salt marsh	1	0.13
Tarn Bay	Sand	1	0.086
Tarn Bay	Sand and stones	1	0.091
Silecroft	Sand and pebbles	1	0.11
Silecroft	Pebbles	1	0.12
Haverigg	Mud	2	0.091
Millom	Mud	1	0.10
Millom	Mud and stones	1	0.11
Low Shaw	Grass	2	0.086
Askam	Mud and sand	2	0.073
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	2	0.085
Walney Channel, S of discharge point	Mud	1	0.094
Walney Channel, S of discharge point	Mud and sand	1	0.097
Tummer Hill Marsh	Salt marsh	1	0.13
Tummer Hill Marsh	Grass	1	0.12
Roa Island	Pebbles and stones	2	0.089
Greenodd Salt Marsh	Grass	2	0.081
Sand Gate Marsh	Grass	4	0.089
Kents Bank 2	Grass	4	0.095
High Foulshaw	Grass and mud	2	0.082
High Foulshaw	Grass	2	0.089
Arnside 1	Mud	2	0.084
Arnside 1	Grass and mud	2	0.087
Arnside 2	Grass	4	0.10
Lancashire and Merseyside			
Morecambe Central Pier	Sand	2	0.078
Half Moon Bay	Mud and rock	1	0.087
Half Moon Bay	Sand and stones	1	0.084
Red Nab Point	Mud and sand	1	0.085
Red Nab Point	Sand	1	0.085
Middleton Sands	Sand	2	0.079
Sunderland Point	Mud	3	0.095
Sunderland Point	Mud and salt marsh	1	0.089
Sunderland	Salt marsh	4	0.094
Colloway Marsh	Salt marsh	3	0.13
Colloway Marsh	Grass	1	0.12
Lancaster	Grass	4	0.083

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lancashire and Merseyside			
Aldcliffe Marsh	Mud	1	0.12
Aldcliffe Marsh	Grass	3	0.10
Conder Green	Mud and sand	1	0.095
Conder Green	Grass and mud	3	0.090
Pilling Marsh	Grass	4	0.095
Knott End	Mud and sand	1	0.078
Knott End	Grass	1	0.076
Heads - River Wyre	Grass and mud	4	0.10
Height o' th' hill - River Wyre	Salt marsh	3	0.11
Height o' th' hill - River Wyre	Grass	1	0.10
Hambleton	Grass and mud	2	0.10
Hambleton	Grass	2	0.11
Skippool Creek 1	Salt marsh	4	0.11
Skippool Creek 2	Salt marsh	4	0.11
Skippool Creek 3	Wood	4	0.10
Skippool Creek boat 2	Wood	4	0.096
Skippool Creek boat 2 - in vicinity of boats	Mud	4	0.086
Fleetwood Marsh Nature Park	Salt marsh	4	0.12
Fleetwood shore 1	Sand	2	0.080
Fleetwood shore 1	Sand and pebbles	1	0.074
Fleetwood shore 1	Sand and stones	1	0.090
Blackpool	Sand	4	0.068
Crossens Marsh	Salt marsh	3	0.094
Crossens Marsh	Grass	1	0.096
Ainsdale	Sand	4	0.066
Rock Ferry	Mud	1	0.093
Rock Ferry	Mud and sand	2	0.093
Rock Ferry	Sand	1	0.094
New Brighton	Sand	4	0.068
West Kirby	Mud	1	0.074
West Kirby	Sand	3	0.072
Little Neston Marsh 1	Salt marsh	1	0.086
Little Neston Marsh 1	Grass	1	0.092
Little Neston Marsh 2	Grass	2	0.079
Flint 1	Mud	2	0.092
Flint 2	Salt marsh	2	0.10
Scotland			
Piltanton Burn	Salt marsh	4^S	0.063
Garlieston	Mud	4^S	0.073
Innerwell	Mud	4^S	0.076
Bladnoch	Mud	4^S	0.074
Carsluith	Mud	4^S	0.086
Skyreburn Bay (Water of Fleet)	Salt marsh	4^S	0.074
Kirkcudbright	Salt marsh	4^S	0.073
Cutters Pool	Winkle bed	4^S	0.080
Rascarrel Bay	Winkle bed	4^S	0.089
Gardenburn	Salt marsh	1^S	<0.047
Palnackie Harbour	Mud	1^S	0.086
Kippford - Slipway	Mud	4^S	0.099
Kippford - Merse	Salt marsh	1^S	0.092
Southerness	Winkle bed	4^S	0.059
Kirkconnell Marsh	Salt marsh	1^S	0.066
Isle of Man			
Ramsey	Sand and stones	1	0.086
Wales			
Prestatyn	Sand	2	0.070
Rhyl	Mud and salt marsh	1	0.091
Rhyl	Salt marsh	1	0.090
Llandudno	Sand	1	0.093
Llandudno	Sand and pebbles	1	0.088
Caerhun	Grass	2	0.088
Llanfairfechan	Sand	2	0.085

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Northern Ireland			
Lishally	Mud	1[N]	0.062
Eglington	Shingle	1[N]	0.051
Carrichue	Mud	1[N]	0.071
Bellerena	Mud	1[N]	0.060
Benone	Sand	1[N]	0.057
Castlerock	Sand	1[N]	0.059
Portstewart	Sand	1[N]	0.058
Portrush, Blue Pool	Sand	1[N]	0.055
Portrush, White Rocks	Sand	1[N]	0.059
Portballintrae	Sand	1[N]	0.054
Giant's Causeway	Sand	1[N]	0.059
Ballycastle	Sand	1[N]	0.058
Cushendun	Sand	1[N]	0.060
Cushendall	Sand and stones	1[N]	0.064
Red Bay	Sand	1[N]	0.067
Carnlough	Sand	1[N]	0.058
Glenarm	Sand	1[N]	0.052
Half Way House	Sand	1[N]	0.054
Ballygally	Sand	1[N]	0.057
Drains Bay	Sand	1[N]	0.056
Larne	Sand	1[N]	0.056
Whitehead	Sand	1[N]	0.063
Carrickfergus	Sand	1[N]	0.057
Jordanstown	Sand	1[N]	0.060
Helen's Bay	Sand	1[N]	0.059
Groomsport	Sand	1[N]	0.064
Millisle	Sand	1[N]	0.066
Ballywalter	Sand	1[N]	0.068
Ballyhalbert	Sand	1[N]	0.065
Cloghy	Sand	1[N]	0.064
Portaferry	Shingle and stones	1[N]	0.091
Kircubbin	Sand	1[N]	0.070
Greyabbey	Sand	1[N]	0.071
Ards Maltings	Mud	1[N]	0.071
Island Hill	Mud	1[N]	0.068
Nicky's Point	Mud	1[N]	0.094
Strangford	Shingle and stones	1[N]	0.097
Kilclief	Sand	1[N]	0.067
Ardglass	Mud	1[N]	0.075
Killough	Mud	1[N]	0.082
Rocky Beach	Sand	1[N]	0.072
Tyrella	Sand	1[N]	0.072
Dundrum	Sand	1[N]	0.085
Newcastle	Sand	1[N]	0.089
Annalong	Sand	1[N]	0.11
Cranfield Bay	Sand	1[N]	0.081
Mill Bay	Sand	1[N]	0.11
Greencastle	Sand	1[N]	0.076
Rostrevor	Sand	1[N]	0.10
Narrow Water	Mud	1[N]	0.087

[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, 2011

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
A	Nets	4	0.062
	Rope	4	0.047
S	Nets	4	0.063
	Pots	4	0.084
T	Gill nets	4	0.069
	Pots	4	0.12
W	Gill nets	2	0.058
	Pots	2	0.089
X	Gill nets	4	0.064
	Pots	4	0.073
Z	Nets	4	0.081

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2011

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, mSv h^{-1}
Whitehaven – outer harbour	Sand	2	0.020
Whitehaven – outer harbour	Pebbles and sand	2	0.030
St Bees	Sand	3	0.13
St Bees	Pebbles and sand	1	0.080
Sellafield pipeline	Sand	2	<0.020
Ravenglass – Raven Villa	Mud and salt marsh	2	0.10
Ravenglass – Raven Villa	Grass and salt marsh	1	*
Tarn Bay	Sand	1	*
Tarn Bay	Sand and stones	1	0.12

** Not detected by the method used*

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria								
Silloth	Seaweed	2	<0.66		<1.8	<0.40	76	<4.1
Harrington Harbour	Seaweed	2	<0.66		<1.8	<0.39	140	<4.1
St Bees	*Porphyra*[a]	4[F]	<0.12	0.11	<0.16	<0.17	0.78	3.0
St Bees	Seaweed	2	<0.70	<0.60	<1.9	<0.44	530	<4.5
Braystones South	*Porphyra*	4[F]	<0.09		<0.16	<0.16		3.8
Sellafield	*Rhodymenia* spp.	2[F]	<0.17		<0.34	<0.43		2.5
Sellafield	Seaweed	2	1.8	<1.5	<1.8	<0.41	1200	<4.3
Seascale	*Porphyra*[b]	52[F]	<0.37		<0.53	<0.30		<6.8
Ravenglass	Samphire	1[F]	<0.05		<0.13	<0.14	0.76	<0.53
Ravenglass	Seaweed	2	<1.3		<2.0	<0.52	310	<5.3
Lancashire								
Half Moon Bay	Seaweed	2	<0.57		<0.77	<0.39	270	<3.6
Marshside Sands	Samphire	1[F]	<0.08		<0.20	<0.17		<0.85
Cockerham Marsh	Samphire	1[F]	<0.10		<0.23	<0.19		<1.1
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10		<0.13	<0.42	19	<0.30
Lerwick	*Fucus vesiculosus*	1[S]	<0.10		<0.46	<0.82	11	<0.77
Lewis	*Fucus vesiculosus*	1[S]	<0.10		<0.25	<0.34	13	<0.52
Islay	*Fucus vesiculosus*	1[S]	<0.10		<0.22	<0.18	59	<0.74
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10		<0.11	<0.12	140	<0.26
Port William	*Fucus vesiculosus*	4[S]	<0.10		<0.26	<0.28	99	<0.68
Garlieston	*Fucus vesiculosus*	4[S]	<0.14		<0.26	<0.31	94	<0.60
Auchencairn	*Fucus vesiculosus*	4[S]	0.19		<0.20	<0.26	340	<0.55
Isle of Man	*Fucus vesiculosus*	4	<0.72		<1.1	<0.49	110	<4.3
Wales								
Cemaes Bay	Seaweed	2	<0.56		<0.91	<0.39	48	<3.4
Porthmadog	Seaweed	2	<0.63		<0.83	<0.42	3.1	<3.6
Lavernock Point	Seaweed	2	<0.90		<1.3	<0.66	2.9	<5.4
Fishguard	Seaweed	2	<0.68		<0.84	<0.45	5.1	<4.0
South Wales, manufacturer A	Laverbread	1[F]	<0.12		<0.29	<0.29		<1.1
South Wales, manufacturer C	Laverbread	1[F]	<0.12		<0.28	<0.28		<1.1
South Wales, manufacturer D	Laverbread	1[F]	<0.07		<0.13	<0.10		<0.62
South Wales, manufacturer E	Laverbread	1[F]	<0.07		<0.22	<0.27		<0.70
Northern Ireland								
Portrush	*Fucus* spp.	4[N]	<0.06		<0.12	<0.10		<0.46
Portaferry	*Rhodymenia* spp.	4[N]	<0.07		<0.18	<0.19	1.1	<0.65
Ardglass	*Ascophyllum nodosum*	1[N]	<0.06		<0.17	<0.20		<0.43
Ardglass	*Fucus vesiculosus*	3[N]	<0.09		<0.18	<0.15	190	<0.76
Carlingford Lough	*Ascophyllum nodosum*	2[N]	<0.07		<0.18	<0.18	110	<0.54
Carlingford Lough	*Fucus* spp.	2[N]	<0.09		<0.23	<0.22		<0.71
Isles of Scilly	Seaweed	1	<0.79		<0.95	<0.49	4.8	<4.4

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{125}Sb	^{131}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu
Cumbria									
Silloth	Seaweed	2	<2.2	<2.3	<0.51	5.6	<1.8		
Harrington Harbour	Seaweed	2	<2.3	<2.3	<0.52	2.9	<1.8		
St Bees	*Porphyra*[a]	4[F]	<0.18	<0.19	<0.06	0.75	<0.26	<0.12	0.34
St Bees	Seaweed	2	<2.4	<2.5	<0.52	2.9	<1.9		1.6
Braystones South	*Porphyra*	4[F]	<0.21	<0.54	<0.06	0.88	<0.24	<0.11	0.22
Sellafield	*Rhodymenia* spp.	2[F]	<0.37	<1.1	<0.10	9.6	<0.40	<0.18	0.54
Sellafield	Seaweed	2	<2.5	<2.1	<0.53	6.4	<2.1		2.4
Seascale	*Porphyra*[b]	52[F]	<1.2	<0.54	<0.33	1.3	<1.4	<0.69	
Ravenglass	Samphire	1[F]	<0.12		<0.05	0.70	<0.19	<0.08	
Ravenglass	Seaweed	2	<3.0	<2.6	<0.64	8.9	<2.3		
Lancashire									
Half Moon Bay	Seaweed	2	<2.0	<0.92	<0.46	3.1	<1.7		
Marshside Sands	Samphire	1[F]	<0.20	*	<0.09	0.47	<0.40	<0.19	
Cockerham Marsh	Samphire	1[F]	<0.24	*	<0.11	1.3	<0.35	<0.16	
Scotland									
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10		<0.10	0.12	<0.21	0.14	
Lerwick	*Fucus vesiculosus*	1[S]	<0.19		<0.10	<0.10	<0.48	<0.19	
Lewis	*Fucus vesiculosus*	1[S]	<0.15		<0.10	1.6	<0.42	<0.16	
Islay	*Fucus vesiculosus*	1[S]	<0.22		<0.10	0.18	<0.43	<0.21	
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10		<0.10	0.50	<0.18	0.16	
Port William	*Fucus vesiculosus*	4[S]	<0.20		<0.10	0.92	<0.41	<0.22	
Garlieston	*Fucus vesiculosus*	4[S]	<0.32		<0.10	5.0	<0.38	<0.16	
Auchencairn	*Fucus vesiculosus*	4[S]	0.36		<0.10	3.0	<0.35	<0.18	
Isle of Man	*Fucus vesiculosus*	4	<2.4	<2.6	<0.59	<0.56	<1.8	<0.83	
Wales									
Cemaes Bay	Seaweed	2	<2.0	<1.5	<0.49	<0.58	<1.5		
Porthmadog	Seaweed	2	<2.1	<0.78	<0.48	<0.48	<1.3		
Lavernock Point	Seaweed	2	<3.1	<1.0	<0.72	<0.68	<2.1	<1.0	
Fishguard	Seaweed	2	<2.3	<0.59	<0.54	<0.49	<1.6		
South Wales, manufacturer A	Laverbread	1[F]	<0.23	*	<0.11	<0.11	<0.36	<0.15	
South Wales, manufacturer C	Laverbread	1[F]	<0.22	*	<0.13	<0.10	<0.35	<0.16	
South Wales, manufacturer D	Laverbread	1[F]	<0.14	<0.76	<0.06	<0.06	<0.22	<0.09	
South Wales, manufacturer E	Laverbread	1[F]	<0.15	*	<0.07	0.15	<0.24	<0.09	
Northern Ireland									
Portrush	*Fucus* spp.	4[N]	<0.11	<0.16	<0.06	0.12	<0.22	<0.11	
Portaferry	*Rhodymenia* spp.	4[N]	<0.14	*	<0.07	0.63	<0.23	<0.10	0.075
Ardglass	*Ascophyllum nodosum*	1[N]	<0.10	*	<0.06	0.34	<0.15	<0.07	
Ardglass	*Fucus vesiculosus*	3[N]	<0.18	<0.55	<0.09	0.59	<0.29	<0.14	
Carlingford Lough	*Ascophyllum nodosum*	2[N]	<0.13	<0.22	<0.07	0.45	<0.21	<0.10	
Carlingford Lough	*Fucus* spp.	2[N]	<0.17	<0.66	<0.10	0.39	<0.31	<0.27	
Isles of Scilly	Seaweed	1	<2.5	<0.72	<0.60	<0.53	<1.7	<0.82	

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Cumbria								
Silloth	Seaweed	2			3.0			
Harrington Harbour	Seaweed	2			2.4			
St Bees	*Porphyra*[a]	4[F]	1.8	12	4.5	0.0072	0.0050	220
St Bees	Seaweed	2	7.9		4.9			
Braystones South	*Porphyra*	4[F]	1.2	7.5	2.6	*	*	
Sellafield	*Rhodymenia* spp.	2[F]	3.0		8.3	*	0.014	
Sellafield	Seaweed	2	11		10			
Seascale	*Porphyra*[b]	52[F]			4.5			
Ravenglass	Samphire	1[F]			2.0			
Ravenglass	Seaweed	2			23			
Lancashire								
Half Moon Bay	Seaweed	2			<1.0			
Marshside Sands	Samphire	1[F]			<0.18			
Cockerham Marsh	Samphire	1[F]			1.1			45
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]			<0.10			
Lerwick	*Fucus vesiculosus*	1[S]			<0.13			
Lewis	*Fucus vesiculosus*	1[S]			0.29			
Islay	*Fucus vesiculosus*	1[S]			<0.13			
Campbeltown	*Fucus vesiculosus*	1[S]			<0.10			
Port William	*Fucus vesiculosus*	4[S]			0.66			
Garlieston	*Fucus vesiculosus*	4[S]			7.5			
Auchencairn	*Fucus vesiculosus*	4[S]			3.1			
Isle of Man	*Fucus vesiculosus*	4			<0.61			
Wales								
Cemaes Bay	Seaweed	2			<0.48			
Porthmadog	Seaweed	2			<0.44			
Lavernock Point	Seaweed	2			<0.74			
Fishguard	Seaweed	2			<0.53			
South Wales, manufacturer A	Laverbread	1[F]			0.28			
South Wales, manufacturer C	Laverbread	1[F]			<0.09			
South Wales, manufacturer D	Laverbread	1[F]			<0.05			96
South Wales, manufacturer E	Laverbread	1[F]			0.09			
Northern Ireland								
Portrush	*Fucus* spp.	4[N]			<0.10			
Portaferry	*Rhodymenia* spp.	4[N]	0.45		0.81	*	0.0011	
Ardglass	*Ascophyllum nodosum*	1[N]			0.09			
Ardglass	*Fucus vesiculosus*	3[N]			0.24			
Carlingford Lough	*Ascophyllum nodosum*	2[N]			<0.06			
Carlingford Lough	*Fucus* spp.	2[N]			<0.20			
Isles of Scilly	Seaweed	1			<0.55			

* *Not detected by the method used*
[a] *The concentration of ^{14}C was 55 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, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Sellafield 14[b]	Cabbage	1	<0.04	<0.10	<0.09	30	<0.38	<0.08
Sellafield 14[b]	Onions	1	<0.02	<0.04	<0.03	1.1	<0.16	<0.04
Sellafield 14[b]	Potatoes	1	<0.16	<0.35	<0.30	6.6	<1.5	<0.33
Sellafield 14[b]	Soil	1	3.2	<1.2	<1.6	950	<3.3	<1.0
Sellafield 154[b]	Potatoes	1	<0.12	<0.31	<0.32	<0.19	<1.1	<0.24
Sellafield 154[b]	Soil	1	<0.53	<2.5	<3.5	0.66	<5.4	<1.5
Sellafield 474[b]	Chard	1	<0.06	<0.10	<0.07	0.093	<0.46	<0.10
Sellafield 474[b]	Courgettes	1	<0.05	<0.11	<0.11	<0.06	<0.44	<0.09
Sellafield 474[b]	Potatoes	1	<0.06	<0.11	<0.08	<0.26	<0.45	<0.11
Sellafield 474[b]	Shallots	1	<0.12	<0.22	<0.18	<0.23	<1.1	<0.25
Sellafield 474[b]	Swedes	1	<0.06	<0.11	<0.07	<0.11	<0.52	<0.12
Sellafield 474[b]	Soil	1	<0.31	<2.4	<5.2	0.61	<3.7	<0.88

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Sellafield 14[b]	Cabbage	1	<0.04	0.11	<0.13	<0.13	<0.06	<0.03
Sellafield 14[b]	Onions	1	<0.02	0.06	<0.07	<0.07	<0.04	<0.02
Sellafield 14[b]	Potatoes	1	<0.15	0.28	<0.49	<0.45	<0.21	<0.11
Sellafield 14[b]	Soil	1	<0.42	55	<2.0	<1.0	<0.89	53
Sellafield 154[b]	Potatoes	1	<0.11	0.22	<0.38	<0.34	<0.15	<0.08
Sellafield 154[b]	Soil	1	<0.68	33	<4.2	<1.5	<1.9	<2.0
Sellafield 474[b]	Chard	1	<0.05	<0.04	<0.17	<0.19	<0.08	<0.04
Sellafield 474[b]	Courgettes	1	<0.05	<0.04	<0.14	<0.16	<0.06	<0.04
Sellafield 474[b]	Potatoes	1	<0.05	<0.05	<0.19	<0.21	<0.09	<0.06
Sellafield 474[b]	Shallots	1	<0.11	<0.10	<0.42	<0.36	<0.18	<0.09
Sellafield 474[b]	Swedes	1	<0.06	<0.05	<0.19	<0.19	<0.09	<0.05
Sellafield 474[b]	Soil	1	<0.43	3.7	<2.2	<0.97	<0.93	<0.62

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

Table 2.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2011

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		4	<4.2	17	<0.19	0.034	<0.29	<0.26	<0.0060	<1.2	<0.37	<0.0088
Milk	max		<4.3	20	<0.20	0.051	<0.30	<0.30			<0.39	<0.013
Apples		1	<4.0	13	<0.20	0.10	<0.30	<0.10	<0.020	<0.80	<0.30	<0.026
Barley		1	<7.0	90	<0.20	0.27	<0.20	<0.20	0.078	<1.3	<0.30	0.058
Beef kidney		1	<8.0	14	<0.20	0.20	<0.30	<0.20	0.033	<1.6	<0.50	<0.067
Beef liver		1	<8.0	11	<0.20	0.076	<0.20	<0.10	<0.026	<0.50	<0.20	<0.040
Beef muscle		1	<6.0	11	<0.20	0.013	<0.30	<0.10	<0.020	<1.0	<0.40	<0.051
Beetroot		1							0.073			
Blackberries		1	<4.0	13	<0.20	0.22	<0.20	<0.20	<0.021	<1.0	<0.30	<0.030
Broad beans		1							<0.023			
Cabbage		1	<4.0	<3.0	<0.20	0.34	<0.20	<0.20	0.034	<0.80	<0.40	<0.022
Carrots		1	<4.0	5.0	<0.10	0.099	<0.30	<0.20	<0.032	<1.1	<0.40	<0.026
Honey		1	<7.0	100	<0.10	0.045	<0.20	<0.20	<0.021	<1.2	<0.50	<0.012
Pheasant		1	<6.0	36	<0.20	0.0080	<0.20	<0.20	<0.024	<0.90	<0.30	0.049
Potatoes		1	<5.0	16	<0.20	0.033	<0.20	<0.20	<0.027	<0.80	<0.30	<0.025
Runner beans		1	<4.0	4.0	<0.10	0.089	<0.20	<0.20	<0.021	<1.3	<0.30	<0.026
Sheep muscle		2	<6.5	16	<0.20	0.021	<0.25	<0.20	<0.034	<1.3	<0.30	<0.044
Sheep muscle	max		7.0	17		0.025	<0.30		0.047	<1.5	<0.40	<0.053
Sheep offal		2	<8.0	23	<0.20	0.24	<0.40	<0.30	<0.028	<1.6	<0.60	<0.053
Sheep offal	max			30		0.28				<1.7	<0.70	0.063
Grass		2							<0.027			
Grass	max								0.027			

Material and selection[a]		No. of sampling observ-ations[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]		4		<0.75				<0.00010	<0.00018	<0.036	<0.00017
Milk	max			<0.76					<0.00020	<0.043	0.00028
Apples		1	0.12	<0.60				<0.00020	0.0011	<0.077	0.0019
Barley		1	0.17	<0.50				0.0017	0.0081	0.11	0.018
Beef kidney		1	2.1	<1.1	0.0032	0.00050	0.0036	<0.00010	0.00040	<0.11	0.00040
Beef liver		1	1.0	<0.70				0.00030	0.00030	<0.096	0.00030
Beef muscle		1	7.3	<0.70				<0.00020	<0.00030	<0.10	<0.00030
Beetroot		1			0.0050	0.00050	0.0035				
Blackberries		1	0.076	<0.60				<0.00020	<0.00030	0.080	0.0012
Broad beans		1			0.00080	<0.00040	<0.0010				
Cabbage		1	0.10	<0.70				<0.00010	<0.00030	<0.061	0.0012
Carrots		1	0.18	<0.60				<0.00020	<0.00030	0.10	0.00030
Honey		1	0.29	<1.0				0.00040	<0.00030	<0.066	0.00050
Pheasant		1	0.25	<0.70				<0.00020	<0.00040	<0.093	<0.00030
Potatoes		1	0.23	<0.50				<0.00010	<0.00030	<0.057	0.00040
Runner beans		1	0.081	<0.60				0.00030	0.00050	<0.068	0.0017
Sheep muscle		2	3.0	<0.55				<0.00015	<0.00040	<0.069	<0.00035
Sheep muscle	max		4.0	<0.60				<0.00020	0.00040	<0.085	0.00040
Sheep offal		2	1.2	<1.3				0.00025	<0.00035	<0.083	0.00090
Sheep offal	max		1.3					0.00040	<0.00040	<0.11	0.0013
Soil		1			10	0.43	9.8				

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

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

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

[d] *The mean concentrations of ^{134}Cs and ^{137}Cs were <0.20 and <0.19 (max <0.20) Bq l^{-1}*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2011

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}								
		^{3}H	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+$ ^{240}Pu	Gross alpha	Gross beta
Ehen Spit beach[a]	4	200	<0.24	<0.060	<0.23	<0.27	<0.0052	<0.0077	<4.4	12
River Ehen (100m downstream of sewer outfall)	4	7.3	<0.26	<0.055	<0.25	<0.21	<0.0065	<0.0054	<0.085	0.45
River Calder (downstream)	4	<4.6	<0.25	<0.050	<0.24	<0.21	<0.0063	<0.0050	<0.037	0.16
River Calder (upstream)	4	<3.9	<0.24	<0.050	<0.22	<0.20	<0.0060	<0.0060	<0.030	<0.082
Wast Water	1	<3.0	<0.23			<0.19			<0.070	<0.10
Ennerdale Water	1	<3.0	<0.11		<0.09	<0.09			<0.040	<0.10
Devoke Water	1	<5.0	<0.11		<0.09	<0.09			<0.020	<0.10
Thirlmere	1	<4.0	<0.23			<0.20			<0.050	<0.10

[a] *The concentration of ^{99}Tc was <0.83 Bq l^{-1}*

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2011

Location	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}						
		^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+$ ^{240}Pu	^{241}Am
Seascale SS 204	1	<1.2	3.6	<1.0	430	3.2	19	20
Seascale SS 233	1	<0.62	<10	<0.65	450	4.2	37	36
Seascale SS 209	1	<0.33	<2.0	<0.26	7.0	<0.70	2.6	3.1
Seascale SS 232	1	<1.1	<2.0	<1.0	99	3.6	18	28
Seascale SS 231	1	<1.4	<2.0	<1.3	38	3.7	19	34
Seascale SS 206	1	<1.2	22	<1.3	890	9.3	85	83
Seascale SS 208	1	<1.3	<2.0	<1.2	46	1.3	7.8	15
Seascale SS 234	1	<1.5	<2.0	<1.4	140	2.3	18	27
Seascale SS 235	1	<1.4	<2.0	<1.1	300	3.8	27	42
Whitehaven SS 201	1	<1.9	<2.0	2.4	30	<0.70	1.9	2.6

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2007-2011

	Exposure, mSv per year				
Group	2007	2008	2009	2010	2011
Isle of Man	0.006	0.007	0.007	<0.005	<0.005
Northern Ireland	0.015	0.017	0.012	0.010	0.010
Dumfries and Galloway	0.060	0.047	0.047	0.040	0.040
Whitehaven	0.009	0.009	0.011	0.010	0.010
Sellafield (5 year average consumption)	0.24	0.23	0.20	0.18	0.15
Morecambe Bay	0.037	0.042	0.041	0.046	0.034
Fleetwood	0.013	0.016	0.013	0.015	0.008
North Wales	0.014	0.018	0.015	0.013	0.014

Table 2.18. Individual radiation exposures, Sellafield, 2011

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	Direct radiation from site
Total dose - **maximum effect of all sources**								
Adult consumers of marine plants and algae	0.18[e]	0.046	0.11	-	0.022	-	-	-
Total dose - **maximum effect of gaseous release and direct radiation sources**								
Infant consumers of milk	0.010	<0.005	<0.005	0.010	<0.005	-	<0.005	<0.005
Total dose - **maximum effect of liquid release source**								
Adult consumers of marine plants and algae	0.18	0.046	0.11	-	0.022	-	-	-
Source specfic doses								
Seafood consumers								
Local seafood consumers (habits averaged 2007-11)	0.26[f]	0.12	0.11	-	0.036	-	-	
Local seafood consumers (habits for 2011)	0.23[g]	0.074	0.13	-	0.034	-	-	
Whitehaven seafood consumers	0.010	0.010	-	-	-	-	-	
Dumfries and Galloway seafood consumers	0.040	0.025	-	-	0.015	-	-	
Morecambe Bay seafood consumers	0.034	0.014	-	-	0.020	-	-	
Fleetwood seafood consumers	0.008	0.008	-	-	-	-	-	
Isle of Man seafood consumers	<0.005	<0.005	-	-	-	-	-	
Northern Ireland seafood consumers	0.010	0.007	-	-	<0.005	-	-	
North Wales seafood consumers	0.014	0.007	-	-	0.007	-	-	
Other groups								
Ravenglass Estuary, nature warden	0.038	-	-	-	0.031	0.007	-	
Fishermen handling nets or pots[c]	0.072	-	-	-	0.072	-	-	
Bait diggers and shellfish collectors[c]	0.055	-	-	-	0.055	-	-	
Ribble Estuary houseboats	0.13	-	-	-	0.13	-	-	
Local consumers at Ravenglass[b]	0.011	-	-	0.011	-	-	-	
Local consumers of vegetables grown on land with seaweed added[b]	0.009	-	-	0.009	-	-	-	
Local consumers at LLWR near Drigg[b]	0.013	-	-	0.013	-	-		
Local consumers in the Isle of Man[b]	0.006	-	-	0.006	-	-	-	
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-	
Inhabitants and consumers of locally grown food[b]	0.020	-	-	0.019	-	-	<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[d]	0.007	-	-	0.007	-	-	-	
Typical visitor to Cumbria	<0.005	<0.005	<0.005	-	<0.005	-	-	

Table 2.18. continued

Exposed population[a,g]	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
Recreational user of beaches							
North Cumbria	0.011	-	-	-	0.011	-	-
Sellafield	0.011	-	-	-	0.011	-	-
Lancashire	0.008	-	-	-	0.008	-	-
North Wales	0.009	-	-	-	0.009	-	-
Isle of Man	0.009	-	-	-	0.009	-	-
Recreational user of mud/saltmarsh areas							
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-
North Cumbria	0.006	-	-	-	0.006	-	-
Sellafield	0.014	-	-	-	0.014	-	-
Lancashire	0.008	-	-	-	0.008	-	-
North Wales	0.005	-	-	-	0.005	-	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *Infants*

[c] *Exposure to skin for comparison with the 50 mSv dose limit*

[d] *Only the adult age group is considered for this assessment.*

[e] *The dose due to nuclear industry discharges was 0.068 mSv*

[f] *The dose due to nuclear industry discharges was 0.15 mSv*

[g] *The total dose due to nuclear industry discharges was 0.11mSv*

3. Research establishments

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and SEPA near 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 non-nuclear site at Culham 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. In 2009, Research Sites Restoration Limited (RSRL) and Dounreay Site Restoration Limited (DSRL) (both wholly-owned subsidiaries of UKAEA) became the site licence companies for Harwell and Winfrith, and Dounreay respectively. UKAEA Limited itself was sold to Babcock International Group plc, including its subsidiary companies DSRL and RSRL, as a preliminary to NDA starting the Dounreay Parent Body Organisation competition. The NDA completed the Parent Body competition process and Babcock Dounreay Partnership was awarded the contract. 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 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.

The medium-term trends in doses, discharges and environmental concentrations at Dounreay, Harwell and Winfrith were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

Other research sites considered in this section are the Imperial College Reactor Centre and Culham.

Key points

- Public radiation doses from all sources were less than 2 per cent of the dose limit at all those sites assessed
- Doses, discharges, environmental concentrations and dose rates in 2011 were broadly similar to those in 2010

Dounreay, Highland

- Babcock Dounreay Partnership became the Parent Body Organisation in 2012
- The estimate of dose for terrestrial food consumption was affected by the type of game sampled in 2011
- There were small increases in public radiation doses from liquid discharges due to higher gamma dose rates in intertidal areas

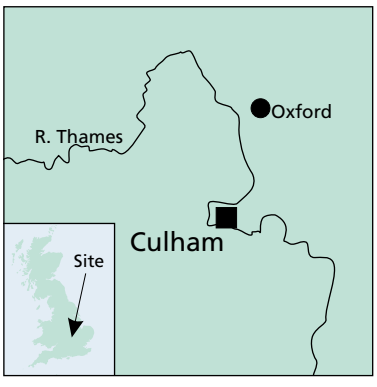
Harwell, Oxfordshire

- A revised permit was issued, with lower limits for liquid discharges
- Liquid discharges of caesium-137 to the River Thames decreased to the lowest value in recent years

Winfrith, Dorset

- Liquid discharges of tritium increased in comparison to most recent years

3.1 Culham, Oxfordshire

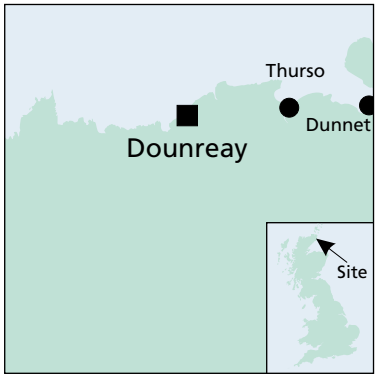


Culham Centre for Fusion Energy (CCFE), based at the Culham Science Centre, is the UK's national laboratory for fusion research. CCFE hosts an experimental fusion reactor, the Joint European Torus (JET), owned and operated by the UKAEA. Although not currently designated, the NDA understands that the intention of Government is to designate that part of the Culham Site occupied by the JET facilities as an NDA site at an appropriate time after JET operation ceases. The NDA would then take responsibility for the decommissioning programme. *Total dose* is not determined at this site, in this report, because an integrated habits survey has not been undertaken. The

source specific dose, from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2011, was estimated to be much less than 0.005 mSv (Table 3.1).

Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2011. Locations and data are shown in Figure 3.1 and Table 3.2, respectively. In previous years, the main effect of the site's operation was the increased tritium concentrations found in grass collected near the site perimeter. In 2011, measurements of tritium were very close to or 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.

3.2 Dounreay, Highland



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

From 2005, the NDA became responsible for the UK's civil nuclear liabilities 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. The NDA completed the Parent Body competition process and Babcock Dounreay Partnership was awarded the contract on 2 April 2012.

SEPA is currently determining DSRL's application for a new authorisation for the disposal of radioactive waste arising from the decommissioning of the Dounreay site. The content of the application is based upon the predicted requirements of the decommissioning activities which are to be undertaken.

In August 2012, SEPA varied DSRL's gaseous authorisation. The variation increased the Prototype Fast Reactor stack krypton-85 discharge limit and decreased the Fuel Cycle Area stack krypton-85 discharge limit, resulting in an overall reduction of the site's authorised krypton-85 discharge limit.

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

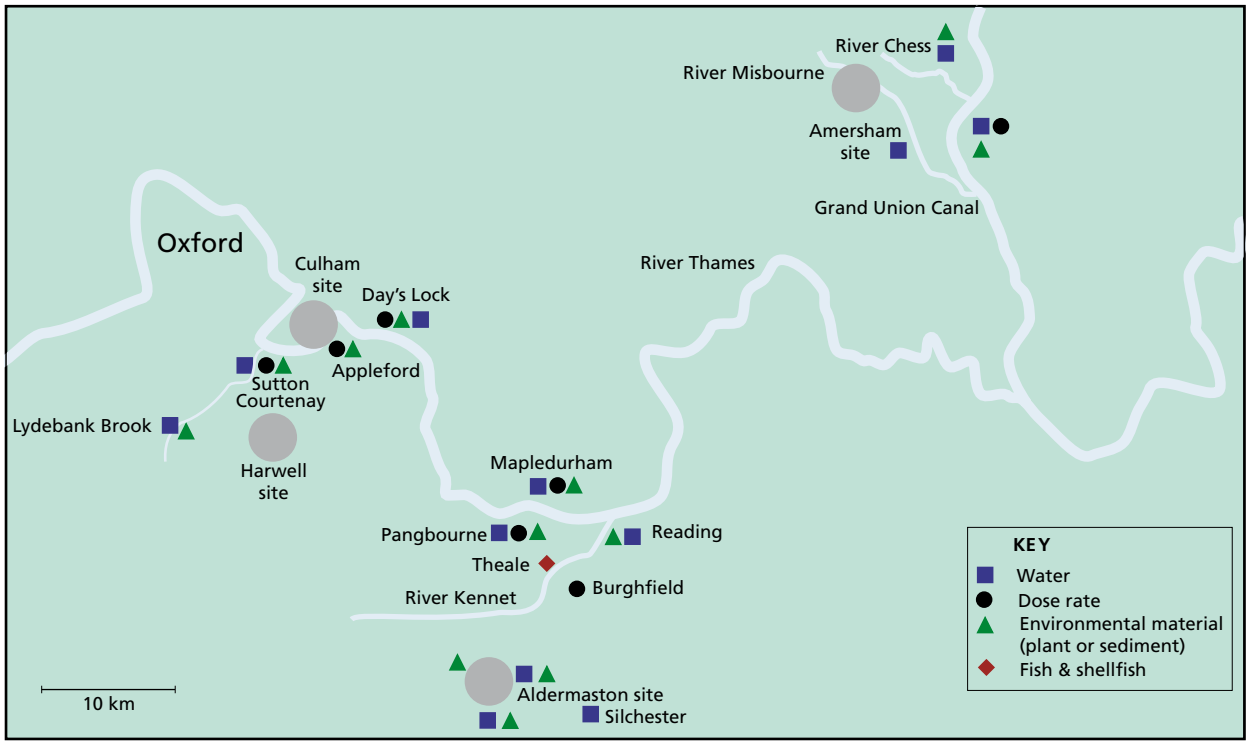


Figure 3.1. Monitoring locations at Thames sites, 2011 (not including farms)

During 2011, DSRL continued to process batches of Sodium/Potassium (NaK) liquid coolant through the NaK destruction plant in the Dounreay Fast Reactor. Following a leak of radioactive liquor within the NaK destruction plant's ion exchange facility, SEPA undertook an inspection to assess the environmental impact of the incident and confirmed that there had been no release to the environment.

During 2011, SEPA undertook a range of inspections which included the following topics:

- Content, application and use of Environmental Support files (which form part of the Environmental Management System)
- The facility level documents, which underpin the identification and consignment of solid radioactive waste; solid waste consignment records and waste management procedures
- Liquid discharge sampling arrangements
- Groundwater monitoring arrangements
- Decommissioning projects

In 2011, radioactive waste discharges from Dounreay were made by DSRL under authorisations granted by SEPA. The quantities of both gaseous and liquid discharges were generally similar to those in 2010 (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*., 2011a). Figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1 (Table X2.2). A habits 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*., 2011c).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation is assessed to have been 0.018 mSv (Table 3.1) or less than 2 per cent of the dose limit. The people most exposed were high-rate consumers (1-year-old infants) of milk, as opposed to adults consuming game meat in 2010. The change in dose (from 0.047 mSv in 2010) and the most exposed age group was due to the type of game sampled and associated activity concentrations (of the significant contributor) used in the assessment (from venison in 2010 to rabbit in 2011), which had a reduced caesium-137 concentration in 2011. The doses to 1-year-old infants in 2011 and 2010 (0.018 mSv) were unchanged. Venison is the most consumed of the game meats in the area. Therefore, by estimating the exposure, using reported activity concentrations for venison samples collected in 2010, a more conservative assessment of the *total dose* is estimated to have been 0.047 mSv in 2011 and the people most exposed were adults consuming game meat (similar to 2010).

The trend in *total dose* over the period 2004 – 2011 is given in Figure 1.1. The variations in recent years were due to changes in caesium-137 concentrations in game meat and the type of game sampled, but *total doses* were low.

Source specific assessments of exposures for high-rate consumers of seafood and for external pathways (both for Geo occupants, who live at or regularly visit Oigin's Geo, and fishermen) give exposures of less than 0.018 mSv in 2011 (Table 3.1). As in 2010, the dose to consumers of terrestrial foodstuffs was 0.028 mSv or less than 3 per cent of the dose limit for members of the public of 1 mSv. The dose to consumers of fish and shellfish, including external exposure from occupancy over local beaches, was 0.010 mSv. The increase in dose from 0.006 mSv in 2010 was due to increased dose rates over the winkle bed at Sandside Bay in 2011.

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 2011 included the sampling of air, freshwater, grass, soil and locally grown terrestrial foods including meat, vegetables and cereals as well as wild foods. 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 2011. Additional monitoring for caesium-137 in rabbit samples was carried out in 2011 to determine typical background concentration in the vicinity of the site, but no venison (deer muscle) was sampled. 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. In 2011, low concentrations of caesium-137, strontium-90, europium-155, uranium, plutonium and americium-241 were reported in samples. In rabbit, the caesium-137 concentration was 1.1 Bq kg^{-1} in 2011 (and just above the LoD) in contrast to the value measured below the LoD in 2009 (rabbit was not sampled in 2010), but much lower than caesium-137 activity in 2008 (110 Bq kg^{-1}). The variation of caesium-137 concentrations 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. Activity concentrations in air samples at locations near to the site were below the LoD.

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 is operated by the Defence Procurement Agency.

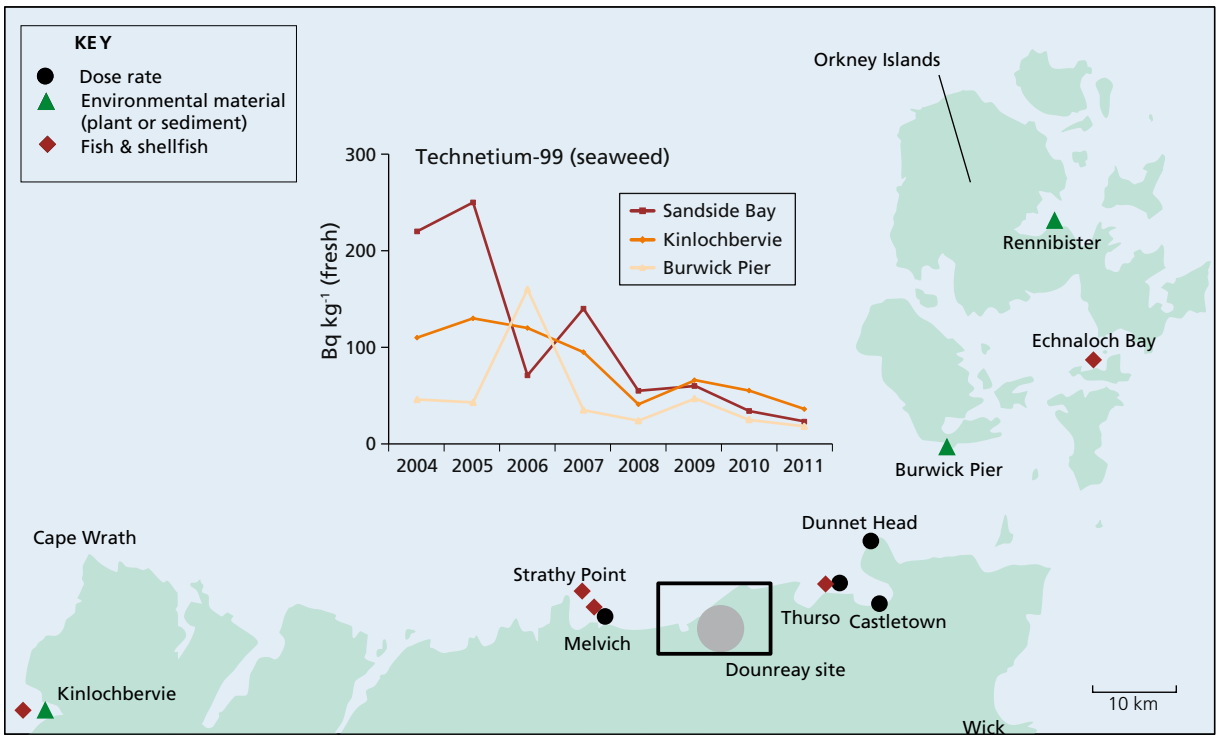


Figure 3.2. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2011 (not including farms)

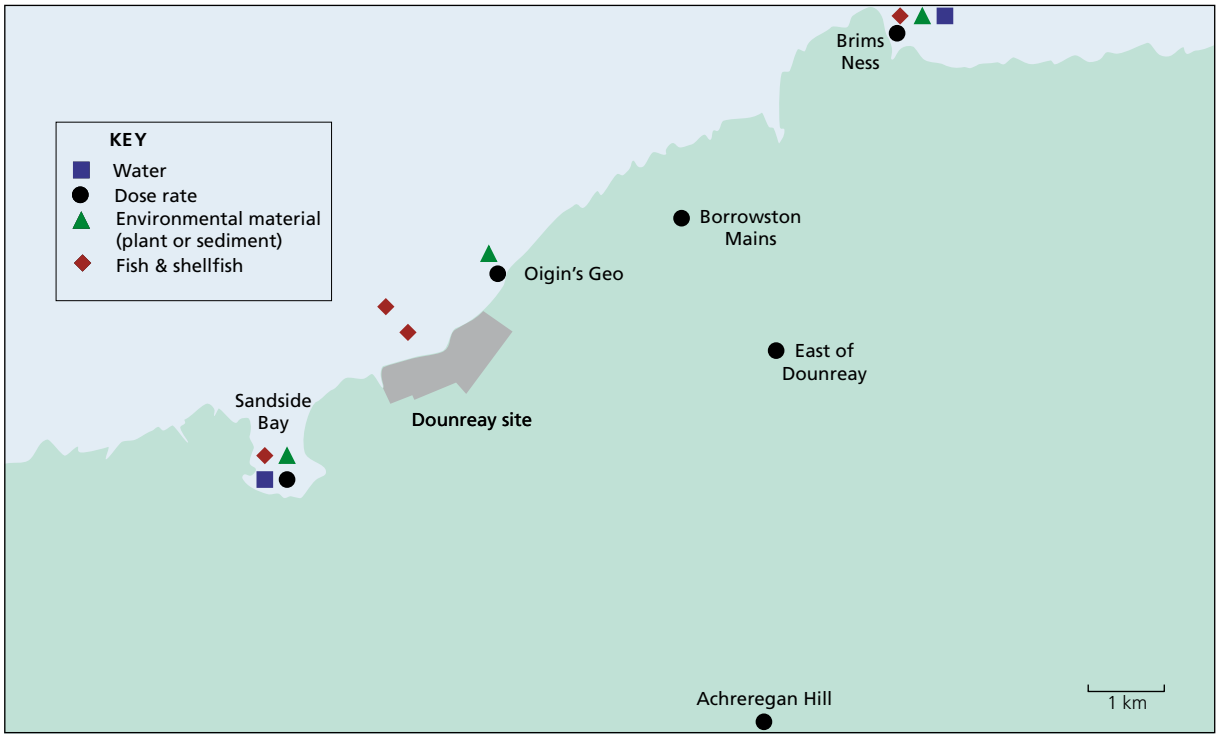


Figure 3.3. Monitoring locations at Dounreay, 2011 (not including farms)

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 2011 and are similar to those in recent years. Although gamma dose rates were generally similar to those in 2010, rates increased over the winkle bed at Sandside Bay in 2011. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were smaller than those in 2010. 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 2011, DSRL continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. In 2011, 45 fragments were recovered from Sandside Bay and 10 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 0.32 kBq and 250 kBq (similar to ranges observed in 2010).

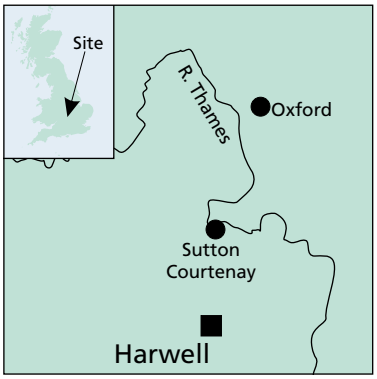
In February 2012, a particle was recovered from Sandside Bay which had a different composition compared to those previously detected at this location. Preliminary results have indicated that the activity of the particle is dominated by strontium-90. Previously detected and recovered particles have had equal activity quantities of caesium-137 and strontium-90. The initial results indicate the particle has a strontium-90 activity of approximately 1 - 2 MBq, with a few kBq of caesium-137.

During 2011, operations were undertaken to recover fragments from the seabed using a remotely operated vehicle. The retrieval operations undertaken between May and July recovered 352 fragments from an area of 23 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 Dounreay Particles Advisory Group (†DPAG) completed its work following the production of its Fourth Report (Dounreay Particles Advisory Group, 2008). Since the work of DPAG was concluded, the Particles Retrieval Advisory Group (Dounreay) (†PRAG (D)) have published reports in March 2010 and March 2011 (Particles Retrieval Advisory Group (Dounreay), 2010; 2011).

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. In 2009, FSA in Scotland announced that the FEPA Order would remain in place, and be reviewed again when the seabed remediation work was complete.

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. Decommissioning of redundant nuclear facilities is well underway. The 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 2011, GE Healthcare occupied a building in one small area embedded within the licensed site. Decommissioning of this building was completed in December 2011. GE Healthcare applied to surrender their permit (and nuclear site licence) in January 2012. The most recent habits survey was conducted during 2007 (Garrod *et al.*, 2008).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was 0.017 mSv (Table 3.1), which is less than 2 per cent of the dose limit. The dominant contribution to this dose was direct radiation from the site and the most exposed people were the prenatal children of local inhabitants. This dose was very similar to that in 2010 (0.018 mSv). The trend in *total dose* over the period 2004 – 2011 is given in Figure 1.1. The *total doses* remained broadly similar from year to year, and were very low.

* *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.*

† *DPAG was set up in 2000, and PRAG (D) thereafter, to provide independent advice to SEPA and UKAEA on issues relating to the Dounreay fragments.*

Source specific assessments for high-rate consumers of terrestrial foods, and for anglers, give exposures that were less than *the total dose* (Table 3.1). The dose to anglers was 0.008 mSv in 2011 and the increase, from 0.006 mSv in 2010, was due to a small increase in gamma dose rates at Sutton Courtenay.

Gaseous discharges and terrestrial monitoring

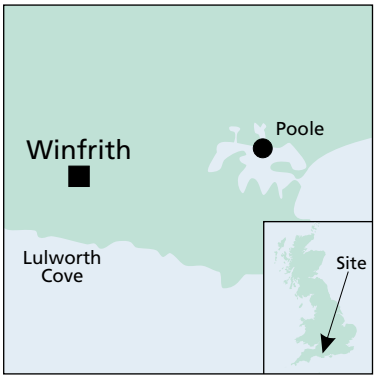
Gaseous wastes are discharged via stacks to the local environment. The monitoring programme sampled milk and other terrestrial foodstuffs. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.1. The results of the terrestrial programme are shown in Table 3.4(a).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

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive wastes from Harwell continued in 2011 to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site. A new permit, with lower limits for discharged radionuclides, became operative on 7 November 2011. Liquid discharges of caesium-137 to the River Thames were the lowest in recent years. Figure 3.4 shows trends of discharges over time (2000 – 2011) for cobalt-60 and caesium-137. There was an overall reduction in the discharges over the whole 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.

Tritium and cobalt-60 concentrations in all aquatic samples, and caesium-137 concentrations in freshwater samples, were below the LoD. Caesium-137 concentrations in sediments were slightly enhanced close to the outfall at Sutton Courtenay but were small in terms of any radiological effect. Iodine-131 was positively detected in sediment collected from Day's Lock in 2011. The reported value is believed to originate from the therapeutic use of this radionuclide in a local hospital. Concentrations of transuranic elements and sediments were either very low or below the LoD. Overall, gamma dose rates were generally similar to those in recent years. A small increase in the dose rates was measured at Sutton Courtenay in 2011 (in comparison to 2010). 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.

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 most recent habits survey undertaken for Winfrith was in 2003 (McTaggart *et al.*, 2004b).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 3.1), or less than 0.5 per cent of the dose limit. The main component of this dose in 2011 was from external gamma radiation exposure. Adults spending time on local beaches were the most exposed people at this site. Trends in *total doses* in the area of the south coast (and the Severn Estuary) over time are shown in Figure 6.2. At Winfrith, *total doses* remained broadly similar from year to year, and were very low.

Source specific assessments for high-rate consumers of locally grown food, and for fish and shellfish, give exposures that were also less than 0.005 mSv in 2011 (Table 3.1). Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are disposed of from various stacks on site. Discharges of radioactive wastes from this site continued in 2011 at very low rates. The main focus of the terrestrial sampling was for the content of tritium and carbon-14 in milk, crops and fruit. Local freshwater samples were also analysed. Sampling locations at Winfrith are shown in Figure 3.5. Data for 2011 are given in Table 3.5(a). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. As in previous years, carbon-14 was detected in locally produced foods, just above background concentrations, 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.

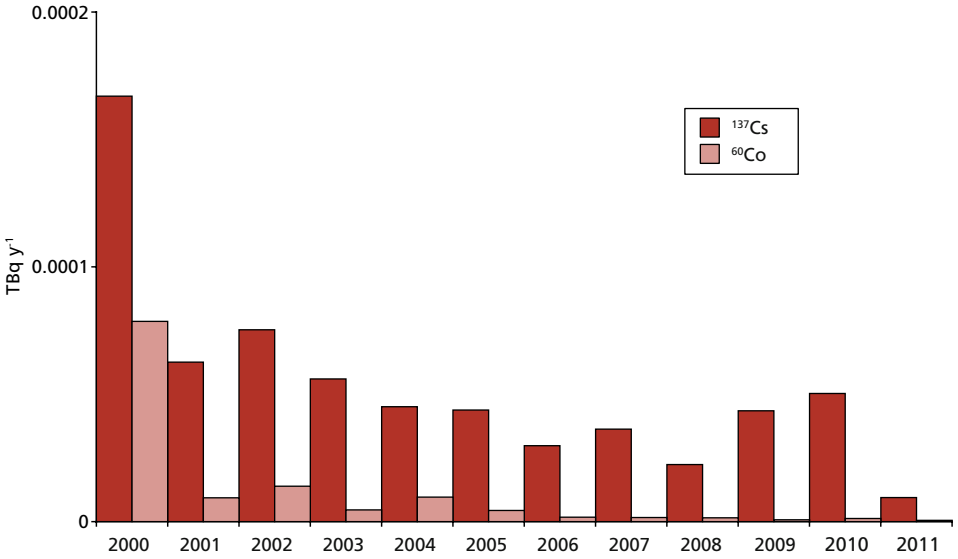


Figure 3.4. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2011

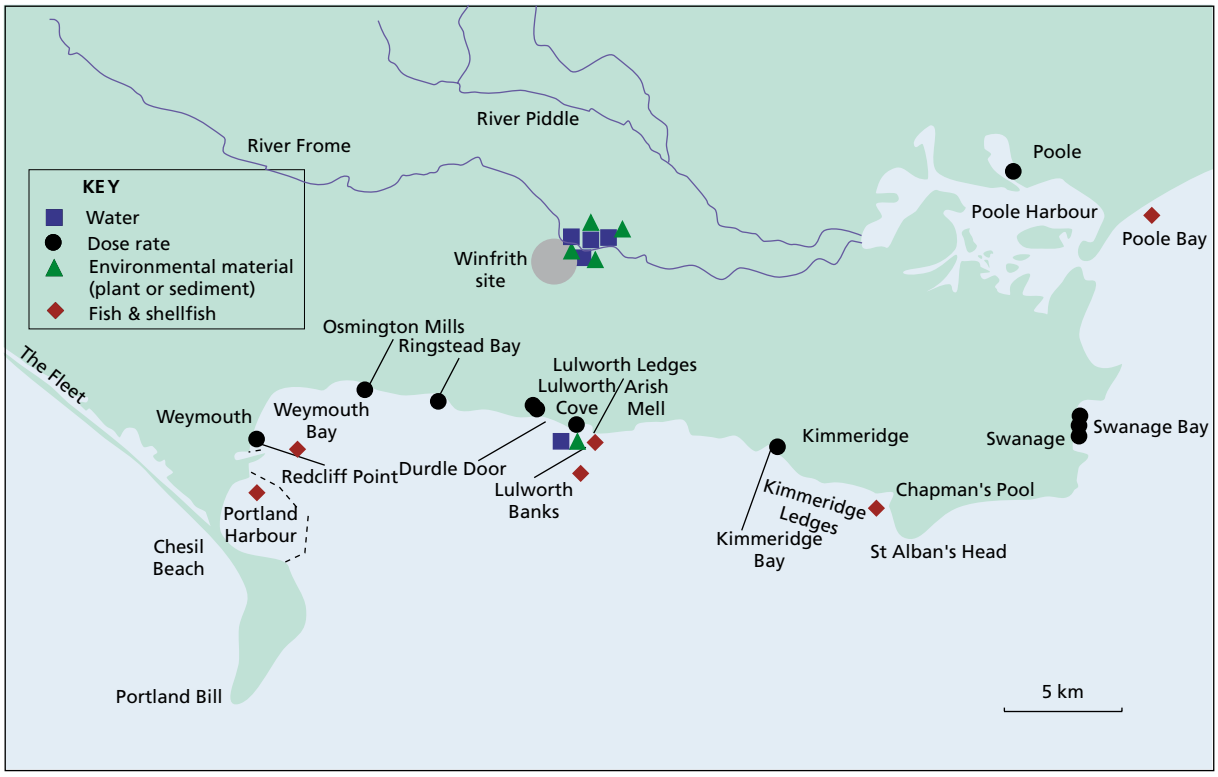


Figure 3.5. Monitoring locations at Winfrith, 2011 (not including farms)

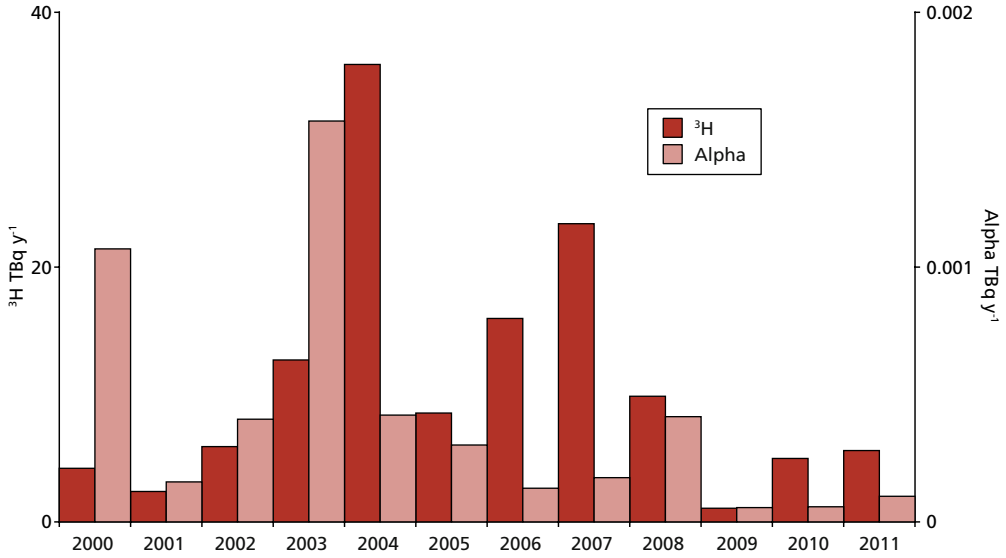


Figure 3.6. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2011

Liquid waste discharges and aquatic monitoring

Liquid wastes are disposed of under permit to deep water in Weymouth Bay. Tritium discharges from Winfrith were enhanced in comparison to most recent years. Figure 3.6 shows trends of liquid discharges over time (2000 – 2011) for tritium and alpha emitting 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.

Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Data for 2011 are given in Tables 3.5(a) and (b). 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.

3.5 Imperial College Reactor Centre, Ascot, Berkshire

The licensed reactor at Imperial College is a minor site with very low radioactive discharges, and is monitored using a small sampling programme of environmental materials.

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 2011, gaseous and aqueous discharges were very low (Appendix 2) and environmental monitoring of their effects comprises analysing a grass samples by gamma-ray spectrometry. Activity concentrations in 2011 were either close to or less than the limits of detection.

Table 3.1. Individual radiation exposures - research sites, 2011

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	Direct radiation from site
Culham								
Source specific dose	Drinkers of river water	<0.005	-	-	-	<0.005	-	-
Dounreay								
Total dose - all sources	**Infant milk consumers**	**0.018**	**-**	**0.018**	**<0.005**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.010	<0.005	-	0.009	-	-	-
	Geo occupants[b]	<0.005	-	-	<0.005	-	-	-
	Infant consumers of locally grown food	0.028	-	0.028	-	-	<0.005	-
Harwell								
Total dose - all sources	**Prenatal children of local inhabitants (0 - 0.25km)**	**0.017**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.016**
Source specific doses	Anglers	0.008	<0.005	-	0.007	-	-	-
	Infant consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005	-
Winfrith								
Total dose - all sources	**Adult occupants over sediment**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment Adults are the most exposed group unless otherwise stated*

[b] *People who visit Oigin's Geo, a coastal feature to the east of Dounreay*

Table 3.2. Concentrations of radionuclides in the environment near Culham, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Freshwater	River Thames (upstream)	2	<3.8				<0.19	<0.060	0.42
Freshwater	River Thames (downstream)	2	<3.8				<0.20	<0.065	0.45
Grass	1 km East of site perimeter	1	31	13	<1.3	<0.40	<1.2		200
Sediment	River Thames (upstream)	2					9.9		
Sediment	River Thames (downstream)	2					13		
Soil	1 km East of site perimeter	1	6.8	<4.4	4.1	<2.0	3.9		350

[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, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{54}Mn	^{60}Co	^{65}Zn	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Scrabster	2		<0.13	<0.12	<0.30			0.55
Crabs	Pipeline inner zone	4		<0.12	<0.11	<0.32	<0.10	13	<0.11
Crabs	Pipeline outer zone	4		<0.12	<0.11	<0.28		1.1	<0.10
Crabs	Strathy	4		<0.10	<0.10	<0.20			<0.10
Crabs	Kinlochbervie	3		<0.11	<0.11	<0.27		1.0	<0.12
Crabs	Melvich Bay	4		<0.10	<0.10	<0.16		0.86	<0.10
Winkles	Brims Ness	4		<0.13	<0.14	<0.28			<0.14
Winkles	Sandside Bay	3		<0.10	<0.12	<0.20	<0.10	2.6	<0.11
Mussels	Echnaloch Bay	4		<0.11	<0.11	<0.20		4.6	<0.11
Mussels	Thurso East Mains	4		<0.10	<0.10	<0.18			0.25
Fucus vesiculosus	Kinlochbervie	4		<0.10	<0.10	<0.22		36	0.20
Fucus vesiculosus	Brims Ness	4		<0.10	<0.10	<0.25			<0.11
Fucus vesiculosus	Sandside Bay	4		<0.10	<0.10	<0.16		23	<0.14
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.10	<0.18		18	<0.10
Sediment	Oigins Geo	2		<0.11	<0.13	<0.51			3.3
Sediment	Brims Ness	1		<0.10	<0.10	<0.21			1.3
Sediment	Sandside Bay	1		<0.10	<0.10	<0.22			2.2
Sediment	Rennibister	1		<0.10	<0.10	<0.33			20
Seawater	Brims Ness	4	<1.0	<0.10	<0.10	<0.15			<0.10
Seawater	Sandside Bay	4	<1.0	<0.10	<0.10	<0.18			<0.10
Spume	Oigins Geo	2		<0.13	<0.23	<0.71			3.8

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples									
Cod	Scrabster	2	<0.17	<0.17	<0.00036	0.0012	0.0031		
Crabs	Pipeline inner zone	4	<0.14	<0.25	<0.0015	0.0076	0.049	<0.85	140
Crabs	Pipeline outer zone	4	<0.12	<0.21	<0.0016	0.0064	<0.17	<2.1	<100
Crabs	Strathy	4	<0.11	<0.18	<0.00063	0.0043	0.0041	1.1	47
Crabs	Kinlochbervie	3	<0.12	<0.22	0.0011	0.0057	0.0065		
Crabs	Melvich Bay	4	<0.11	<0.14	0.00066	0.0045	0.0032		
Winkles	Brims Ness	4	<0.14	<0.23	0.014	0.062	0.060		
Winkles	Sandside Bay	3	<0.11	<0.14	0.019	0.082	0.081		
Mussels	Echnaloch Bay	4	<0.12	<0.19	0.0066	0.045	0.020		
Mussels	Thurso East Mains	4	<0.11	<0.16	<0.018	0.067	0.087		
Fucus vesiculosus	Kinlochbervie	4	<0.10	<0.16			<0.11		
Fucus vesiculosus	Brims Ness	4	<0.11	<0.18			<0.12	4.6	400
Fucus vesiculosus	Sandside Bay	4	<0.10	<0.12			<0.14	3.2	420
Fucus vesiculosus	Burwick Pier	4	<0.11	<0.15			<0.11		
Sediment	Oigins Geo	2	<0.23	<0.65	0.60	2.1	0.79		
Sediment	Brims Ness	1	<0.10	<0.17			7.8		
Sediment	Sandside Bay	1	<0.10	<0.19			9.9		
Sediment	Rennibister	1	<0.17	0.94	<0.57	0.73	0.74		
Seawater	Brims Ness	4	<0.10	<0.15			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.18			<0.11		
Spume	Oigins Geo	2	<0.31	<0.61	2.8	13	5.1		

Table 3.3(a). continued

Material	Location or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
				^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce
Terrestrial samples												
Apples			1	<5.0	<0.05	0.10	<0.05	<0.08	<0.05	<0.05	0.08	<0.06
Beef liver			1	<5.0	<0.05	<0.10	<0.13	<0.43	<0.16	<0.05	0.19	<0.25
Beef muscle			1	<5.0	<0.05	<0.10	<0.20	<0.38	<0.15	<0.05	0.21	<0.21
Goats' milk			1		<0.05		<0.10	<0.41		<0.05	<0.05	<0.23
Grain			1		<0.05	0.27	<0.21	<0.38	<0.05	<0.05	0.09	<0.28
Lamb muscle			1	<5.0	<0.05	<0.10	<0.09	<0.29	<0.26	<0.05	0.12	<0.19
Pear			1	<5.0	<0.05	0.24	<0.06	<0.23	<0.05	<0.05	<0.05	<0.15
Pheasants			1	<5.0	<0.05	<0.10	<0.05	<0.20	<0.22	<0.05	0.11	<0.12
Potatoes			1	<5.0	<0.05	<0.10	<0.08	<0.37	<0.05	<0.05	0.08	<0.25
Rabbit			1	<5.0	<0.05	<0.10	<0.08	<0.36		<0.05	1.1	<0.24
Rabbit[c]			5								<1.8	
Rabbit[c]		max									2.9	
Rhubarb			1	<5.0	<0.05	0.11	<0.13	<0.44	<0.05	<0.05	<0.05	<0.25
Rosehips			2	<5.0	<0.05	0.46	<0.10	<0.30	<0.05	<0.05	0.67	<0.21
Rosehips		max				0.69	<0.13				0.87	
Wild mushrooms			2	<5.0	<0.05	<0.10	<0.21	<0.32	<0.05	<0.05	5.1	<0.20
Wild mushrooms		max					<0.27	<0.42			9.2	<0.23
Grass			6	<5.0	<0.05	0.66	<0.15	<0.29	<0.05	<0.05	<0.10	<0.20
Grass		max				1.9	<0.24	<0.45	<0.06		0.17	<0.32
Soil			6	<5.0	<0.07	1.6	<0.24	<0.59	<0.13	<0.08	21	<0.51
Soil		max			<0.10	2.3	<0.28	<0.83	<0.21	<0.11	27	<0.80
Freshwater	Loch Calder		1	<1.0							<0.01	
Freshwater	Loch Shurrery		1	<1.0	<0.10		<0.10	<0.10		<0.10	<0.10	<0.10
Freshwater	Loch Baligill		1	<1.0	<0.01		<0.02	<0.07		<0.01	<0.01	<0.03
Freshwater	Heldale Water		1	<1.0	<0.01		<0.01	<0.05		<0.01	<0.01	<0.03

Material	Location or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
				^{155}Eu	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples												
Apples			1					<0.050	<0.050	<0.010		
Beef liver			1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Beef muscle			1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Goats' milk			1							<0.07		
Grain			1					<0.050	0.016	<0.050		
Lamb muscle			1		<0.012	<0.012	<0.012	<0.050	<0.050	<0.050		
Pear			1					<0.050	<0.050	<0.010		
Pheasants			1							<0.065		
Potatoes			1					<0.050	<0.050	<0.050		
Rabbit			1							<0.10		
Rhubarb			1					<0.050	<0.050	<0.050		
Rosehips			2					<0.050	<0.050	<0.010		
Rosehips		max										
Wild mushrooms			2					<0.050	<0.050	<0.050		
Wild mushrooms		max										
Grass			6		<0.088	<0.050	<0.075	<0.050	<0.050	<0.036		
Grass		max			0.19		0.14			<0.050		
Soil			6	1.9	28	1.2	26	<0.049	0.36	0.22		
Soil		max			63	2.5	58	<0.050	0.61	0.37		
Freshwater	Loch Calder		1								0.016	0.051
Freshwater	Loch Shurrery		1							<0.10	<0.010	0.026
Freshwater	Loch Baligill		1							<0.01	<0.010	0.040
Freshwater	Heldale Water		1							<0.01	<0.010	<0.010

[a] *Except for seawater and goats' milk where units are Bq l^{-1}, and for soil and sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'Max' in this column. 'Max' data are selected to be maxima*
If no 'max' value is given the mean value is the most appropriate for dose assessments
[c] *Ad hoc monitoring to determine typical background caesium-137 in the vicinity of the site*

Table 3.3(b). Monitoring of radiation dose rates near Dounreay, 2011

Location	Material or ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.066
Sandside Bay	Winkle bed	2	0.13
Oigin's Geo	Spume/sludge	4	0.15
Brims Ness	Shingle and stones	2	0.089
Melvich	Salt marsh	2	0.062
Melvich	Sand	2	0.054
Strathy	Sand	2	0.048
Thurso	Riverbank	2	0.084
Achreregan Hill	Soil	2	0.059
Thurso Park	Soil	2	0.085
Borrowston Mains	Soil	2	0.089
East of Dounreay	Soil	2	0.082
Castletown Harbour	Sand	2	0.085
Dunnet	Sand	2	0.060
Mean beta dose rates			μSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Thurso	Riverbank	2	<1.0
Castletown Harbour	Surface sediment	2	<1.0

Table 3.3(c). Radioactivity in air near Dounreay, 2011

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	12	<0.011	<0.010	<0.19
Reay	11	<0.011	<0.012	<0.19
Balmore	12	<0.012	<0.014	<0.19

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			^{3}H	^{60}Co	^{131}I	^{137}Cs
Freshwater samples						
Flounder	Woolwich Reach	1	<25	<0.06	*	0.06
Sediment	Appleford	4[E]		<0.65		8.1
Sediment	Outfall (Sutton Courtenay)	4[E]		<1.1		21
Sediment	Day's Lock	4[E]		<0.73	89	6.5
Sediment	Lydebank Brook	4[E]		<1.6		4.2
Freshwater	Day's Lock	4[E]	<4.1	<0.26		<0.21
Freshwater	Lydebank Brook	4[E]	<3.8	<0.24		<0.19
Freshwater	R Thames (above discharge point)	4[E]	<3.6	<0.26		<0.21
Freshwater	R Thames (below discharge point)	4[E]	<3.6	<0.26		<0.21

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross Beta
Freshwater samples							
Flounder	Woolwich Reach	1			<0.05		
Sediment	Appleford	4[E]	<0.60	<0.50	<1.5	<160	290
Sediment	Outfall (Sutton Courtenay)	4[E]	<0.60	0.72	1.8	<220	390
Sediment	Day's Lock	4[E]	<0.50	<0.40	<1.3	190	370
Sediment	Lydebank Brook	4[E]	<0.50	<0.60	1.9	<130	390
Freshwater	Day's Lock	4[E]				<0.067	0.37
Freshwater	Lydebank Brook	4[E]				<0.11	0.16
Freshwater	R Thames (above discharge point)	4[E]				<0.060	0.34
Freshwater	R Thames (below discharge point)	4[E]				<0.055	0.38

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	<4.2	<4.2	<0.20
Milk	max		<4.3	<4.3	
Apples		1	<4.0	<4.0	<0.20
Beetroot		1	<5.0	<5.0	<0.30
Blackberries		1	<4.0	<4.0	<0.20
Broad beans		1		<4.0	<0.20
Honey		1		<7.0	<0.10
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, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Grass	2	0.071
Sutton Courtenay	Grass and mud	2	0.081
Day's Lock	Grass and mud	2	0.073

Table 3.5 (a). Concentrations of radionuclides in food and the environment near Winfrith, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples							
Plaice	Weymouth Bay	2		<0.04		0.08	
Bass	Weymouth Bay	2		<0.05		0.21	
Crabs	Chapman's Pool	1		<0.09		<0.07	0.000096
Crabs	Lulworth Banks	1	39	0.15		<0.04	0.00020
Pacific Oysters	Poole	1		<0.04		<0.04	
Cockles	Poole	1		<0.09		<0.07	
Whelks	Poole Bay	1		<0.05		<0.04	0.00028
Whelks	Lyme Regis	1		<0.18		<0.14	0.00019
Scallops	Lulworth Ledges	1		<0.04		<0.03	0.00075
Clams	Portland Harbour	1		<0.12		<0.09	
Seaweed	Lulworth Cove	1[E]			9.0	<0.49	
Seaweed	Bognor Rock	2[E]		<0.43	9.6	<0.32	
Seawater	Lulworth Cove	1[E]				<0.19	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Weymouth Bay	2		<0.04				
Bass	Weymouth Bay	2		<0.08				
Crabs	Chapman's Pool	1	0.00047	0.0012	*	*		
Crabs	Lulworth Banks	1	0.00092	0.0019	*	0.000035		
Pacific Oysters	Poole	1		<0.04				
Cockles	Poole	1		<0.06				
Whelks	Poole Bay	1	0.0016	0.0021	*	0.000033		
Whelks	Lyme Regis	1	0.0017	0.0010	*	0.000023		
Scallops	Lulworth Ledges	1	0.0045	0.0020	*	0.000023		
Clams	Portland Harbour	1		<0.07				
Seaweed	Lulworth Cove	1[E]		<0.54				
Seaweed	Bognor Rock	2[E]		<0.43				
Seawater	Lulworth Cove	1[E]		<0.30			<4.7	10

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		4	<4.0	<4.0	16	<0.19	<0.20		
Milk	max				18	<0.20			
Apples		1	<4.0	<4.0	13	<0.20	<0.20		
Beetroot		1	<4.0	<4.0	11	<0.20	<0.20		
Blackberries		1	<4.0	<4.0	14	<0.20	<0.30		
Chard		1	<4.0	<4.0	7.0	<0.30	<0.20		
Honey		1		<7.0	68	<0.10	2.4		
Potatoes		1	<5.0	<5.0	11	<0.30	<0.20		
Grass		2	<5.0	<5.0	28	<0.20	<0.60		
Grass	max						1.0		
Sediment	North of site (Stream A)	1[E]				<0.18	5.7	<120	<110
Sediment	R Frome (upstream)	1[E]				<0.18	0.44	<100	<80
Sediment	R Frome (downstream)	1[E]				<0.31	4.9	200	260
Sediment	R Win, East of site	1[E]				<0.19	0.36	<70	<90
Freshwater	North of site (Stream A)	2[E]		17		<0.23	<0.20	<0.040	0.11
Freshwater	R Frome (upstream)	2[E]		<3.8		<0.23	<0.20	<0.050	0.11
Freshwater	R Frome (downstream)	2[E]		<3.8		<0.33	<0.25	<0.050	0.11
Freshwater	R Win, East of site	2[E]		<4.9		<0.26	<0.21	<0.070	0.14

* *Not detected by the method used.*

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

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

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

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

Table 3.5(b). Monitoring of radiation dose rates near Winfrith, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand	1	0.061
Red Cliffe Point to Black Head	Shingle	1	0.055
Osmington Mills	Rock and sand	1	0.064
Ringstead Bay	Pebbles and sand	1	0.056
Durdle Door	Sand	1	0.059
St Oswald's Head	Pebbles and sand	1	0.054
Lulworth Cove	Sand	1	0.058
Kimmeridge Bay	Pebbles and sand	1	0.080
Swanage Bay 1	Sand	1	0.057
Swanage Bay 2	Sand	1	0.056
Swanage Bay 3	Sand	1	0.061
Poole Harbour	Sand	1	0.054

4. Nuclear power stations

Key points

- Public radiation doses from all sources were less than or equal to 5 per cent of the dose limit for all sites assessed
- Electricity production continued at two Magnox stations (Oldbury and Wylfa) and all the EDF power stations in 2011
- Discharges, environmental concentrations and dose rates in 2011 were broadly similar to those in 2010
- Concentrations of radiocaesium and transuranic elements were enhanced around some sites. These were mainly due to discharges from Sellafield

Berkeley, Gloucestershire and Oldbury, South Gloucestershire

- Public radiation doses from all sources decreased in 2011
- At Oldbury, Reactor 2 ceased power generation in 2011
- The Oldbury discharge permit was re-issued, allowing for new waste transfer routes
- There were small decreases in public radiation doses from liquid discharges due to lower gamma dose rates in intertidal areas
- Gaseous tritium and carbon-14 discharges increased from Berkeley and gaseous discharges generally decreased from Oldbury

Bradwell, Essex

- Public radiation doses from all sources decreased in 2011
- Liquid caesium-137 and other radionuclides discharges decreased in 2011

Chapelcross, Dumfries and Galloway

- Public radiation doses from all sources increased in 2011
- As in recent years, tritium was detected in surface water around the site in 2011

Dungeness, Kent

- Public radiation doses from all sources decreased in 2011
- There were decreases in public radiation doses from liquid discharges due to lower gamma dose rates in intertidal areas in 2011
- A revised permit was issued for gaseous discharges at Dungeness A
- Gaseous tritium, sulphur-35 and argon-41 discharges, and all permitted liquid discharges, decreased from Dungeness B

Hartlepool, Cleveland

- Gaseous discharges of sulphur-35 decreased in 2011

Heysham, Lancashire

- Public radiation doses from all sources decreased in 2011
- Gaseous discharges of argon-41 and carbon-14 increased from Heysham 2. Liquid discharges of sulphur-35 increased from Heysham 1, and tritium increased from both stations

Hinkley Point, Somerset

- A permit was granted relating to discharges of waste water generated from site preparation and construction activities at the Hinkley Point C site
- Liquid discharges of tritium and other radionuclides decreased from Hinkley A

Hunterston, North Ayrshire

- Public radiation doses from all sources decreased in 2011
- At Hunterston B the authorisation was revised to allow for the disposal of solid low-level waste
- Gaseous discharges of tritium, sulphur-35 and argon-41 decreased from Hunterston B

Sizewell, Suffolk

- Gaseous discharges of carbon-14, and liquid discharges of tritium and caesium-137, increased from Sizewell B

Torness, East Lothian

- Public radiation doses from all sources decreased in 2011
- A variation to the site's discharge authorisation was granted to allow the disposal of solid waste through additional routes
- Liquid discharges of tritium increased in 2011

Trawsfynydd, Gwynedd

- Public radiation doses from all sources decreased in 2011
- There were small increases in public radiation doses from liquid discharges due to higher activity concentration in lake sediments
- Gaseous discharges of tritium increased and carbon-14 decreased in 2011

Wylfa, Isle of Anglesey

- Power generation is to continue beyond 2011
- Gaseous discharges of sulphur-35 decreased and liquid discharges of tritium increased in 2011

This section considers the results of monitoring by the Environment Agency, Food Standards Agency and SEPA from nuclear power stations. 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. The NDA (set up under the Energy Act 2005) 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 2011, the NDA published their strategy for long-term development, and in March 2012 a business plan for 2012/15 was published (Nuclear Decommissioning Authority, 2011; 2012).

In 2010, Magnox power stations were managed by two Site Licence Companies: Magnox North Limited and Magnox South Limited; the former being the operator for Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa; the latter being the operator for Berkeley, Bradwell, Dungeness A, Hinkley Point A and Sizewell A. In September 2010, Magnox North Limited applied to transfer the EPR 10 permits from Magnox South Limited sites in order to facilitate restructuring of the management of the ten Magnox sites under one Site Licence Company. At the same time (under the Nuclear Installations Act 1965) it applied to transfer the nuclear site licences for the five Magnox South sites. Magnox North and Magnox South were recombined into one entity as Magnox Limited in January 2011.

Magnox Limited is owned and operated by Energy Solutions on behalf of the NDA. During 2011, only two of these Magnox stations (Oldbury and Wylfa) continued to generate electricity, others are in the process of de-fuelling or decommissioning. In October 2011, Magnox produced the Magnox Integrated Waste Strategy summarising the key waste management issues and opportunities for the ten nuclear licensed sites operated by Magnox Limited.

Calder Hall is operated by Sellafield Limited and discharges from this magnox power station 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 2011. The parent company British Energy Group plc, acquired by Électricité de France (EDF) Energy in early 2009, continued as a wholly owned subsidiary of EDF until June 2011. By July 2011, the renaming of the operating company from British Energy Generation Limited to EDF Energy Nuclear Generation Limited was concluded. EDF Energy Nuclear Generation Limited 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. All of these were generating electricity during 2011.

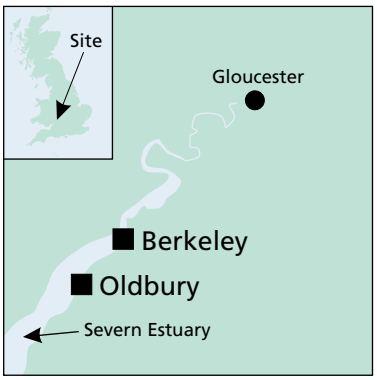
Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency for England and Wales, and by SEPA for Scotland. In 2011, gaseous and liquid discharges were below regulated limits for each of the power stations (see Appendix 2). Independent monitoring of the environment 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.

The medium-term trends in dose, discharges and environmental concentrations at these sites were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

The sites are grouped in this Section according to whether they are in England, Scotland or Wales.

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire



Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station is situated on the eastern bank of the River Severn 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 a corporate support centre for the Company including providing technical expertise and support across the Company.

The Oldbury Power Station is located on the south bank of the River Severn close to the village of Oldbury-on-Severn and has two Magnox reactors. Oldbury Power Station ceased to be an electricity generator on 29 February 2012, with the closure of Reactor 1. Reactor 2 was previously shut-down in June 2011. A major part of the Oldbury site (32 hectares) was de-licensed by ONR and a variation to the licence was issued and came into force on 3 June 2011. In November 2011, the Environment Agency re-issued the permit to allow for new waste transfer routes, following a variation application by the operator.

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

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.006 mSv in 2011 (Table 4.1), which was approximately 0.5 per cent of the dose limit, and down from 0.011 mSv in 2010. The lower value in 2011 was due to a decrease in the direct radiation from the site. The dose assessment identifies the prenatal children of local inhabitants as the most exposed age group. The dose received was from external exposure over intertidal areas (in contrast to direct radiation in 2010). The trend in the *total dose* over the period 2004 – 2011 is given in Figure 4.1. Any variations in *total doses* with time were attributed to changes in the contribution from direct radiation.

The source specific assessment for consumers of locally grown foods, at high-rates, gives exposures less than the *total dose* in 2011. The dose to consumers of fish and shellfish was estimated to be 0.008 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This includes external radiation, a component due to the tritium historically originating from GE Healthcare at Cardiff, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The dose in 2010 was 0.012 mSv, and the decrease in 2011 was mostly due to a decrease in gamma dose rates near the Oldbury site.

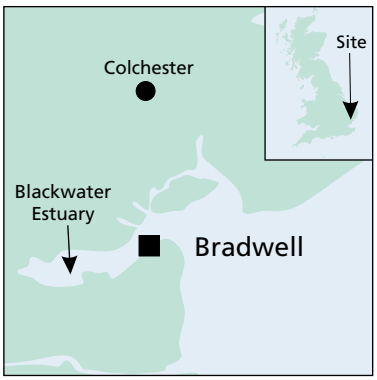
Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. Discharges of tritium and carbon-14 from Berkeley increased in 2011, compared with 2010, whilst discharges generally decreased from Oldbury. 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 2011 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. 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 historic discharges from the GE Healthcare radiopharmaceutical plant in Cardiff (see Section 6). Data for 2011 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 were smaller in 2011 compared to 2010 at a few sites (including 1 km south of Oldbury). Most of the artificial radioactivity detected was due to caesium-137. 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 4.2), with a suggestion of a small peak in 2004. In 2011, tritium concentrations in fish were measured below the LoD. In recent years, these activities have been relatively high and were likely to be mainly due to historic discharges from GE Healthcare, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance.

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 2002 after 40 years of operation, and defuelling was completed in 2006. The focus for the site is now the completion of decommissioning projects. The most recent habits survey was undertaken in 2007 (Tipple *et al.*, 2008).

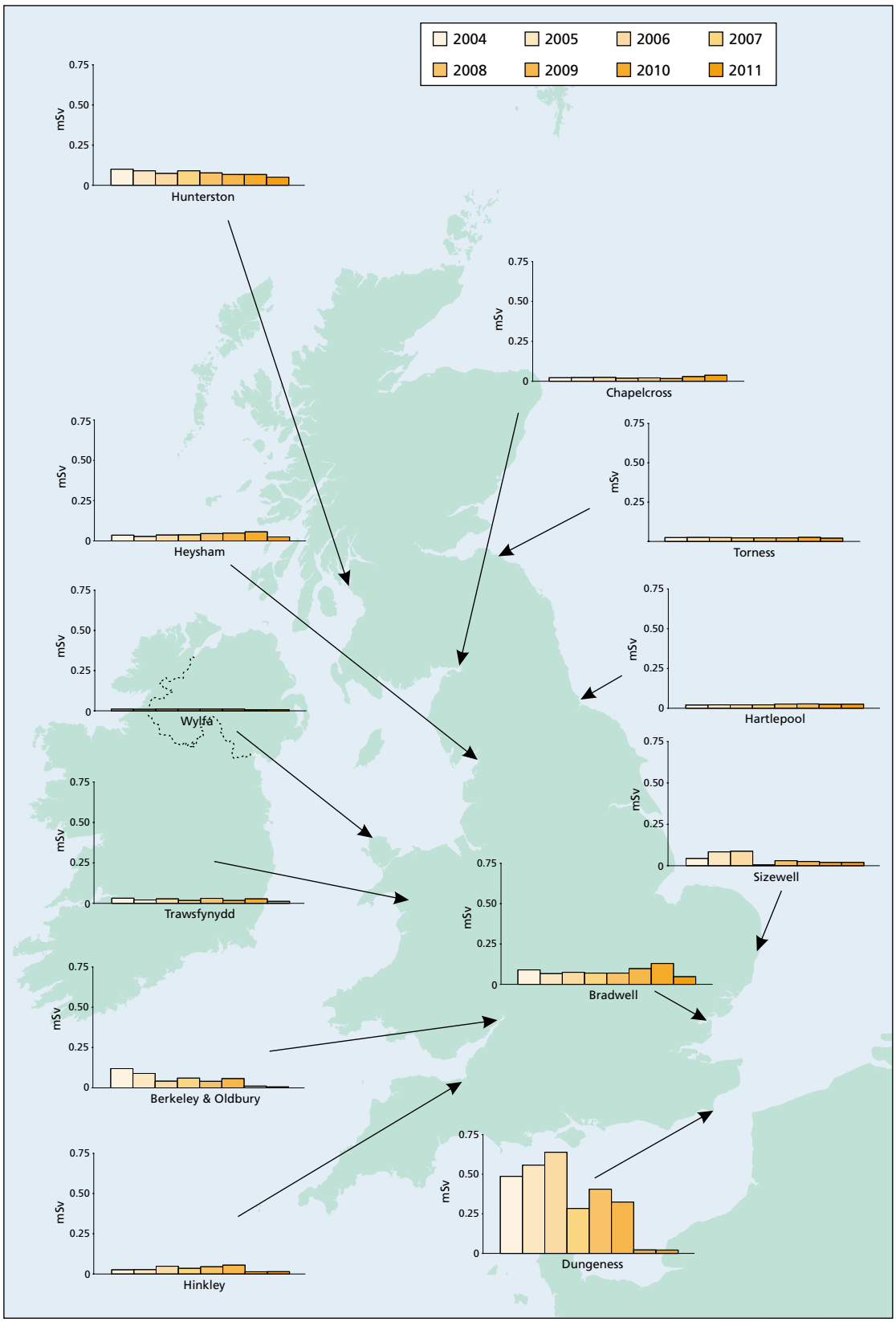


Figure 4.1. *Total dose* at nuclear power stations, 2004-2011
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.048 mSv in 2011 (Table 4.1), which was less than 5 per cent of the dose limit for members of the public of 1 mSv, and a decrease from 0.13 mSv in 2010. Direct radiation was the dominant contributor to this dose, and the dose assessment identifies prenatal children of local inhabitants as the most exposed age group. The lower value in 2011 was due to a decrease in the estimate of direct radiation from the site. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. Any variations in *total dose* with time were attributed to changes in the estimate of direct radiation.

Source specific assessments for both consumers of locally grown foods and for fish and shellfish, at high-rates, give exposures that were less than the *total dose* in 2011 (Table 4.1).

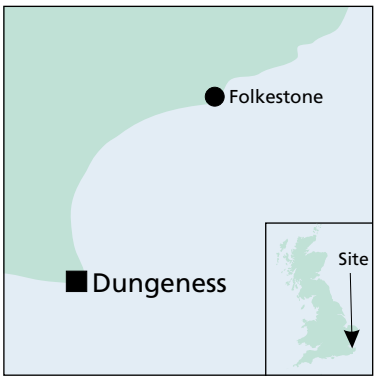
Gaseous discharges and terrestrial monitoring

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 2011 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}). Tritium concentrations in coastal ditches were similar to those in 2010, 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. Discharges of caesium-137 and other radionuclides continued to decrease in 2011, in comparison to the previous two years. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. Seaweeds were analysed as an environmental indicator material and leaf beet was collected because it is eaten locally and grows in areas that become tidally inundated. Data for 2011 are given 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; however concentrations were generally similar to those for 2010. There is an overall decline in caesium-137 concentrations in sediments (Figure 4.2). 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.

4.3 Dungeness, Kent



The Dungeness power stations are located on the south Kent coast between Folkestone and Rye. 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. Dungeness A ceased generating electricity in 2006. As part of the decommissioning process, both Magnox reactors continued to be defuelled in 2011 (this was completed in 2012) with the spent fuel being dispatched to Sellafield (Cumbria) for reprocessing. In 2011, there were prolonged periods of time when both reactors at Dungeness B were shut-down therefore resulting in a decrease in radioactive discharges. It is estimated that Dungeness B will end power generation by 2018. The most recent habits survey was undertaken in 2010 (Clyne *et al*., 2011d).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was 0.021 mSv (Table 4.1), or approximately 2 per cent of the dose limit of 1 mSv, and unchanged from 2010. As in recent years, this is almost entirely due to direct radiation from the site. Adults living near to the site were the most exposed people. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* ranged between 0.021 and 0.63 mSv, over the time period and were dominated by direct radiation. Following the shut down of the Magnox reactors in 2006, this dose has significantly declined.

Source specific assessments for high-rate consumers of locally grown foodstuffs, for local bait diggers and houseboat occupants, give exposures that were less than the *total dose*. 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 0.007 mSv, which was less than 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). The decrease in dose (from 0.014 mSv

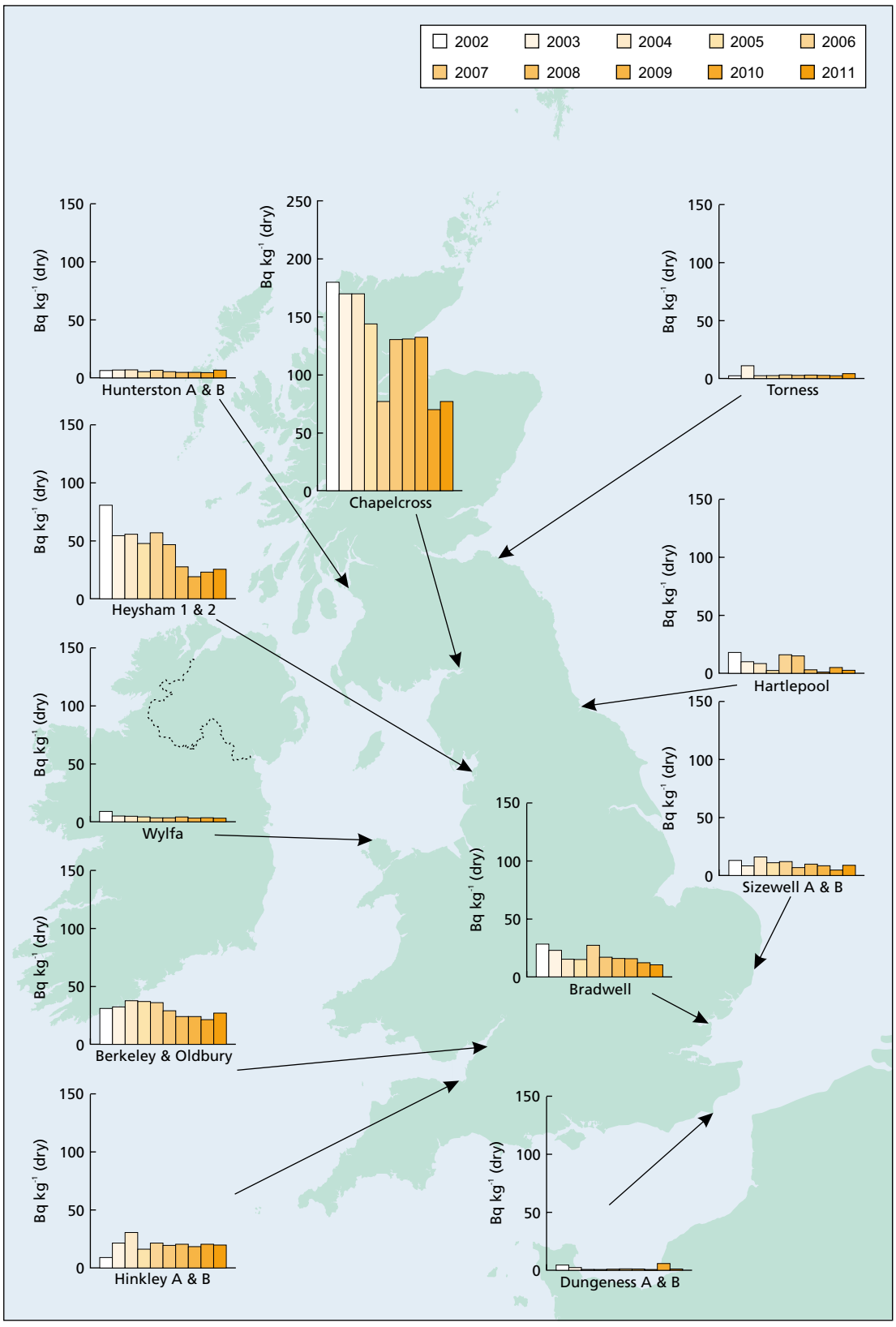


Figure 4.2. Caesium-137 concentration in marine sediments near nuclear power stations between 2002-2011

in 2010) was due to an overall reduction in gamma dose rate measurements taken at Dungeness East in 2011.

Gaseous discharges and terrestrial monitoring

In 2011, the Environment Agency revised the permit at Dungeness A, with gaseous discharges of sulphur-35 and argon-41 no longer in the permit. Discharges of tritium, sulphur-35 and argon-41 decreased from Dungeness B, in comparison to releases in 2010. Total discharges of carbon-14 did not change significantly between 2010 and 2011. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. The results of monitoring for 2011 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the limits of detection. Small enhancements of carbon-14 concentrations, above expected background, were observed in most foodstuffs in 2011. 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

All permitted discharges decreased from Dungeness B, in comparison to releases in 2010. Marine monitoring included gamma dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2011 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 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 except in whiting (measured just above the LoD). Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2); the apparent increase in 2010 was due to the inclusion of a value (< 5.8 Bq kg^{-1}) which was reported as below the analytical limit of detection. Gamma dose rates were generally difficult to distinguish from the natural background, but there was an overall reduction in rate measurements at Dungeness East in 2011.

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 continue until at least 2019. The most recent habits survey was conducted in 2008 (Garrod *et al.*, 2009).

Doses to the public

As in 2010, the *total dose* from all pathways and sources of radiation was 0.025 mSv in 2011 (Table 4.1), which was less than 3 per cent of the dose limit. The most exposed people were adults living near to the site whose dose was from direct radiation from the site and, to lesser extent, external exposure from activity in sand and sediment on local beaches. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both high-rate consumers of locally grown foodstuffs, and for consumers of fish and shellfish, give exposures that were less than the *total dose*. The dose to local fish and shellfish consumers, including external radiation, was 0.009 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This dose was similar to that in 2010 (0.008 mSv), the small increase was mostly due to higher gamma dose rates reported in 2011. Higher gamma dose rates in 2011 also increased the dose received from people collecting sea coal at Carr House from 0.007 mSv in 2010 to 0.012 mSv in 2011.

Gaseous discharges and terrestrial monitoring

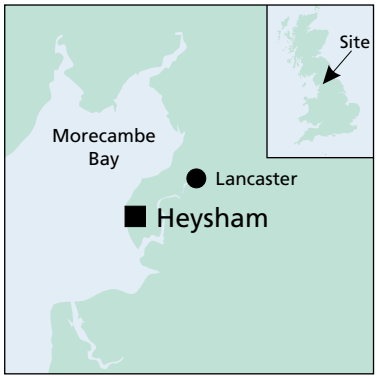
Gaseous radioactive waste is discharged via stacks to the local environment. Discharges of sulphur-35 decreased in 2011, compared with 2010, discharges of other radionuclides were broadly comparable. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. Samples of water are also taken from a borehole and public supplies. Data for 2011 are given in Table 4.5(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though small enhancements of sulphur-35 concentrations in a few terrestrial samples were apparent. Also, a few of the carbon-14 concentrations were enhanced relative to the default values used to represent background levels (blackberries and honey).

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. Results of the aquatic monitoring programme conducted in 2011 are shown in Tables 4.5(a) and (b). Small enhancements of carbon-14 concentrations, above expected background, were observed in some seafood samples (plaice and mussels). Enhancements are most likely to be due to carbon-14 discharges from a nearby non-nuclear site since carbon-14 discharges from the power station are low. The reported carbon-14 concentration in mussels decreased again in 2011, in comparison to that in 2010, and is the lowest value in recent years. Technetium-99 analysis in seaweed is used as a specific indication of the far-field effects of disposals to sea from Sellafield. Concentrations in seaweed (*Fucus vesiculosus*) were low and much less than the peak observed in 1998 (see also Figure 2.8). They are less than 1 per cent of the equivalent concentrations near Sellafield. Unlike in recent years, iodine-131 was not positively detected in samples of seaweed collected around the mouth of the River Tees Estuary in 2011. The detected values in previous years are believed to originate from the therapeutic use of this radionuclide in a local hospital. Detectable concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. In 2011, the lead-210 and polonium-210 concentrations were close to natural background. Overall, small increases in gamma dose rates were measured in 2011, compared to those in 2010.

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 continue to generate electricity until at least 2019 and 2023, respectively. Disposals of radioactive waste from both stations are made under permit via separate outfalls to Morecambe Bay and via stacks, but for the purposes of environmental monitoring both stations are considered together. During August and September 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Garrod *et al.*, 2012). A small increase in the fish and mollusc consumption rates has been observed, together with a decrease in the crustacean rate, in comparison with those of the previous survey in 2006. In 2011, two high-rate groups were identified for radiation exposure from aquatic pathways, each with an occupancy rate (over sand and salt mash). A lower occupancy rate over local beaches has been observed in comparison to the rate over mud in the previous habits survey. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.025 mSv in 2011 (Table 4.1), down from 0.057 mSv in 2010. This was less than 3 per cent of the dose limit for members of the public. The most exposed people in 2011 were adults who consume molluscs at high-rates and this represents a change in the most exposed people (from adults in 2010, who spend a large amount of time on sand and sediments). The decrease in *total dose* (from 2010) was due to a lower occupancy rate over local beaches in 2011. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. Any changes in *total doses* with time prior to 2011 were attributed to environmental variability (in measurements of gamma dose rates).

Source specific assessments for both high-rate terrestrial food consumers and fisherman give exposures that were less than the *total dose* (Table 4.1). The estimated dose to terrestrial food consumers in 2011 was 0.007 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv. The increase in dose from 0.005 mSv (in 2010), was mostly due to enhanced carbon-14 concentrations in milk in 2011. The dose in 2011 to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.034 mSv, which was approximately 3 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). In 2010, the dose was 0.046 mSv, and the decrease in 2011 was due to a lower occupancy rate (over sand). In 2011, a new assessment was undertaken to determine the external exposure for turf cutters over salt marsh at Heysham (as identified in the recent habits survey). The estimated dose was 0.018 mSv for this activity (Table 4.1).

Gaseous discharges and terrestrial monitoring

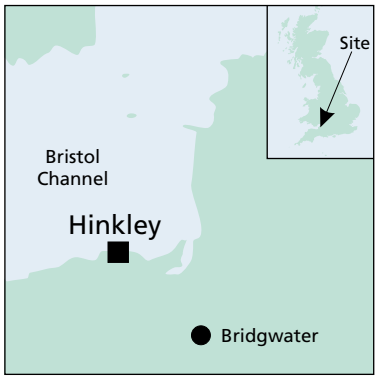
Discharges of argon-41 and carbon-14 at Heysham 2 increased in 2011, compared with 2010; discharges of other radionuclides were broadly comparable (including those from Heysham 1). The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. Data for 2011 are given in Table 4.6(a). The effects of gaseous disposals were difficult to detect in 2011, although carbon-14 concentrations were generally increased in foodstuffs (in comparison to those in 2010) and most were above the default values used to represent background levels in 2011. Small enhancements of concentrations of sulphur-35 were

apparent in some samples and measured activities of cobalt-60 were below the LoD.

Liquid waste discharges and aquatic monitoring

Discharges of sulphur-35 increased from Heysham 1 and tritium discharges increased from both stations (compared with 2010), discharges of other radionuclides were broadly comparable. 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 2011 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2010 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. An elevated tritium concentration was measured in a seawater sample collected during 2011 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. 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 generally in decline (Figure 4.2). Gamma dose rates over intertidal sediment were generally similar to measurements in recent years. No gamma dose measurements were taken at Heysham pipelines in 2011.

4.6 Hinkley Point, Somerset



The Hinkley Point Power Station sites are 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. It is estimated that Hinkley Point B will end power generation by 2016. Environmental monitoring covers the effects of the two power stations together. In 2011, EDF Energy's and Centrica's joint venture company, NNB Generation Company Limited (NNB GenCo) applied for an environmental permit relating to discharges of waste water generated from site preparation and construction activities at their Hinkley Point site. Following a public consultation, the Environment Agency granted a permit to NNB Generation Company Limited on 29 February 2012. The most recent habits survey was conducted in 2010 (Clyne *et al*, 2011e).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.014 mSv (Table 4.1), or less than 2 per cent of the dose limit, and unchanged from 2010. Adults who spend a large amount of time on local beaches were the most exposed people. The trend in *total dose* over the period 2005 – 2011 is given in Figure 4.1.

Source specific assessments for consumers of locally grown food and for fish and shellfish (excluding external exposure), at high rates, give exposures that were less than the *total dose* (Table 4.1). The dose to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.020 mSv in 2011, which was 2 per cent of the dose limit for members of the public of 1 mSv, and unchanged from 2010. 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).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. Data for 2011 are given in Table 4.7(a). Activity concentrations of tritium and gamma emitters (including caesium-137) in terrestrial materials were mostly below, or at, 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 in 2011 were higher than the default values used to represent background levels (milk, apples and blackberries). Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water.

Additional programme of soil analyses

In January 2011, allegations were made that soil at the Hinkley Point site was contaminated with enriched uranium from nuclear fuel. The Environment Agency considered that there is no route by which uranium from irradiated fuel could have been released and dispersed from the site without large amounts of other radionuclides (fission products) being released simultaneously. These releases would have been detected in the routine monitoring carried out by the operators and regulators.

However, public concerns were caused by these allegations. Therefore the Environment Agency undertook soil sampling and radioanalysis to provide scientific information to determine whether or not uranium contamination is present on the Hinkley Point site. To investigate these allegations, 20 soil samples were taken (in total) on the proposed site of Hinkley Point C, and at three farms several kilometres away from the site. The samples were independently analysed by GAU-Radioanalytical (Geosciences Advisory Unit, part of the National Oceanography Centre, Southampton) using Inductively Coupled Plasma Mass Spectrometry (ICPMS). ICPMS is an analytical method capable of accurately measuring the uranium isotopes present in the soil. The results of the sampling and analyses are given in Table 4.7(c) and indicate that the isotopic ratios of uranium-235 and uranium-238 were around 21.5, with one result of 22.6. Variability in the measured concentrations of uranium was also found. Uranium-238 concentrations, for example, ranged from 35.6 Bq kg^{-1} to 60.5 Bq kg^{-1}.

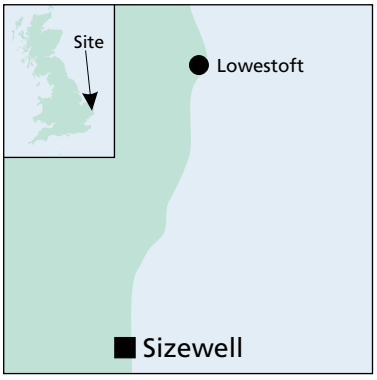
The results provide the expected isotopic ratios for natural uranium (i.e. no enriched uranium was present) and the overall levels of uranium are in the range reported by the British Geological Survey for UK soils.

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. Discharges of tritium and other radionuclides at Hinkley Point A decreased in 2011, in comparison to 2010; discharges of other permitted radionuclides were broadly comparable (including those from Hinkley Point B). 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 historic discharges from the GE Healthcare plant at Cardiff.

The environmental results for 2011 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 recent years (see also Figure 4.2). Concentrations of tritium in shellfish in 2011 were decreased in comparison to those in 2010. Further information on tritium concentrations in seawater from the Bristol Channel is given in Section 9. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors to the aquatic environment are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl fallout. Apportionment is generally difficult at the low concentrations detected. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Overall, gamma radiation dose rates over intertidal sediment were generally similar to measurements in recent years.

4.7 Sizewell, Suffolk



The two Sizewell Power Stations are located on the Suffolk coast, near Leiston. The A station has two Magnox reactors whilst the B station is the UK's only commercial PWR power station. The B station began operation in 1995 and it is estimated that it will end power generation by 2035. Sizewell A power station ceased to be an electricity generator in 2006 and has begun defuelling (completion expected in 2013) as part of the site's decommissioning plan. The most recent habits survey was conducted in 2010 (Garrod *et al*., 2011).

Doses to the public

As in 2010, the *total dose* from all pathways and sources was 0.021 mSv in 2011 (Table 4.1) or 2 per cent of the dose limit. The dominant contribution to *total dose* at this site was from direct radiation. 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. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. The *total dose* declined at the end of 2006, following the closure of the Magnox reactors at Sizewell A.

Source specific assessments for both high-rate consumers of locally grown foodstuffs, and fish and shellfish, and from external exposure for houseboat dwellers, give exposures that were less than the *total dose* in 2011 (Table 4.1).

Gaseous discharges and terrestrial monitoring

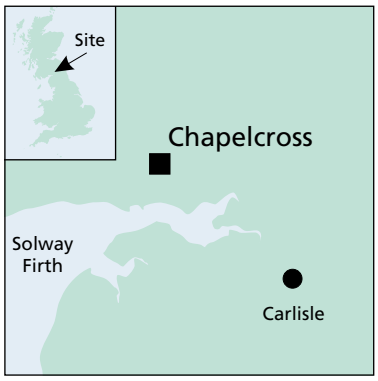
Gaseous wastes are discharged via separate stacks to the local environment. Carbon-14 discharges in 2011 increased from Sizewell B in comparison to 2010. The results of the terrestrial monitoring in 2011 are shown in Table 4.8 (a). Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit generally showed very low concentrations of artificial radionuclides near the power stations in 2011. Tritium concentrations in local freshwater were all low, although activities at the Leisure Park were positively detected at the LoD (but lower than in 2010). Carbon-14 concentrations in foods in 2011 were generally similar to those in 2010. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made via outfalls to the North Sea. Tritium and caesium-137 discharges increased from Sizewell B in comparison to 2010. In the aquatic programme, analysis of seafood, sediment, and seawater, and measurements of gamma dose rates were conducted in intertidal areas. Data for 2011 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.

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 2013. The major hazards on the site will now be decommissioned early, by 2017.

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey was conducted in 2010 (Clyne *et al.*, *in press*). 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.*, 2011b). The results of this survey are used to determine the potential exposure pathways relating to permitted liquid discharges from the Sellafield nuclear site in Cumbria (see Section 2.3.1).

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.037 mSv in 2011 (Table 4.1), which is less than 4 per cent of the dose limit. As in 2010, infants consuming milk at high-rates were the most exposed people. The increase in dose from 0.029 mSv (in 2010) was mostly attributable to the increased value for the maximum carbon-14 concentration in milk in 2011. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for high-rate consumers of seafood (crustaceans), and for wildfowlers, give exposures that were less than the *total dose* in 2011 (Table 4.1). The annual dose for high-rate terrestrial food consumers was estimated to be 0.025 mSv in 2011. The increase in dose in 2011 (from 0.021 mSv in 2010) was mostly due to the increased value for the maximum carbon-14 concentration in milk, and to a lesser extent, a higher reported LoD for sulphur-35 in milk in 2011.

A consideration of the discharges from Chapelcross indicates that they contribute a very small fraction of the dose to the local population from seafood consumption and occupancy over salt marsh; the greater proportion of the dose can be attributed to the emissions from Sellafield.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit, crops and game, as well as grass, soil and freshwater 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 2011 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 recent years. The maximum concentration of carbon-14 in milk was 35 Bq l^{-1} and higher than the value in 2010 (28 Bq l^{-1}). 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 at or below the LoD with the exception of an elevated tritium concentration in honey (89 Bq l^{-1}). Activity concentrations in air samples at locations near to the site were below the LoD (Table 4.9(c)).

Further sampling and analysis of the local surface waters in and around the Chapelcross site showed comparable enhanced results with those reported previously (Scottish Environment Protection Agency, 2009). Little evidence for organically bound tritium (OBT) was found in the environmental samples analysed for OBT (tritium mostly determined as tritiated water). Weekly sampling and analysis for tritium of rainwater deposited close to the village of Creca was continued in 2011 (from May 2011). As in 2010, the levels of tritium were measured above the detection limit, but do not account for the current levels of tritium observed in local surface waters. Rainfall sampling is being continued in the routine monitoring programme for a further year.

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 2011 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 and gamma dose rates remained at similar levels to those detected in recent years, with the exception that increases were measured for plutonium radionuclides and americium-241 in winkles and flounder in 2011. Concentrations of technetium-99 in biota were generally similar to those observed in 2010. Measurements of the contact beta dose rate on stake nets were below the LoD.

Between 1992 and 2009, a number of particles were found at the end of the discharge outfall consisting of lime-scale originating from deposits within the pipeline. Magnox Limited continues to monitor this area frequently and no particles were found during 2011(as with 2010). The relining of the pipeline and grouting at strategic points, which was undertaken in 2009/2010, has reduced the potential for particles to be released.

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 A was powered by twin Magnox reactors until it ceased electricity production in 1990. Hunterston B is powered by a pair of AGRs and is expected to cease electricity generation in 2016. However, EDF is seeking to extend the life of the plant beyond this date. Environmental monitoring in the area considers the effects of both sites together.

As reported last year, in September 2010, contaminated silt originating (from an area of contaminated land on the Hunterston A site) was washed out of two coastline outfalls during a period of extremely high rainfall. This resulted in SEPA issuing a Final Warning Letter to Magnox North Limited in December 2010. During 2011, Hunterston A carried out an optioneering study to determine the best option to prevent any future escape of contaminated silt onto the foreshore and have decided to contain the contamination *in situ* by installing a grout curtain. This work will be carried out in 2012.

In May 2011, SEPA varied the authorisation for Hunterston B to allow solid low-level waste to be consigned to: (i) the Low Level Waste Repository (LLWR); (ii) the Sellafield Site Operator; (iii) the Winfrith Site Operator; (iv) the Hythe Incinerator Operator, for disposal in accordance with the permits held by those operators. This variation permits the possible onward consignment of waste to a disposal site authorised to receive such waste.

The most recent habits survey was undertaken in 2007 (Sherlock *et al.*, 2011).

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.050 mSv in 2011 (Table 4.1), which is 5 per cent of the dose limit, and down from 0.067 mSv in 2010. The dose was mainly from direct radiation from the site, and the most exposed people were the prenatal children of local inhabitants. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. The decrease in *total dose* in recent years reflected a downward trend in the reported direct radiation.

Source specific assessments for high-rate consumers of both locally grown food and local seafood give exposures that were generally unchanged from 2010 and less than the *total dose* in 2011 (Table 4.1).

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. Discharges of tritium, sulphur-35 and argon-41 decreased from Hunterston B, in comparison to releases in 2010. There is a substantial terrestrial monitoring programme which includes the analyses of a comprehensive range of wild and locally produced foods. In addition, air, freshwater, grass and soil are sampled to provide background information. The results of terrestrial food and air monitoring in 2011 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. However, in 2011, strontium-90 was positively detected in soil samples (but not in grass). Activity concentrations in air at locations near to the site were below the LoD (Table 4.10(c)).

Liquid waste discharges and aquatic monitoring

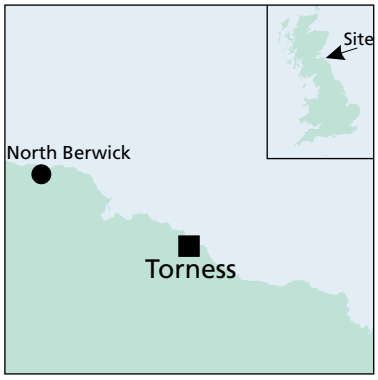
Authorised liquid discharges are made to the Firth of Clyde by Hunterston B via the stations' cooling water outfall. Discharges from Hunterston B were generally similar to those in 2010. Authorised liquid discharges from Hunterston A are also made via the same outfall. The main part of the aquatic monitoring 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 and to facilitate the draining and decommissioning of the cartridge cooling pond. Commissioning trials continued during 2011 with the first discharge of cooling pond water made in November 2011. The plant will enter full service in 2012, commencing with the emptying of the cooling pond, which will result in routine discharges of cooling pond water.

The results of aquatic monitoring in 2011 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 very low (just above the LoD). In contrast, the technetium-99 concentrations in lobsters increased in 2011, in comparison to most recent years. Small concentrations of activation products (silver-110m and cobalt-60) that are likely to have originated from the site were also detected (in foodstuffs and seaweed), but were of negligible radiological significance. Gamma dose rates were similar to those in 2010.

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. In July 2011, British Energy Generation Limited changed its company name to EDF Energy Generation Limited. This did not require any change to the extant authorisations.

As reported last year a variation to the 2007 authorisation was granted by SEPA in the early part of 2011, to allow the disposal of solid wastes through additional routes, but did not change gaseous and liquid discharge limits (Scottish Environment Protection Agency, 2011). These additional routes were used during the year for the disposal of desiccant and for the recycling of metal wastes. The liquid and gaseous discharges from the site are given in Appendix 2.

During June and July 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al.*, *in press*). An increase in the fish and mollusc consumption rates has been observed, together with a decrease in the crustacea consumption rate, in comparison with those of the previous survey in 2006. Occupancy and handling rates also increased in 2011. Revised figures for consumption rates, together with occupancy and handling rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was 0.020 mSv (Table 4.1) or 2 per cent of the dose limit. Direct radiation was the dominant contributor to this dose, and the most exposed people were adults. In 2010, the *total dose* was higher at 0.025 mSv, and the most exposed people were adults consuming local root vegetables. The decrease was due to americium-241 concentrations in vegetables being excluded from the assessment in 2011 (americium-241 was positively detected in one terrestrial sample and therefore included in 2010). The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for high-rate consumers of both locally grown foods and local fish and shellfish give exposures that were less than the *total dose* in 2011 (Table 4.1). The estimated dose to terrestrial food consumers was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv. The reason for the decrease in dose in 2011 (from 0.014 mSv in 2010) is the same as that for *total dose*. The dose to people consuming fish and shellfish was less than 0.005 mSv.

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), were not sampled in 2011. Air sampling at two locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2011 are given in Tables 4.11(a) and (c). As in the previous two years, 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. In 2011, americium-241 concentrations, measured by gamma–ray spectrometry were below the LoD. Measured concentrations of radioactivity in air at locations near to the site were below the LoD (Table 4.11(c)).

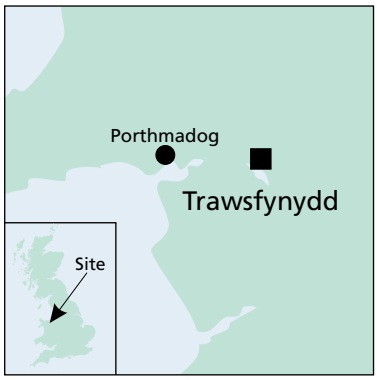
Liquid waste discharges and aquatic monitoring

Discharges of tritium increased, in comparison to releases in 2010. 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 2011 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 2010. Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates over intertidal areas were generally indistinguishable from natural background and were similar to those measured in recent years.

WALES

4.11 Trawsfynydd, Gwynedd



Trawsfynydd Power Station is located on the northern bank of an inland lake in the heart of Snowdonia National Park, North Wales and 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. Monitoring is conducted on behalf of the Welsh Government. The most recent habits survey was undertaken in 2005 (Tipple *et al.,* 2006).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.012 mSv in 2011 (Table 4.1), which was approximately 1 per cent of the dose limit, and down from 0.029 mSv in 2010. The lower value in 2011 was due to a decrease in the direct radiation from the site. Adults were the most exposed people and a change from 2010 (infants living near to the site). In 2011, the majority of the dose was received from the consumption of fish combined with external exposure from activity in lakeside sediment. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for consumers of both locally grown foods and for anglers, at high-rates, give exposures that were less than the *total dose* in 2011 (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 2011, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv. The observed activity 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 0.006 mSv in 2010 was due to the higher activity concentrations in lake sediments in 2011.

Gaseous discharges and terrestrial monitoring

In 2011, the discharges of tritium were increased, and carbon-14 decreased, in comparison to 2010. 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 2011, concentrations of carbon-14 were generally higher than the default values used to represent background levels, particularly in animal samples, in comparison to those in 2010. As in previous years, measured activities of caesium-137 in terrestrial foods were mostly below the LoD, blackberries being the exception measured just above the LoD. The most likely source of radiocaesium 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 2011.

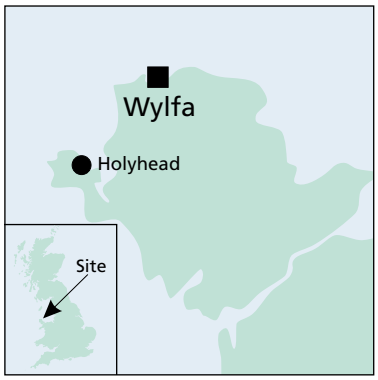
Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. In 2011, discharges of strontium-90 were nil (as in 2010). 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 the 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 2011 are given in Tables 4.12(a) and (b). Concentrations of radiocaesium in fish in 2011 were similar to those in 2010. 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 were also detected, particularly in lake sediments (in recent years' monitoring, it has been demonstrated that these increase with depth beneath the sediment surface). In the lake sediments, caesium-137 concentrations were increased in comparison to 2010, but generally similar to those in previous years. However, strontium-90, americium-241 and plutonium radionuclide concentrations were the highest levels at two locations (Bailey Bridge and fish farm) over a number of years (~ 5 years) and europium-154 was positively detected just above background in one sediment sample. Nevertheless, strontium-90 and transuranic concentrations in fish continue to be very low in 2011 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, although there is limited evidence to suggest that rates were slightly higher in comparison to those in earlier years. The predominant radionuclide was 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. In the earlier part of the last decade, the observed concentrations were mainly affected by sample variability. In more recent years, with sustained reductions in discharges of caesium-137, there is now a suggestion of progressive decreases in these concentrations in sediments, with the lowest concentrations reported in 2010.

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. Magnox North Limited requested a short-term life extension (for a few additional years) to continue power generation at Wylfa beyond December 2010 (the date previously scheduled for the cessation of generating electricity). Wylfa Site's Reactor 2 ceased generating electricity on the 25 April 2012, in line with the station's agreed operating plan. Efforts are now focusing on optimising generation on Reactor 1, which will be allowed to operate until 2014. Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is conducted on behalf of the Welsh Government. The most recent habits survey was undertaken in 2009 (Garrod *et al.*, 2010).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.008 mSv in 2011 (Table 4.1), which was less than 1 per cent of the dose limit, and unchanged from 2010. The most exposed people were local adults consuming marine plants and algae. The trend in *total dose* over the period 2004 – 2011 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both consumers of locally grown foods and for fish and shellfish, at high-rates, give exposures that were less than the *total dose* in 2011 (Table 4.1). The dose to high-rate consumers of fish and shellfish (including external radiation) was 0.010 mSv, which was 1 per cent of the dose limit for members of the public of 1 mSv.

Gaseous discharges and terrestrial monitoring

Discharges of sulphur-35 were decreased in comparison to releases in 2010. The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Data for 2011 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, with some elevated above those concentrations expected for background levels. A relatively high concentration of tritium was detected in blackberries in 2011 and this was likely to be due to sample collection coinciding with a gaseous discharge from the site. Overall the effects of discharges are very low. Gross alpha and beta activities in surface water were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium were increased, in comparison to releases in 2010. The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates. The results of the programme in 2011 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 activity concentrations in 2011 were similar to those for 2010, including technetium-99 derived from Sellafield. Gamma dose rates, measured using portable instruments, were generally similar to those found in 2010.

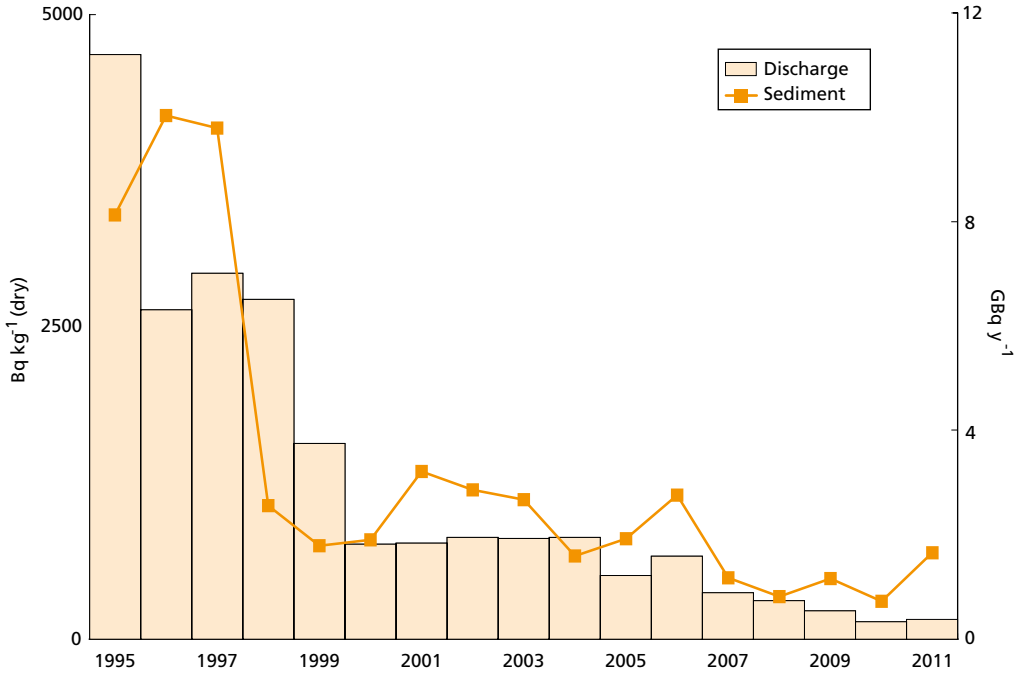


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2011

Table 4.1. Individual radiation exposures - nuclear power stations, 2011

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	Direct radiation from site
England							
Berkeley and Oldbury							
***Total dose* - all sources**	**Prenatal children of occupants over sediment**	**0.006**	**<0.005**	**<0.005**	**0.006**	**-**	**-**
Source specific doses	Seafood consumers	0.008	<0.005	-	0.008	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Bradwell							
***Total dose* - all sources**	**Prenatal children of local inhabitants (0 - 0.25km)**	**0.048**	**-**	**<0.005**	**-**	**<0.005**	**0.048**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Dungeness							
***Total dose* - all sources**	**Local adult inhabitants (0.5 - 1km)**	**0.021**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers	0.007	<0.005	-	0.005	-	-
	Houseboat occupants	0.012	-	-	0.012	-	-
	Infant inhabitants and consumers of locally grown food	0.005	-	<0.005	-	<0.005	-
Hartlepool							
***Total dose* - all sources**	**Local adult inhabitants (0 - 0.25km)**	**0.025**	**-**	**-**	**0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers[b]	0.009	<0.005	-	0.008	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
	Sea coal collectors	0.012	-	-	0.012	-	-
Heysham							
***Total dose* - all sources**	**Adult mollusc consumers**	**0.025**	**0.014**	**-**	**0.011**	**-**	**-**
Source specific doses	Seafood consumers	0.034	0.014	-	0.020	-	-
	Turf cutters	0.018	-	-	0.018	-	-
	Infant inhabitants and consumers of locally grown food	0.007	-	0.006	-	<0.005	-
Hinkley Point							
***Total dose* - all sources**	**Adult occupants over sediment**	**0.014**	**<0.005**	**<0.005**	**0.013**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers	0.020	<0.005	-	0.020	-	-
	Infant inhabitants and consumers of locally grown food	0.005	-	<0.005	-	<0.005	-
Sizewell							
***Total dose* - all sources**	**Local adult inhabitants (0 - 0.25km)**	**0.021**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-

Table 4.1. continued

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	Direct radiation from site
Scotland							
Chapelcross							
Total dose - all sources	**Infant milk consumers**	**0.037**	**<0.005**	**0.037**	**<0.005**	**-**	**-**
Source specific doses	Salmon and wildfowl consumers	<0.005	<0.005	<0.005	<0.005	-	-
	Crustacean consumers	<0.005	<0.005	-	-	-	-
	Infant inhabitants and consumers of locally grown food	0.025	-	0.025	-	<0.005	-
Hunterston							
Total dose - all sources	**Prenatal children of local inhabitants (0.25 - 0.5km)**	**0.050**	**-**	**<0.005**	**-**	**<0.005**	**0.049**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	0.009	-	0.008	-	<0.005	-
Torness							
Total dose - all sources	**Local adult inhabitants (0.5 - 1km)**	**0.020**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	0.006	-	0.006	-	<0.005	-
Wales							
Trawsfynydd							
Total dose - all sources	**Adult fish consumers**	**0.012**	**0.007**	**-**	**0.005**	**-**	**-**
Source specific doses	Anglers	0.011	0.005	-	0.007	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Wylfa							
Total dose - all sources	**Adult consumers of marine plants and algae**	**0.008**	**<0.005**	**<0.005**	**0.006**	**-**	**-**
Source specific doses	Seafood consumers	0.010	<0.005	-	0.007	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *Excluding possible enhancement of naturally occurring radionuclides. See Section 4*

Table 4.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{99}Tc	^{134}Cs	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Marine samples									
Salmon	Beachley	2	<25		<0.06	0.16	<0.06		
Mullet	River Severn	2	<25		<0.08	0.54	<0.14		
Elvers	River Severn	1	<25		<0.13	0.25	<0.10		
Seaweed	Pipeline	2[E]		<1.1	<0.38	<0.61	<0.36		
Sediment	Hills Flats	2[E]				21	<1.6		
Sediment	1 km south of Oldbury	2[E]			<1.4	27	<1.7		
Sediment	2 km south west of Berkeley	2[E]			<1.5	30	<1.8		
Sediment	Sharpness	2[E]				24	<1.8		
Seawater	Local beach	2[E]			<0.31	<0.25	<0.32	<2.3	6.5

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		8	<4.3	17	<0.38	<0.20		
Milk	max		<4.5	21	0.63			
Apples		2	<4.0	15	<0.20	<0.20		
Apples	max			17				
Blackberries		1	<4.0	14	0.20	<0.20		
Cabbage		1	<4.0	5.0	1.7	<0.30		
Onions		1	<4.0	10	0.50	<0.20		
Potatoes		1	<5.0	12	0.20	<0.20		
Runner beans		1	<4.0	8.0	0.50	<0.20		
Wheat		1	<7.0	110	1.1	<0.20		
Freshwater	Gloucester and Sharpness Canal	2[E]	<4.8		<0.65	<0.25	<0.055	0.23
Freshwater	Public supply	2[E]	<5.3		<0.65	<0.21	<0.055	0.23

[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, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud and salt marsh	2	0.080
2 km south west of Berkeley	Mud and salt marsh	2	0.076
Guscar Rocks	Mud and salt marsh	2	0.082
Lydney Rocks	Mud and salt marsh	2	0.082
Sharpness	Mud and salt marsh	2	0.077
Hills Flats	Mud and salt marsh	2	0.079

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples							
Sole	Bradwell	2			0.17		
Bass	Pipeline	1			0.50		
Thornback ray	Pipeline	1			0.47		
Lobsters	West Mersea	1			0.12		
Native oysters	Tollesbury N. Channel	1			0.12	0.00025	0.0016
Pacific oysters	Goldhanger Creek	2			<0.10		
Winkles	Pipeline	2			<0.17		
Winkles	Heybridge Basin	2			<0.21		
Seaweed	Waterside	2[E]		7.9	<0.58		
Leaf beet	Tollesbury	1			<0.08		
Samphire	Tollesbury	1			0.22		
Sediment	Pipeline	2[E]	<2.0		<3.7		
Sediment	Waterside	2[E]	<2.0		11		
Sediment	West Mersea Beach Huts	2[E]	<2.0		<1.4		
Sediment	West Mersea Boatyard	2[E]	<2.0		8.5		
Sediment	Maldon	2[E]	<2.0		28		
Sediment	N side Blackwater Estuary	2[E]	<2.0		9.5		
Seawater	Bradwell	2[E]			<0.21		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Sole	Bradwell	2	<0.07				
Bass	Pipeline	1	<0.20				
Thornback ray	Pipeline	1	<0.03				
Lobsters	West Mersea	1	<0.07				
Native oysters	Tollesbury N. Channel	1	0.0051	*	0.00016		
Pacific oysters	Goldhanger Creek	2	<0.11				
Winkles	Pipeline	2	<0.10				
Winkles	Heybridge Basin	2	<0.10				
Seaweed	Waterside	2[E]	<0.64				
Leaf beet	Tollesbury	1	<0.06				
Samphire	Tollesbury	1	<0.06				
Sediment	Pipeline	2[E]	<1.2				
Sediment	Waterside	2[E]	<1.9				
Sediment	West Mersea Beach Huts	2[E]	<1.2				
Sediment	West Mersea Boatyard	2[E]	<1.9				
Sediment	Maldon	2[E]	<2.1				
Sediment	N side Blackwater Estuary	2[E]	<2.0				
Seawater	Bradwell	2[E]	<0.29			<12	14

Table 4.3(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk			3	<4.0	17		<0.19		
Milk		max			18		<0.20		
Apples			1	<4.0	17		<0.20		
Cabbage			1	<5.0	11		<0.20		
Carrots			1	<4.0	16		<0.20		
Lucerne			1	<4.0	14		<0.20		
Potatoes			1	<4.0	20		<0.20		
Rabbit			1	<5.0	24		<0.20		
Strawberries			1	<4.0	9.0		<0.20		
Wheat			1	<7.0	95		<0.20		
Freshwater	Public supply, N side Estuary		1[E]	<4.0		<0.30	<0.21	<0.070	0.33
Freshwater	Public supply, S side Estuary		1[E]	<3.5		<1.0	<0.19	<0.070	0.23
Freshwater	Coastal ditch 1		1[E]	<5.4		<1.0	<0.20	<0.80	4.3
Freshwater	Coastal ditch 2		2[E]	<4.6		<0.81	<0.19	<1.4	6.7
Freshwater	Coastal ditch 3		2[E]	10		<0.84	<0.19	<1.4	8.0
Freshwater	Coastal ditch 4		2[E]	12		<0.84	<0.20	<0.90	11

* *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, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and sand	2	0.071
Beach opposite power station, N side of Estuary	Mud and salt marsh	2	0.074
Waterside	Mud and salt marsh	1	0.081
Waterside	Salt marsh	1	0.065
Maldon	Mud	2	0.059
West Mersea Beach Huts	Sand and mud	1	0.068
West Mersea Beach Huts	Sand	1	0.061
West Mersea	Mud and sand	1	0.053
West Mersea	Mud and shingle	1	0.061

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Pipeline	1		<25		<0.06			0.19
Whiting	Pipeline	1		30		<0.07			0.25
Bass	Pipeline	1		<25		<0.08			0.42
Sole	Pipeline	2	<25	<25		<0.05			<0.05
Crabs	Eastbourne / Folkestone landed	1				<0.06			0.06
Shrimps	Pipeline	2	<25	<25	31	<0.07			<0.07
Scallops	Pipeline	2				<0.05	<0.052		<0.03
Sea kale	Dungeness Beach	1				<0.06			0.12
Seaweed	Folkestone	2[E]				<0.91		4.2	<0.65
Sediment	Rye Harbour 1	2[E]				<1.3			<1.1
Sediment	Camber Sands	2[E]				<0.78			<0.66
Sediment	Pilot Sands	2[E]				<0.91			<0.78
Seawater	Dungeness South	2[E]		<5.0		<0.24			<0.20

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Cod	Pipeline	1			<0.03				
Whiting	Pipeline	1			<0.19				
Bass	Pipeline	1			<0.08				
Sole	Pipeline	2			<0.04				
Crabs	Eastbourne / Folkestone landed	1			<0.06				
Shrimps	Pipeline	2			<0.04				
Scallops	Pipeline	2	0.00031	0.0013	0.0019	*	0.000020		
Sea kale	Dungeness Beach	1			<0.04				
Seaweed	Folkestone	2[E]			<0.77				
Sediment	Rye Harbour 1	2[E]	<0.50	<0.90	<1.8				460
Sediment	Camber Sands	2[E]			<1.1				
Sediment	Pilot Sands	2[E]			<1.1				
Seawater	Dungeness South	2[E]			<0.28			<6.0	16

Material	Location selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<4.1	17	<0.20	<0.18	<0.20		
Milk	max		<4.3						
Blackberries		1	<4.0	22	0.40	<0.10	<0.20		
Cauliflower		1	<4.0	7.0	0.90	<0.20	<0.20		
Potatoes		1	<5.0	29	0.40	<0.20	<0.20		
Rape		1	<11	46	1.6	<0.10	<0.20		
Sea kale		1	<5.0	9.0	1.6	<0.20	0.20		
Wheat		1	<7.0	97	1.1	<0.20	<0.20		
Grass		1				<0.20	<0.20		
Freshwater	Long Pits	2[E]	<4.5		<0.65	<0.24	<0.19	<0.040	<0.13
Freshwater	Pumping station Well number 1	1[E]	<3.4		<1.0	<0.25	<0.20	<0.030	0.12
Freshwater	Pumping station Well number 2	1[E]	<4.0		<0.20	<0.23	<0.20	<0.050	0.18
Freshwater	Reservoir	1[E]	<4.0		<0.20	<0.22	<0.19	<0.040	0.32

* *Not detected by the method used*

[a] *Except for milk and water where units are Bq l^{-1}, and for 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, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Pebbles and sand	1	0.065
Littlestone-on-Sea	Sand and shingle	1	0.054
Greatstone-on-Sea	Sand	2	0.058
Dungeness East	Sand and shingle	1	0.054
Dungeness East	Pebbles and sand	1	0.060
Dungeness South	Pebbles and sand	1	0.059
Dungeness South	Shingle	1	0.048
Jury's Gap	Pebbles and sand	1	0.061
Jury's Gap	Sand and shingle	1	0.056
Rye Bay	Pebbles and sand	1	0.062
Rye Bay	Sand and shingle	1	0.052

Table 4.5 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I
Marine samples								
Plaice	Pipeline	2	<25	<25	36	<0.05		<0.52
Cod	Pipeline	2				<0.06		<0.43
Crabs	Pipeline	2			26	<0.05		*
Winkles	South Gare	2	<25	<25		<0.06		<0.66
Mussels	South Gare	2				<0.07		<0.83
Mussels	Seal Sands	1			60			
Seaweed	Pilot Station	2[E]				<0.70	6.6	<19
Sediment	Old Town Basin	2[E]				<0.63		
Sediment	Seaton Carew	2[E]				<0.57		
Sediment	Paddy's Hole	2[E]				<0.98		
Sediment	North Gare	2[E]				<0.88		
Sediment	Greatham Creek	2[E]				<0.97		
Sea coal	Old Town Basin	2[E]				<1.6		
Sea coal	Carr House Sands	2[E]				<1.4		
Seawater	North Gare	2[E]		<5.8		<0.24		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{210}Pb	^{210}Po	^{238}Pu	$^{239}Pu+$ ^{240}Pu
Marine samples							
Plaice	Pipeline	2	0.22				
Cod	Pipeline	2	0.31				
Crabs	Pipeline	2	0.07			0.00029	0.0020
Winkles	South Gare	2	0.10	1.6	10	0.0076	0.049
Mussels	South Gare	2	<0.07				
Seaweed	Pilot Station	2[E]	<0.51				
Sediment	Old Town Basin	2[E]	2.5				
Sediment	Seaton Carew	2[E]	<0.46				
Sediment	Paddy's Hole	2[E]	2.6				
Sediment	North Gare	2[E]	<0.76				
Sediment	Greatham Creek	2[E]	5.5				
Sea coal	Old Town Basin	2[E]	<1.3				
Sea coal	Carr House Sands	2[E]	<2.0				
Seawater	North Gare	2[E]	<0.20				

Table 4.5 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Marine samples					
Plaice	Pipeline	2	<0.14		
Cod	Pipeline	2	<0.10		
Crabs	Pipeline	2	0.0021	*	0.000019
Winkles	South Gare	2	0.025	0.000095	0.000098
Mussels	South Gare	2	<0.16		
Seaweed	Pilot Station	2[E]	<0.61		
Sediment	Old Town Basin	2[E]	<1.0		
Sediment	Seaton Carew	2[E]	<0.72		
Sediment	Paddy's Hole	2[E]	<1.4		
Sediment	North Gare	2[E]	<1.1		
Sediment	Greatham Creek	2[E]	<1.3		
Sea coal	Old Town Basin	2[E]	<1.3		
Sea coal	Carr House Sands	2[E]	<1.3		
Seawater	North Gare	2[E]	<0.30	<4.5	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<4.4	17	<0.29	<0.18	<0.20		
Milk	max		<5.0	19	0.35	<0.20			
Apples		1	<4.0	12	<0.20	<0.20	<0.20		
Beetroot		1	<4.0	5.0	<0.20	<0.10	<0.20		
Blackberries		1	<4.0	23	<0.20	<0.10	<0.20		
Cabbage		1	<4.0	8.0	<0.30	<0.20	<0.20		
Honey		1	<7.0	85	<0.20	<0.10	<0.20		
Potatoes		1	<5.0	20	0.30	<0.30	<0.30		
Runner beans		1	<4.0	5.0	<0.20	<0.30	<0.30		
Wheat		1	<7.0	100	1.1	<0.20	<0.20		
Freshwater	Public supply	2[E]	<3.8		<0.70	<0.23	<0.19	<0.14	0.21
Freshwater	Borehole, Dalton Piercy	2[E]	<3.7		<0.70	<0.24	<0.20	<0.14	<0.15

* *Not detected by the method used*

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

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

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

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

Table 4.5(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.068
Fish Sands	Rock and sand	1	0.075
Old Town Basin	Mud and coal	1	0.080
Old Town Basin	Sand	1	0.074
Carr House	Sand	1	0.068
Carr House	Sand and coal	1	0.072
Seaton Carew	Sand	2	0.065
Seaton Sands	Sand	2	0.063
North Gare	Sand	2	0.065
Paddy's Hole	Stones	1	0.17
Paddy's Hole	Grass and pebbles	1	0.18
Greatham Creek Bird Hide	Mud	1	0.096
Greatham Creek Bird Hide	Mud and stones	1	0.095

Table 4.6 (a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Marine samples									
Flounder	Flookburgh	4			92	<0.10			<0.98
Flounder	Morecambe	4	<31	<32		<0.11	0.033	1.5	<0.97
Whiting	Morecambe	4				<0.12			<1.1
Bass	Morecambe	2				<0.08			<0.78
Whitebait[b]	Sunderland Point	1				<0.10	<0.11		<0.92
Shrimps	Flookburgh	4			93	<0.11		0.27	<0.91
Shrimps	Morecambe	2				<0.05			<0.41
Cockles	Middleton Sands	2				0.26			<1.2
Cockles[c]	Flookburgh	4			49	0.19	0.22	2.4	<0.57
Winkles	Red Nab Point	4				<0.13			<0.64
Mussels	Morecambe	4	46	<42	62	<0.08		16	<0.59
Wildfowl	Morecambe	1				<0.07			<0.61
Samphire	Cockerham Marsh	1				<0.10			<1.1
Seaweed	Half Moon Bay	2[E]				<0.57		270	<3.6
Sediment	Half Moon Bay	2[E]				<0.43			
Sediment	Pott's Corner	2[E]				<0.30			
Sediment	Morecambe Central Pier	2[E]				<0.30			
Sediment	Red Nab Point	2[E]				<0.36			
Sediment	Sunderland Point	4[E]				<0.73			<5.4
Sediment	Conder Green	4[E]				<0.75			<5.5
Sediment	Sand Gate Marsh	4[E]				<0.45			<3.0
Seawater	Heysham Harbour	2[E]		110		<0.23			<1.9

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{125}Sb	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples								
Flounder	Flookburgh	4	<0.26	9.5	<0.21	0.00029	0.0020	
Flounder	Morecambe	4	<0.25	6.8	<0.18			
Whiting	Morecambe	4	<0.26	5.1	<0.21			
Bass	Morecambe	2	<0.20	7.2	<0.18			
Whitebait[b]	Sunderland Point	1	<0.23	4.0	<0.16	0.029	0.16	1.1
Shrimps	Flookburgh	4	<0.25	3.8	<0.21	0.0064	0.041	<0.75
Shrimps	Morecambe	2	<0.11	3.4	<0.08			
Cockles	Middleton Sands	2	<0.28	2.3	<0.18	0.25	1.6	
Cockles[c]	Flookburgh	4	<0.16	2.8	<0.10	0.25	1.5	17
Winkles	Red Nab Point	4	<0.30	4.8	<0.14	0.38	2.2	
Mussels	Morecambe	4	<0.22	2.0	<0.14	0.22	1.3	
Wildfowl	Morecambe	1	<0.12	1.0	<0.07			
Samphire	Cockerham Marsh	1	<0.24	1.3	<0.16			
Seaweed	Half Moon Bay	2[E]	<2.0	3.1				
Sediment	Half Moon Bay	2[E]		56		1.2	8.1	
Sediment	Pott's Corner	2[E]		17				
Sediment	Morecambe Central Pier	2[E]		3.5				
Sediment	Red Nab Point	2[E]		39				
Sediment	Sunderland Point	4[E]	<2.9	55	<1.3			
Sediment	Conder Green	4[E]	<2.9	70	<1.4			
Sediment	Sand Gate Marsh	4[E]	<1.6	66	<0.75			
Seawater	Half Moon Bay	1		0.05				
Seawater	Heysham Harbour	2[E]		<0.20				

Table 4.6 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Flounder	Flookburgh	4	0.0038	0.00015	*		
Flounder	Morecambe	4	<0.12				
Whiting	Morecambe	4	<0.17				
Bass	Morecambe	2	<0.14				
Whitebait[b]	Sunderland Point	1	0.27	*	0.00015		
Shrimps	Flookburgh	4	0.072	0.00017	*		
Shrimps	Morecambe	2	<0.05				
Cockles	Middleton Sands	2	4.5	*	0.0035		
Cockles[c]	Flookburgh	4	4.7	*	0.0050		
Winkles	Red Nab Point	4	4.1	*	0.0057		
Mussels	Morecambe	4	2.6	0.011	*		
Wildfowl	Morecambe	1	<0.04				
Samphire	Cockerham Marsh	1	1.1				45
Seaweed	Half Moon Bay	2[E]	<1.0				
Sediment	Half Moon Bay	2[E]	68				
Sediment	Pott's Corner	2[E]	12				
Sediment	Morecambe Central Pier	2[E]	1.7				
Sediment	Red Nab Point	2[E]	46				
Sediment	Sunderland Point	4[E]	61			230	730
Sediment	Conder Green	4[E]	76			360	630
Sediment	Sand Gate Marsh	4[E]	55			<210	510
Seawater	Heysham Harbour	2[E]	<0.30			<4.5	14

Material	Location or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		7	<4.2	17	<0.35	<0.19	<0.19		
Milk	max		<4.5	20	0.53	<0.23	<0.20		
Apples		1	<4.0	11	<0.20	<0.20	<0.20		
Barley		1	<7.0	92	1.1	<0.10	0.20		
Blackberries		1	<4.0	18	0.40	<0.20	<0.20		
Cabbage		1	<4.0	5.0	0.20	<0.20	<0.20		
Honey		1	<6.0	86	<0.20	<0.10	<0.20		
Onions		1	<4.0	10	<0.20	<0.30	<0.20		
Potatoes		1	<5.0	15	0.20	<0.20	<0.20		
Sprouts		1	<5.0	15	2.1	<0.30	<0.20		
Freshwater	Lancaster	2[E]	<3.8		<0.60	<0.23	<0.20	<0.030	<0.040

* *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 ^{108m}Ag was 0.21 Bq kg^{-1}*

[c] *The concentration of ^{210}Po was 18 Bq kg^{-1}*

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

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

[E] *Measurements 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, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass	2	0.081
Sand Gate Marsh	Grass	4	0.089
High Foulshaw	Grass and mud	2	0.082
High Foulshaw	Grass	2	0.089
Arnside 1	Mud	2	0.084
Arnside 1	Grass and mud	2	0.087
Arnside 2	Grass	4	0.10
Morecambe Central Pier	Sand	2	0.078
Half Moon Bay	Mud and rocks	1	0.087
Half Moon Bay	Sand and stones	1	0.084
Red Nab Point	Mud and sand	1	0.085
Red Nab Point	Sand	1	0.085
Middleton Sands	Sand	2	0.079
Sunderland	Salt marsh	4	0.094
Sunderland Point	Mud	3	0.095
Sunderland Point	Mud and salt marsh	1	0.089
Colloway Marsh	Salt marsh	3	0.13
Colloway Marsh	Grass	1	0.12
Lancaster	Grass	4	0.083
Aldcliffe Marsh	Mud	1	0.12
Aldcliffe Marsh	Grass	3	0.10
Conder Green	Mud and sand	1	0.095
Conder Green	Grass and mud	3	0.090

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{134}Cs
Marine samples									
Cod	Stolford	2	32	41	30	<0.10			<0.10
Shrimps	Stolford	2	60	68	50	<0.11			<0.11
Limpets	Stolford	1		36	16	<0.03			<0.04
Porphyra	Stolford	1				<0.03			<0.03
Sea lettuce	Stolford	1				<0.04			<0.04
Seaweed	Pipeline	2[E]				<0.50		7.9	<0.39
Sediment	Watchet Harbour	2[E]				<1.1	<2.0		
Sediment	Pipeline	2[E]				<1.2	<2.0		
Sediment	Stolford	2[E]				<1.6	<2.0		
Sediment	Steart Flats	2[E]				<1.3	<2.0		
Sediment	River Parrett	2[E]				<1.6	<2.0		
Sediment	Weston-Super-Mare	2[E]				<1.0	<2.0		
Sediment	Burnham-On-Sea	2[E]				<0.91	<2.0		
Sediment	Kilve	2[E]				<1.6	<2.0		
Sediment	Blue Anchor Bay	2[E]				<0.78	<2.0		
Seawater	Pipeline	2[E]				<0.27	<0.050		<0.26

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Cod	Stolford	2	0.32			<0.11				
Shrimps	Stolford	2	0.27	0.000063	0.00045	0.00051	*	*		
Limpets	Stolford	1	0.24			<0.09				
Porphyra	Stolford	1	0.36			<0.04				
Sea lettuce	Stolford	1	0.74			<0.11				
Seaweed	Pipeline	2[E]	<0.63			<0.46				
Sediment	Watchet Harbour	2[E]	9.1			<1.7				
Sediment	Pipeline	2[E]	15			<1.7				
Sediment	Stolford	2[E]	20			<1.7				
Sediment	Steart Flats	2[E]	19			<1.8				
Sediment	River Parrett	2[E]	25			<1.8				
Sediment	Weston-Super-Mare	2[E]	<3.1			<1.3				
Sediment	Burnham-On-Sea	2[E]	2.1			<1.2				
Sediment	Kilve	2[E]	17			<1.7				
Sediment	Blue Anchor Bay	2[E]	5.4			<1.0				
Seawater	Pipeline	2[E]	<0.22			<0.28			<4.5	8.7

Table 4.7(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		7	<4.2	18	<0.32	<0.17	<0.20		
Milk	max		<4.5	21	<0.45	<0.20			
Apples		1	<4.0	14	<0.20	<0.10	<0.10		
Blackberries		1	<4.0	23	0.70	<0.20	<0.20		
Carrots		1	<4.0	10	<0.20	<0.10	<0.20		
Chard		1	<4.0	5.0	0.20	<0.20	<0.20		
Honey		1	<7.0	80	<0.10	<0.10	<0.10		
Potatoes		1	<5.0	18	<0.20	<0.20	<0.20		
Runner beans		1	<4.0	6.0	0.20	<0.20	<0.30		
Wheat		1	<7.0	91	0.80	<0.20	<0.20		
Soil[d]	Stolford	1		14		<0.34	6.7		
Freshwater	Durleigh Reservoir	2[E]	<4.2		<0.65	<0.27	<0.22	<0.045	0.18
Freshwater	Ashford Reservoir	2[E]	<3.8		<0.65	<0.32	<0.26	<0.030	<0.17

* *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 *The concentrations of ^{134}Cs and ^{241}Am were <0.47 and <0.49 Bq kg^{-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 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Mud and sand	4	0.070
Burnham	Mud and sand	4	0.067
River Parrett	Mud and stones	3	0.078
River Parrett	Grass and mud	1	0.075
Steart Flats	Mud	2	0.080
Steart Flats	Mud and sand	2	0.074
Stolford	Mud	2	0.091
Stolford	Mud and sand	1	0.075
Stolford	Mud and pebbles	1	0.094
Hinkley Point	Rock and mud	2	0.092
Hinkley Point	Pebbles and sand	1	0.092
Hinkley Point	Sand and shingle	1	0.093
Kilve	Mud and rock	4	0.087
Watchet Harbour	Mud and sand	2	0.094
Watchet Harbour	Mud and rock	2	0.091
Blue Anchor Bay	Mud and sand	4	0.071

Table 4.7 (c). Uranium isotopes in the environment near Hinkley Point nuclear power stations, 2011

Material[a]	Location[b]	Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}			
			^{234}U	^{235}U	^{238}U	^{238}U/^{235}U activity ratio
Soil	Onsite	1	42.60	2.31	49.30	21.34
Soil	Onsite	2	48.70	2.68	60.50	22.57
Soil	Offsite	3	30.20	1.67	35.60	21.32
Soil	Onsite	4	36.50	2.01	43.00	21.39
Soil	Offsite	5	35.00	1.89	40.50	21.43
Soil	Offsite	6	32.30	1.73	37.10	21.45
Soil	Onsite	7	38.20	1.96	42.00	21.43
Soil	Offsite	8	32.50	1.66	35.80	21.57
Soil	Offsite	9	34.30	1.80	38.70	21.50
Soil	Onsite	10	45.00	2.50	53.60	21.44
Soil	Offsite	11	32.10	1.70	36.30	21.35
Soil	Onsite	12	40.20	2.06	44.20	21.46
Soil	Onsite	13	41.50	2.18	46.80	21.47
Soil	Offsite	14	42.30	2.10	45.10	21.48
Soil	Onsite	15	36.50	1.85	39.70	21.46
Soil	Offsite	16	39.00	1.99	42.60	21.41
Soil	Offsite	17	33.80	1.76	37.80	21.48
Soil	Onsite	18	33.90	1.73	37.10	21.45
Soil	Onsite	19	47.30	2.56	55.00	21.48
Soil	Onsite	20	48.00	2.59	55.70	21.51

[a] *Samples collected and analysed on behalf of the Environment Agency*
[b] *Samples collected as part of a site investigation (http://www.environment-agency.gov.uk/static/documents/Leisure/Uranium_contamination_allegations_at_Hinkley_Point_2.pdf)*

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2011

Material	Location	No. of sampling observ-ations	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		0.27		
Sole	Sizewell	1	<25		0.25		
Skates/rays	Sizewell	1	<25		0.23		
Crabs	Sizewell	2		46	0.18	0.000082	0.00047
Lobsters	Sizewell	1			0.11	0.000073	0.00054
Pacific oysters	Butley Creek	1			<0.09		
Pacific oysters	Blyth Estuary	1			<0.08		
Mussels	River Alde	2	<25		0.15		
Sediment	Rifle range	2[E]			<0.68		
Sediment	Aldeburgh	2[E]			<0.69		
Sediment	Southwold	2[E]			8.8		
Seawater	Sizewell	2[E]	<4.4		<0.20		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Cod	Sizewell	2	<0.04				
Sole	Sizewell	1	<0.23				
Skates/rays	Sizewell	1	<0.10				
Crabs	Sizewell	2	0.0011	*	0.000035		
Lobsters	Sizewell	1	0.0012	*	0.000017		
Pacific oysters	Butley Creek	1	<0.06				
Pacific oysters	Blyth Estuary	1	<0.07				
Mussels	River Alde	2	<0.16				
Sediment	Rifle range	2[E]	<0.88				
Sediment	Aldeburgh	2[E]	<0.92				
Sediment	Southwold	2[E]	<1.7				830
Seawater	Sizewell	2[E]	<0.30			<5.5	19

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk			5	<4.2	16	<0.26	<0.20		
Milk		max		<4.5	18	<0.35			
Apples			1	<4.0	14	<0.20	<0.20		
Cabbage			1	<4.0	<3.0	<0.30	<0.20		
Honey			1	<7.0	80	<0.20	<0.10		
Onions			1	<4.0	5.0	<0.20	<0.20		
Potatoes			1	<5.0	8.0	<0.20	<0.10		
Raspberries			1	<4.0	12	<0.20	<0.30		
Runner beans			1	<4.0	5.0	<0.20	<0.20		
Wheat			1	<7.0	98	0.60	<0.20		
Freshwater	Nature Reserve		2[E]	<4.3		<0.65	<0.23	<0.095	0.34
Freshwater	The Meare		2[E]	<4.5		<0.65	<0.23	<0.070	0.24
Freshwater	Leisure Park		2[E]	4.8		<0.65	<0.20	<0.050	0.22

* *Not detected by the method used.*

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

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

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

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

Table 4.8(b). Monitoring of radiation dose rates near Sizewell, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	2	0.052
Dunwich	Sand and shingle	1	0.053
Dunwich	Shingle	1	0.047
Rifle Range	Sand and shingle	2	0.050
Aldeburgh	Sand and shingle	2	0.054
Southwold Harbour	Mud	2	0.069

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb
Marine samples								
Flounder	Inner Solway	1		47	<0.10	<0.10	<0.22	<0.22
Salmon	Inner Solway	1	<5.0		<0.10		<0.29	<0.28
Sea trout	Inner Solway	1	<5.0		<0.10		<0.17	<0.19
Shrimps	Inner Solway	2	<5.5		<0.10	<0.10	<0.20	<0.19
Cockles	North Solway	1			0.34		<0.26	<0.26
Mussels	North Solway	4	<4.9	56	<0.12	0.42	<0.19	<0.17
Winkles	Southerness	4	<5.0		<0.32	0.29	<0.20	<0.19
Fucus vesiculosus	Pipeline	4			<0.12		<0.23	<0.29
Fucus vesiculosus	Browhouses	4			0.16		<0.16	<0.17
Sediment	Pipeline	4	<5.0		1.1		<0.22	<0.32
Sediment	Powfoot	1			0.16		<0.22	<0.10
Sediment	Redkirk	1			0.13		<0.10	<0.13
Sediment	Southerness	1			0.14		<0.12	<0.17
Seawater	Pipeline	4	<3.2		<0.10		<0.17	<0.16
Seawater	Southerness	4	5.9		<0.10		<0.20	<0.23

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Marine samples								
Flounder	Inner Solway	1	<0.43	<0.70	<0.32	<0.10	12	<0.11
Salmon	Inner Solway	1		<0.96	<0.26	<0.10	0.33	<0.13
Sea trout	Inner Solway	1		<0.48	<0.15	<0.10	10	<0.10
Shrimps	Inner Solway	2	0.70	<0.55	<0.17	<0.10	2.9	<0.10
Cockles	North Solway	1		<0.77	<0.17	<0.10	2.3	<0.14
Mussels	North Solway	4	13	<0.59	<0.19	<0.10	2.1	<0.10
Winkles	Southerness	4	48	<0.67	<0.29	<0.10	1.3	<0.11
Fucus vesiculosus	Pipeline	4	100	<0.53	<0.18	<0.10	4.8	<0.10
Fucus vesiculosus	Browhouses	4		<0.48	<0.16	<0.10	7.9	<0.10
Sediment	Pipeline	4		<1.5	<1.1	<0.12	210	0.59
Sediment	Powfoot	1		<0.91	0.27	<0.12	41	<0.11
Sediment	Redkirk	1		<0.67	<0.25	<0.10	42	<0.15
Sediment	Southerness	1		<0.57	0.27	<0.10	16	<0.13
Seawater	Pipeline	4		<0.58	<0.17	<0.10	<0.11	<0.11
Seawater	Southerness	4		<0.54	<0.16	<0.10	<0.13	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples									
Flounder	Inner Solway	1	<0.20	0.019	0.035		0.074		
Salmon	Inner Solway	1	<0.24				<0.16		
Sea trout	Inner Solway	1	<0.13				0.13		
Shrimps	Inner Solway	2	<0.14	0.0053	0.022		0.045		
Cockles	North Solway	1	<0.22	0.47	2.7		10		
Mussels	North Solway	4	<0.16	0.55	3.1	16	6.5		
Winkles	Southerness	4	<0.18	0.99	5.1	24	4.1		
Fucus vesiculosus	Pipeline	4	<0.22	0.59	3.6		3.6	9.4	370
Fucus vesiculosus	Browhouses	4	<0.26				6.8	16	360
Sediment	Pipeline	4	1.2	14	84		150		
Sediment	Powfoot	1	1.2	3.1	17		27		
Sediment	Redkirk	1	<0.17	2.4	13		23		
Sediment	Southerness	1	0.29	2.6	17		27		
Seawater	Pipeline	4	<0.16				<0.11		
Seawater	Southerness	4	<0.16	0.00027	0.0015		0.0021		

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
Terrestrial samples									
Milk			12	<6.9	<16	<0.57	<0.05	<0.10	<0.14
Milk		max		<13	35	<1.3			<0.16
Barley			1	<5.0	71	<0.59	<0.05	0.15	<0.32
Beef muscle			1	<5.0	26	<0.50	<0.05	<0.10	<0.08
Beetroot			1	5.8	13	<0.50	<0.05	0.26	<0.17
Cabbage			1	5.3	<15	<0.50	<0.05	0.15	<0.05
Carrots			1	<5.0	<15	<0.50	<0.05	0.21	<0.11
Crab apples			2	<5.0	17	<0.50	<0.05	<0.11	<0.05
Crab apples		max			18			0.13	<0.06
Duck			1	<5.0	39	<1.4	<0.05	0.36	<0.20
Goose			3	<4.8	<28	<1.2	<0.12	<0.10	<0.39
Goose		max		<5.0	33	<1.7	<0.13		<0.55
Honey			1	89	14	<2.6	<0.07	<0.10	<0.14
Meadow vetchling			1	<5.0	31	<0.50	<0.06	0.65	<0.24
Pheasant			2	<5.0	<21	<1.2	<0.07	<0.69	<0.36
Pheasant		max			27	<1.6		1.2	<0.45
Pigeon			1	<5.0	29	<1.5	<0.06	<0.10	<0.22
Potatoes			1	4.7	16	<0.50	<0.05	<0.10	<0.05
Turnips			1	14	12	<0.50	<0.05	0.21	<0.23
Wild garlic leaves			1	<5.0	<15	<0.50	<0.05	0.14	<0.12
Grass			4	<5.3	24	<0.50	<0.05	0.35	<0.11
Grass		max		6.0	34			0.56	<0.15
Soil			4	<5.3	<15	<1.9	<0.05	1.5	<0.20
Soil		max		6.3	<17	<2.8		2.5	<0.21
Freshwater	Purdomstone		1	<1.0					
Freshwater	Winterhope		1	1.6					
Freshwater	Black Esk		1	<1.0					
Freshwater	Gullielands Burn		1	35			<0.01		<0.04
Rainwater	Creca		16	9.5					
Rainwater		max		24					
Surface water			4	51					
Surface water		max		93					

Table 4.9(a). continued

Material	Location or selection[b]		No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
				^{95}Nb	^{106}Ru	^{134}Cs	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Terrestrial samples										
Milk			12	<0.18	<0.34	<0.05	<0.05	<0.05		
Milk		max		<0.23	<0.37			<0.06		
Barley			1	<0.62	<0.49	<0.05	<0.05	<0.13		
Beef muscle			1	<0.05	<0.39	<0.05	<0.05	<0.13		
Beetroot			1	<0.18	<0.45	<0.05	<0.05	<0.08		
Cabbage			1	<0.05	<0.07	<0.05	<0.05	<0.05		
Carrots			1	<0.08	<0.38	<0.05	0.056	<0.06		
Crab apples			2	<0.05	<0.18	<0.05	<0.06	<0.05		
Crab apples		max			<0.20		0.078			
Duck			1	<0.26	<0.48	<0.05	2.6	0.093		
Goose			3	<0.50	<0.94	<0.11	0.48	<0.15		
Goose		max		<0.73	<1.3	<0.13	1.0	<0.17		
Honey			1	<0.08	<0.07	<0.07	<0.05	<0.12		
Meadow vetchling			1	<0.28	<0.63	<0.06	<0.07	<0.10		
Pheasant			2	<0.59	<0.69	<0.07	0.15	<0.09		
Pheasant		max		<0.83	<0.72		0.19	<0.10		
Pigeon			1	<0.27	<0.51	<0.05	0.14	<0.08		
Potatoes			1	<0.05	<0.13	<0.05	<0.05	<0.05		
Turnips			1	<0.34	<0.47	<0.05	<0.05	<0.08		
Wild garlic leaves			1	<0.11	<0.40	<0.05	0.52	<0.13		
Grass			4	<0.12	<0.27	<0.05	0.16	<0.08	1.3	270
Grass		max		<0.18	<0.34		0.22	<0.10	2.2	430
Soil			4	<0.23	<0.43	<0.06	9.6	<0.28	<120	280
Soil		max		<0.29	<0.47		12	0.56	210	330
Freshwater	Purdomstone		1				<0.01		<0.010	0.056
Freshwater	Winterhope		1				<0.01		<0.010	0.024
Freshwater	Black Esk		1				<0.01		<0.010	0.020
Freshwater	Gullielands Burn		1	<0.04	<0.08	<0.01	<0.01	<0.01	<0.010	0.15
Surface water			4			0.39	<13			270
Surface water		max					52			

[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, 2011

Location	Material or Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.059
Glencaple Harbour	Mud and sand	4	0.065
Priestside Bank	Salt marsh	4	0.063
Powfoot Merse	Mud	4	0.069
Pipeline	Sand	4	0.080
Pipeline	Salt marsh	4	0.081
Dumbretton	NA	1	0.060
Battlehill	Sand	4	0.075
Dornoch Brow	Mud and sand	4	0.080
Dornoch Brow	Salt marsh	4	0.072
Browhouses	NA	4	0.073
Redkirk	NA	4	0.064
Mean beta dose rates			µSv h^{-1}
Pipeline 500m east	NA	4	<1.0
Pipeline 500m west	NA	4	<1.0
Pipeline	Stake nets	3	<1.0

NA *Not available*

Table 4.9(c). Radioactivity in air near Chapelcross, 2011

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.014	<0.016	<0.22
Kirtlebridge	12	<0.013	<0.012	<0.19
Brydekirk	9	<0.013	<0.014	<0.20

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{35}S	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag
Marine Samples								
Cod	Millport	2			<0.10	<0.10		<0.10
Hake	Millport	1			<0.10	<0.10		<0.10
Mackerel[b]	Firth of Clyde	1	<5.0	<1.1	<0.13	<0.10		<0.16
Pollock	Millport	1			<0.10	<0.10		<0.10
Crabs	Millport	2			<0.10	<0.10	1.6	<0.10
Nephrops	Millport	2			<0.10	<0.10		<0.11
Lobsters	Largs	1			<0.10	<0.10	65	<0.10
Squat lobsters	Largs	4			<0.11	<0.10	20	<0.12
Mussels	Hunterston	1			<0.10	<0.10		<0.10
Winkles	Pipeline	2			<0.35	<0.97		1.4
Scallops	Largs	4			<0.10	<0.10		<0.10
Oysters	Hunterston	1			<0.10	<0.10		0.28
Fucus vesiculosus	N of pipeline	2			0.26	<0.54		<0.13
Fucus vesiculosus	S of pipeline	2			0.29	0.43		<0.28
Sediment	Millport	1			<0.10	<0.10		<0.10
Sediment	Gull's Walk	1			<0.10	<0.10		<0.10
Sediment	Ardneil Bay	1			<0.10	<0.10		<0.10
Sediment	Fairlie	1			<0.10	<0.10		<0.16
Sediment	Pipeline	1			<0.10	<0.10		<0.10
Seawater	Pipeline	2	13	<0.58	<0.10	<0.10		<0.10
Seawater	S of pipeline	2	2.7	<0.50	<0.10	<0.10		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{125}Sb	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine Samples								
Cod	Millport	2	<0.13	1.2	<0.11			<0.10
Hake	Millport	1	<0.16	2.0	<0.15			<0.10
Mackerel[b]	Firth of Clyde	1	<0.27	0.70	<0.25			<0.14
Pollock	Millport	1	<0.14	1.8	<0.14			<0.14
Crabs	Millport	2	<0.15	0.23	<0.14	0.0019	0.0077	0.0015
Nephrops	Millport	2	<0.17	0.61	<0.16			<0.11
Lobsters	Largs	1	<0.10	0.60	<0.10			0.30
Squat lobsters	Largs	4	<0.22	0.39	<0.19	0.0046	0.019	0.025
Mussels	Hunterston	1	<0.10	0.22	<0.10			<0.10
Winkles	Pipeline	2	<0.33	0.33	<0.27	0.048	0.20	0.13
Scallops	Largs	4	<0.16	0.20	<0.15	0.0074	0.047	0.018
Oysters	Hunterston	1	<0.10	0.17	<0.10			<0.10
Fucus vesiculosus	N of pipeline	2	<0.18	0.78	<0.19			<0.15
Fucus vesiculosus	S of pipeline	2	<0.15	0.65	<0.15			<0.10
Sediment	Millport	1	<0.13	4.3	0.33			0.20
Sediment	Gull's Walk	1	<0.14	3.2	<0.17			0.31
Sediment	Ardneil Bay	1	<0.14	2.3	<0.17			<0.21
Sediment	Fairlie	1	<0.30	20	0.32			<0.17
Sediment	Pipeline	1	<0.10	3.9	<0.20			0.54
Seawater	Pipeline	2	<0.19	<0.10	<0.17			<0.11
Seawater	S of pipeline	2	<0.16	<0.10	<0.15			<0.10

Table 4.10(a). continued

Material	Selection[c]		No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr
Terrestrial Samples								
Milk			5	<5.0	<14	<0.57	<0.05	<0.10
Milk		max			<15	<0.66		
Broad beans			1	<5.0	16	<0.50	<0.05	<0.10
Cabbage			1	<5.0	<15	<0.50	<0.05	0.10
Carrots			1	<5.0	<15	<0.50	<0.05	<0.10
Crab apples			1	<5.0	26	<0.50	<0.05	0.14
Eggs			1	<5.0	28	<0.50	<0.05	<0.10
Honey			1	<5.0	120	<2.9	<0.07	<0.10
Nettles			1	<5.0	19	<7.8	<0.09	1.3
Pheasant			3	<5.0	32	<0.68	<0.06	<0.10
Pheasant		max			33	<0.77	<0.08	
Potatoes			1	<5.0	20	<0.50	<0.05	<0.10
Rabbit			1	<5.0	28	<7.0	<0.80	<0.10
Rhubarb			1	<5.0	<15	<0.50	<0.05	0.49
Rosehips			1	<5.0	30	<0.50	<0.06	0.16
Rowan berries			1	<5.0	33	0.61	<0.05	0.14
Grass			3	<5.0	<16	<0.50	<0.05	0.44
Grass		max			19		<0.06	0.59
Soil			3	<5.0	<15	<1.9	<0.05	19
Soil		max				<2.6		55
Freshwater	Knockenden		1	<1.0			<0.01	
Freshwater	Loch Ascog		1	<1.0			<0.01	
Freshwater	Munnoch Reservoir		1	<1.0				
Freshwater	Camphill		1	<1.0				
Freshwater	Outerwards		1	<1.0				

Material	Selection[c]		No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{110m}Ag	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk			5	<0.05	<0.06	<0.06		
Milk		max						
Broad beans			1	<0.05	0.08	<0.07		
Cabbage			1	<0.05	<0.05	<0.07		
Carrots			1	<0.05	<0.05	<0.06		
Crab apples			1	<0.05	<0.05	<0.06		
Eggs			1	<0.05	<0.05	<0.07		
Honey			1	<0.07	0.54	<0.11		
Nettles			1	<0.11	0.11	<0.15		
Pheasant			3	<0.08	0.65	<0.10		
Pheasant		max		<0.11	1.2	<0.12		
Potatoes			1	<0.05	0.06	<0.06		
Rabbit			1	<0.11	1.4	<0.11		
Rhubarb			1	<0.05	<0.05	<0.07		
Rosehips			1	<0.05	0.09	<0.08		
Rowan berries			1	<0.06	0.06	<0.08		
Grass			3	<0.06	0.09	<0.08	2.6	160
Grass		max		<0.07	0.10	<0.09	4.0	220
Soil			3	<0.07	18	<0.21	<160	350
Soil		max		<0.08	25	<0.24	360	600
Freshwater	Knockenden		1	<0.01	<0.01	<0.01	<0.010	0.020
Freshwater	Loch Ascog		1	<0.01	<0.01	<0.01	<0.010	0.10
Freshwater	Munnoch Reservoir		1		<0.01		<0.010	0.044
Freshwater	Camphill		1		<0.01		<0.010	0.014
Freshwater	Outerwards		1		<0.01		<0.010	0.027

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *The concentrations of ^{14}C and ^{90}Sr were 39 and <0.10 Bq kg^{-1} respectively*
[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*

Table 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	Stones	2	0.065
Kilchatten Bay	Sand	2	<0.045
Millport	Sand	2	0.046
Gulls Walk	Mud	2	0.054
0.5 km north of pipeline	Sand	2	0.056
0.5 km south of pipeline	Sand and stones	2	0.057
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	<0.050
Milstonford	NA	2	0.049
Biglies	NA	2	0.061
Beta dose rates			μSv h^{-1}
Millport	Sand	1	<1.0
0.5 km north of pipeline	Sand	1	<1.0
0.5 km south of pipeline	Sand and stones	1	<1.0

NA *Not available*

Table 4.10(c). Radioactivity in air near Hunterston, 2011

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	10	<0.013	<0.011	<0.19
West Kilbride	11	<0.013	<0.010	<0.20
Low Ballees	11	<0.012	<0.011	<0.19

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{137}Cs
Marine Samples								
Cod	White Sands	2		<0.10	<0.10		<0.11	0.30
Bass	Pipeline	2		<0.11	<0.11		<0.12	0.52
Crabs[d]	Torness	1		<0.10	<0.10	0.12	<0.10	<0.10
Lobsters	Torness	1		<0.10	<0.10	7.4	<0.10	0.14
Nephrops	Dunbar	1		<0.10	<0.10		<0.10	0.15
Winkles	Pipeline	2		<0.10	0.26		5.1	0.12
Fucus vesiculosus	Pipeline	2		<0.45	0.37		1.1	0.15
Fucus vesiculosus	Thornton Loch	2		<0.23	0.29	34	0.18	0.13
Fucus vesiculosus	White Sands	2		<0.10	<0.10		<0.10	<0.15
Fucus vesiculosus	Pease Bay	2		<0.10	<0.10		<0.10	<0.11
Fucus vesiculosus	Coldingham Bay	2		<0.10	<0.10		<0.10	0.11
Sediment	Dunbar	1		<0.10	<0.10		<0.14	3.5
Sediment	Barns Ness	1		<0.10	<0.10		<0.10	1.4
Sediment	Thornton Loch	1		<0.10	<0.10		<0.10	1.3
Sediment	Heckies Hole	1		<0.10	<0.11		<0.15	16
Sediment	Belhaven Bay	1		<0.10	<0.10		<0.11	2.0
Salt marsh	Coldingham Bay	1		<0.10	<0.10		<0.10	0.94
Seawater	Pipeline	2	<20	<0.10	<0.10		<0.10	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine Samples								
Cod	White Sands	2	<0.20			<0.12		
Bass	Pipeline	2	<0.21			<0.13		
Crabs[d]	Torness	1	<0.12			<0.10		
Lobsters	Torness	1	<0.18			<0.11		
Nephrops	Dunbar	1	<0.17	0.00096	0.0062	0.0096		
Winkles	Pipeline	2	<0.17			<0.13	<1.1	150
Fucus vesiculosus	Pipeline	2	<0.10			<0.10		
Fucus vesiculosus	Thornton Loch	2	<0.12			<0.10		
Fucus vesiculosus	White Sands	2	<0.14			<0.11		
Fucus vesiculosus	Pease Bay	2	<0.10			<0.10		
Fucus vesiculosus	Coldingham Bay	2	<0.12			<0.10		
Sediment	Dunbar	1	0.80			<0.37		
Sediment	Barns Ness	1	0.81			<0.29		
Sediment	Thornton Loch	1	<0.22			<0.20		
Sediment	Heckies Hole	1	2.5			1.2		
Sediment	Belhaven Bay	1	0.94			<0.32		
Salt marsh	Coldingham Bay	1	0.28			<0.24		
Seawater	Pipeline	2	<0.14			<0.10		

Table 4.11(a). continued

Material	Selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples									
Milk			1	<5.0	<14	<0.68	<0.05	<0.10	<0.13
Apples			1	<5.0	16	<0.50	<0.05	<0.10	<0.06
Beetroot			1	<5.0	15	<0.50	<0.05	<0.10	<0.05
Blackberries			1	<5.0	17	<0.50	<0.05	<0.10	<0.37
Broccoli			1	<5.0	14	<0.50	<0.05	<0.10	<0.10
Cabbage			1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Carrots			1		<15	<0.50	<0.05	<0.10	<0.05
Crab apples			1	<5.0	20	<0.50	<0.05	<0.10	<0.05
Eggs			1	<5.0	25	<3.8	<0.05	<0.10	<0.05
Partridge			1	<5.0	27	<0.50	<0.05	<0.10	<0.09
Pheasant			3	<5.0	31	<0.56	<0.05	<0.10	<0.08
Pheasant		max			32	<0.60	<0.06		<0.10
Potatoes			1	<5.0	18	<0.50	<0.05	<0.10	<0.05
Rosehips			1	<5.0	33	<0.50	<0.05	0.25	<0.13
Rowan berries			1	<5.0	34	<0.50	<0.05	0.12	<0.09
Turnips			1	<5.0	<15	<0.50	<0.05	0.27	<0.05
Grass			3	<5.0	20	<0.50	<0.05	<0.15	<0.49
Grass		max			28			0.22	<0.68
Soil			3	<5.0	<16	<5.2	<0.10	2.1	<0.45
Soil		max			17	<7.4	<0.16	4.6	<0.76
Freshwater	Hopes Reservoir		1	<1.0					
Freshwater	Thorter's Reservoir		1	<1.0					
Freshwater	Whiteadder		1	<1.0					
Freshwater	Thornton Loch Burn		1	<1.0					

Material	Selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{110m}Ag	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk			1	<0.05	<0.05	<0.05		
Apples			1	<0.05	<0.05	<0.05		
Beetroot			1	<0.05	<0.05	<0.05		
Blackberries			1	<0.05	<0.05	<0.06		
Broccoli			1	<0.07	<0.07	<0.11		
Cabbage			1	<0.05	<0.05	<0.12		
Carrots			1	<0.05	<0.05	<0.05		
Crab apples			1	<0.05	<0.05	<0.05		
Eggs			1	<0.05	<0.05	<0.06		
Partridge			1	<0.05	0.16	<0.08		
Pheasant			3	<0.05	<0.05	<0.08		
Pheasant		max		<0.06	<0.06	<0.11		
Potatoes			1	<0.05	<0.05	<0.06		
Rosehips			1	<0.05	<0.05	<0.12		
Rowan berries			1	<0.05	<0.05	<0.09		
Turnips			1	<0.05	<0.05	<0.05		
Grass			3	<0.05	<0.08	<0.11	<3.1	440
Grass		max		<0.06	0.15	<0.14	7.0	530
Soil			3	<0.15	5.6	<0.24	<2.7	230
Soil		max		<0.25	7.9	<0.33	<3.6	240
Freshwater	Hopes Reservoir		1		<0.01		0.024	0.035
Freshwater	Thorter's Reservoir		1		<0.01		0.019	0.060
Freshwater	Whiteadder		1		<0.01		0.011	0.031
Freshwater	Thornton Loch Burn		1		<0.01		<0.010	0.069

[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] *The concentration of ^{14}C was 28 Bq kg^{-1}*

Table 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Sediment	2	0.060
Dunbar Inner Harbour	Sand	2	0.090
Belhaven Bay	Salt marsh	2	0.053
Barns Ness	Mud, sand and stones	2	0.071
Skateraw	Sand	2	<0.049
Thornton Loch	Sand	2	<0.056
Pease Bay	Sand	2	0.058
St Abbs Head	Mud	2	0.10
Coldingham Bay	Sand	2	0.052
West Meikle Pinkerton	Sediment	2	0.066
Mean beta dose rates on fishing gear			
Torness	Lobster pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2011

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	12	<0.011	<0.014	<0.20
Cockburnspath	11	<0.013	<0.015	<0.21

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6			<0.23	0.71	<0.33	31	<0.68
Rainbow trout	Trawsfynydd Lake	6			<0.09		<0.10	1.9	<0.30
Pike	Trawsfynydd Lake	1			<0.08		<0.09	95	<0.25
Sediment	Lake shore	2[E]			<0.48	<2.0	<0.45	580	
Sediment	Bailey Bridge	2[E]			<2.8	41	<2.6	650	
Sediment	Fish farm	2[E]			8.6	11	<1.2	1900	7.3
Sediment	Footbridge	2[E]			<0.67	<2.0	<0.60	280	
Sediment	Cae Adda	2[E]			<0.36	<2.0	<0.34	66	
Freshwater	Public supply	2[E]	<3.8	<0.65	<0.23		<0.23	<0.20	
Freshwater	Gwylan Stream	2[E]	<4.1	<0.65	<0.24		<0.22	<0.36	
Freshwater	Hot Lagoon	2[E]	<3.8	<0.65	<0.23		<0.23	<0.20	
Freshwater	Afon Prysor	2[E]	<3.7	<0.65	<0.23		<0.23	<0.20	
Freshwater	Trawsfynydd Lake	2[E]	<4.1	<0.65	<0.09		<0.08	<0.07	
Freshwater	Afon Tafarn-helyg	2[E]	<3.8	<0.65	<0.23		<0.23	<0.20	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6	0.000079	0.00029	0.00054	*	*		
Rainbow trout	Trawsfynydd Lake	6			<0.20				
Pike	Trawsfynydd Lake	1			<0.13				
Sediment	Lake shore	2[E]	<0.75	1.5	3.5				
Sediment	Bailey Bridge	2[E]	3.9	13	29				
Sediment	Fish farm	2[E]	14	35	68				
Sediment	Footbridge	2[E]	<0.65	0.88	2.4				
Sediment	Cae Adda	2[E]	<0.63	<0.95	3.3				
Freshwater	Public supply	2[E]						<0.050	<0.090
Freshwater	Gwylan Stream	2[E]						<0.020	<0.075
Freshwater	Hot Lagoon	2[E]						<0.030	<0.090
Freshwater	Afon Prysor	2[E]						<0.040	<0.13
Freshwater	Trawsfynydd Lake	2[E]						<0.025	<0.075
Freshwater	Afon Tafarn-helyg	2[E]						<0.019	<0.075

Table 4.12(a). continued

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs
Terrestrial Samples							
Milk		2	<4.3	18	<0.21	0.030	
Milk	max			21	<0.23	0.035	
Apples		1	<4.0	15	<0.20		<0.20
Blackberries		1	<4.0	19	<0.10		0.20
Cabbage		1	<4.0	4.0	<0.20		<0.20
Eggs		1	<6.0	29	<0.20		<0.20
Parsnips		1	<4.0	16	<0.20		<0.20
Potatoes		1	<4.0	21	<0.30		<0.20
Sheep muscle		2	<5.5	66	<0.20	0.028	
Sheep muscle	max		<6.0	79		0.035	
Sheep offal		2	<8.0	51	<0.20	0.28	
Sheep offal	max			60		0.38	

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples						
Milk		2	0.13			
Apples		1		<0.00010	<0.00020	0.00060
Blackberries		1		<0.00010	0.00050	0.00090
Eggs		1		<0.00010	<0.00010	0.00030
Parsnips		1		0.00010	<0.00020	0.00020
Potatoes		1		<0.00010	<0.00020	0.00020
Sheep muscle		2	1.8	<0.00010	<0.00030	0.00045
Sheep muscle	max		1.9			0.00060
Sheep offal		2	0.58	<0.00015	<0.00025	0.00080
Sheep offal	max		0.62	<0.00020	<0.00030	0.0010

* *Not detected by the method used*

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

[b] *The concentration of ^{14}C was 65 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, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Grass and stones	1	0.11
Footbridge	Pebbles and stones	1	0.12
Lake shore	Pebbles	1	0.096
Lake shore	Pebbles and stones	1	0.11
Bailey Bridge	Grass	2	0.077
Fish farm	Pebbles	1	0.11
Fish farm	Pebbles and stones	1	0.10
Cae Adda	Mud and stones	1	0.095
Cae Adda	Pebbles and stones	1	0.098

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples									
Plaice	Pipeline	2	<25	<25	23		0.88		
Bass	Outfall	1					4.1		
Crabs	Pipeline	2				0.66	0.28	0.0016	0.011
Lobsters	Pipeline	2				26	0.42		
Winkles	Cemaes Bay	2	<25	<25	41		0.45	0.018	0.11
Seaweed	Cemaes Bay	2[E]				48	<0.58		
Sediment	Cemaes Bay	2[E]					3.2		
Sediment	Cemlyn Bay West	2[E]					2.9		
Seawater	Cemaes Bay	2[E]		<3.8			<0.20		
Seawater	Cemlyn Bay West	2[E]					<0.20		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Pipeline	2		<0.07				
Bass	Outfall	1		<0.27				
Crabs	Pipeline	2		0.049	*	0.000063		
Lobsters	Pipeline	2		<0.12				130
Winkles	Cemaes Bay	2	0.85	0.16	*	0.00011		
Seaweed	Cemaes Bay	2[E]		<0.48				
Sediment	Cemaes Bay	2[E]		1.6				
Sediment	Cemlyn Bay West	2[E]		<0.64				
Seawater	Cemaes Bay	2[E]		<0.30			<4.1	10
Seawater	Cemlyn Bay West	2[E]		<0.29			<5.0	12

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		5	<4.0	18	0.45	<0.20		
Milk	max			19	0.58			
Apples		1	<4.0	13	<0.10	0.10		
Blackberries		1	39	51	3.1	<0.20		
Broad beans		1	<4.0	34	1.1	<0.20		
Cabbage		1	<4.0	10	0.40	<0.20		
Honey		1	<7.0	84	<0.20	<0.20		
Potatoes		1	<5.0	19	0.20	<0.20		
Swede		1	<4.0	6.0	0.30	<0.20		
Wheat		1	<7.0	100	1.2	<0.20		
Freshwater	Public supply	1[E]	<3.4		<1.0	<0.19	<0.050	<0.10

* *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, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	1	0.070
Cemaes Bay	Pebbles and sand	1	0.068
Cemlyn Bay West	Pebbles	1	0.074
Cemlyn Bay West	Pebbles and stones	1	0.076

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 Ministry of Defence (MoD) makes arrangements for monitoring at other defence sites where contamination may occur. The operator at the Atomic Weapons Establishment in Berkshire carries out environmental monitoring to determine the effects from low level gaseous discharges at its sites. Monitoring at nuclear submarine berths is also conducted by the MoD (DSTL Radiological Protection Services, 2012).

The medium-term trends in doses, discharges and environmental concentrations at Aldermaston, Devonport, Faslane and Coulport, and Rosyth were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

Key points

- Public radiation doses from all sources were less than 0.5 per cent of the dose limit at all those sites assessed
- Discharges, environmental concentrations and dose rates in 2011 were broadly similar to those in 2010 at all establishments

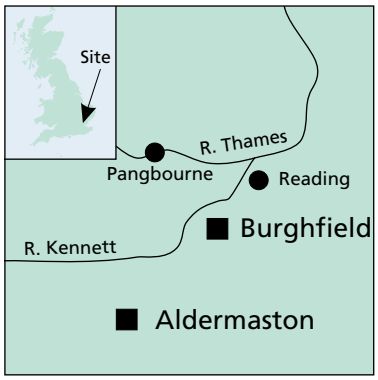
Aldermaston, Berkshire

- Discharges, concentrations and public dose rates in 2011 were broadly similar to those in 2010

Devonport, Devon

- Gaseous discharges of tritium decreased in 2011
- Environmental concentrations of radionuclides were generally below the limits of detection

5.1 Aldermaston, Berkshire



The Atomic Weapons Establishment (AWE) at Aldermaston provides and maintains the fundamental components of the UK's nuclear deterrent (Trident). The site and facilities at Aldermaston remain in Government ownership under a Government Owned Contractor Operator (GOCO) arrangement. The day-to-day operations and the maintenance of Britain's nuclear stockpile are managed, on behalf of the MoD, by AWE plc. The site is regulated by the Environment Agency to discharge low concentrations of radioactive waste to the environment. During September 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Ly *et al.*, 2012). An increase in occupancy rates was observed compared with the previous study in 2002 and no consumption of freshwater fish or crustaceans affected by liquid discharges was recorded. With the closure of the Pangbourne pipeline in 2005, fish and shellfish consumption and riverside occupancy along the River Thames (between Pangbourne and Reading) is no longer considered as part of habits survey area. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), or less than 0.5 per cent of the dose limit. Infants consuming milk at high-rates were the most exposed group and this represents a change in the most exposed group from 2010 (from adults spending time on the local riverbank).

Source specific assessments for high-rate consumers of locally grown foods and for anglers, give exposures that were also less than 0.005 mSv in 2011 (Table 5.1). Estimates of activity concentrations in fish have been based on shellfish samples from the aquatic monitoring programme for dose determination, and for anglers the assessment has conservatively included consumption of fish at a low rate of 1 kg per year. In 2011, a new assessment was undertaken, to determine the specific exposure for workers at the Silchester sewage treatment plant, and this was determined to be much less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks on the site. Gaseous discharges in 2011 were generally similar to those reported in 2010. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the site (Figure 3.1). Activity concentrations in milk and foodstuffs (Table 5.2(a)) were generally below the limits of detection, as in 2010. The tritium concentrations in all milk and foodstuffs were

below the LoD in 2011. The tritium levels in grass and soil, at different locations to 2010, were elevated above the LoD, but are comparable to previous years. Tritium is considered in the dose assessment and is of very low significance. In soil samples, where comparisons can be drawn at the same location, concentrations of caesium-137 were similar to values in 2010. Levels of uranium isotopes also remained similar to 2010. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made to the sewage works at Silchester (Figure 3.1), and to the Aldermaston stream. Discharges to Silchester in 2011, for alpha and other beta radionuclides, were higher than those reported in 2010; the discharge of tritium to Aldermaston Stream was low. 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 (the replacement facility uses sophisticated abatement technology that results in the discharge of significantly less tritium into the environment), and historical contamination of groundwater. The historical contamination has been reduced in recent years by radioactive decay and dilution by natural processes. Environmental monitoring of the River Thames (Pangbourne and Mapledurham) has been continued to assess the effect of historical discharges.

Activity concentrations for freshwater, fish and sediments samples, and measurements of dose rates, are given 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 2010. Concentrations of tritium in freshwater samples were below the LoD. As in 2010, no enhancements of tritium (all below LoD) were observed in sediments collected from road gullypots close to the site.

Activity concentrations of artificial radionuclides in River Kennet shellfish were at very low levels and similar to those reported in 2010. Analyses of radiocaesium and uranium activity levels in River Kennet sediments were broadly consistent with previous years. 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).

5.2 Barrow, Cumbria

At Barrow, BAE Systems Marine Limited (BAESM) builds, tests and commissions new nuclear powered submarines. A minor variation to the permit was made (effective from 26 July 2011) by introducing a new limit for carbon-14 in liquid waste. These and other permitted discharges from Barrow continued to be very low. The Food Standards Agency's monitoring is limited to grass sampling, and in 2011 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 2011.

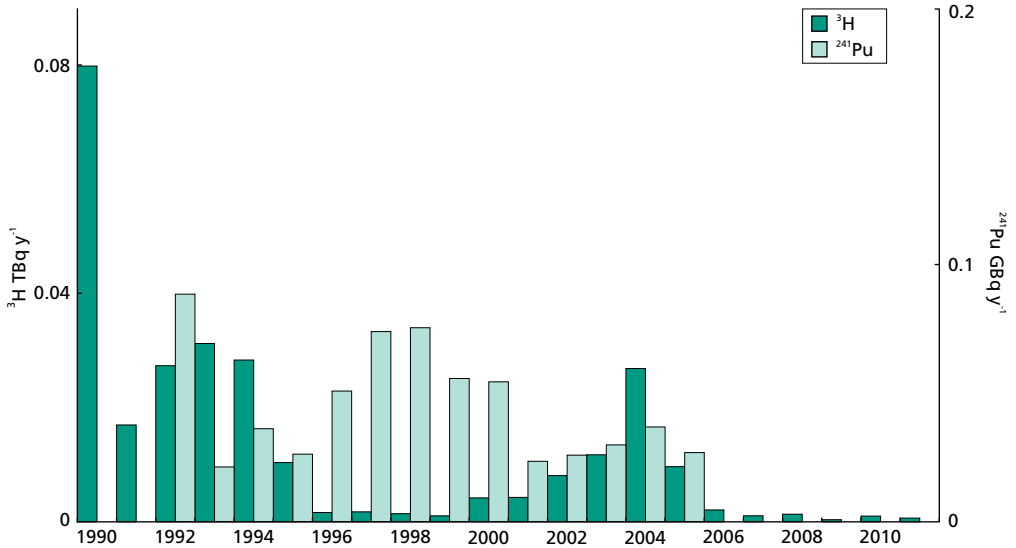
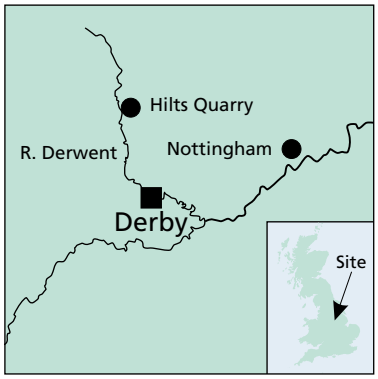


Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2011 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

5.3 Derby, Derbyshire



Rolls-Royce Marine Power Operations Limited (RRMPOL), a subsidiary of Rolls-Royce plc, 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. The only habits survey undertaken at Derby was in 2009 (Elliott *et al.*, 2010).

Doses to the public

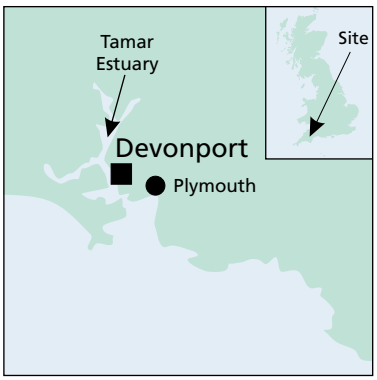
In 2011, the *total dose* from all pathways and sources of radiation (based on a limited amount of monitoring data with which to perform the assessment) was less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. The most exposed people were infants consuming water extracted from the river. Although this pathway was not quantified during the 2009 habits survey, it has been included in the *total dose* assessment as river water is known to be extracted.

Source specific assessments for consumption of fish and drinking river water at high-rates, and for local residents exposed to external and inhalation pathways from gaseous discharges, give exposures that were also less than 0.005 mSv in 2011 (Table 5.1).

Results of the routine monitoring programme at Derby are given in Table 5.3(a). Analysis of uranium activity in grass and soil samples taken around the site in 2011 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 was much less than 0.005 mSv per year (Table 5.1).

Table 5.3(a) also includes analysis results from a water sample taken from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for the controlled burial of solid low level radioactive waste. Uranium isotopes detected in the sample were similar to those levels observed elsewhere in Derbyshire (Table 9.11).

5.4 Devonport, Devon



Devonport consists of two parts: the Naval Base and Devonport Royal Dockyard, which are owned and operated by the MoD and by Babcock International Group plc, respectively. Devonport Royal Dockyard 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. During June 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al.*, 2012). A slight increase in the houseboat occupancy rate has been observed, together with a decrease in the consumption of fish, crustaceans, and molluscs, and occupancy over riverside sediment rates, 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 (Table X2.2). The routine monitoring programme in 2011 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)).

Doses to the public

In 2011, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. Adult fish consumers were the most exposed people; this is a change from 2010 (adults spending a long time over riverside sediments, which included houseboat occupancy) but the radiological significance of this site continued to be low. Trends in *total doses* in the area of the south coast (and the Severn Estuary) are shown in Figure 6.2.

Source specific assessments for high-rate consumers of locally grown food and for fish and shellfish, and for occupants of houseboats, give exposures that were also less than 0.005 mSv (Table 5.1) which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv.

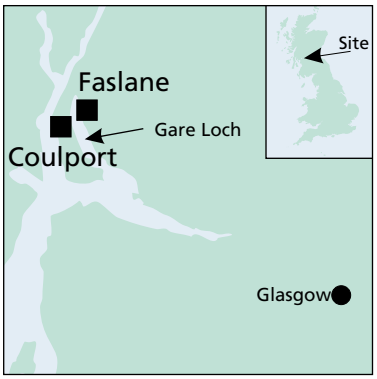
Gaseous discharges and terrestrial monitoring

Gaseous discharges of tritium, which are very small from this site, decreased in 2011 in comparison to those in 2010. Samples of fruit and vegetables were analysed for a number of radionuclides, and concentrations were below the limits of detection in all terrestrial foods.

Liquid waste discharges and marine monitoring

Discharges of all four permitted radionuclides to the Hamoaze were at levels similar to those reported in 2010. Figure 5.2 shows the discharge history of tritium and cobalt-60 since 1990. The main contributor to the variations in tritium discharges over time has been the re-fitting of Vanguard class submarines. These submarines have a higher tritium inventory in their primary circuit as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. The underlying reason for the overall decrease in cobalt-60 discharges over this period was the improvement in submarine reactor design so that less cobalt-60 was produced during operation, and therefore less was released during submarine maintenance operations. In marine samples, concentrations of tritium and cobalt-60 were below limits of detection. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapons test fallout, were measured in fish samples. The seaweed samples contained very low concentrations of iodine-131 in 2011, which were most likely to have originated from the therapeutic use of this radionuclide in a local hospital. Gamma dose rates in the vicinity of Devonport were similar to 2010, although some small changes (at the same locations) were noted because rates were measured on different types of substrate from one year to the next.

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, Faslane 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 2011 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 2011. SEPA initiated a review of all the letters of agreement held by MoD for both sites.

At Faslane, the primary effluent barge, which had been out of service for a number of years, was decommissioned and work is ongoing to improve the civil structure of the radioactive effluent treatment facility building. There were no significant changes to operations or procedures at Coulport in relation to radioactive waste disposal.

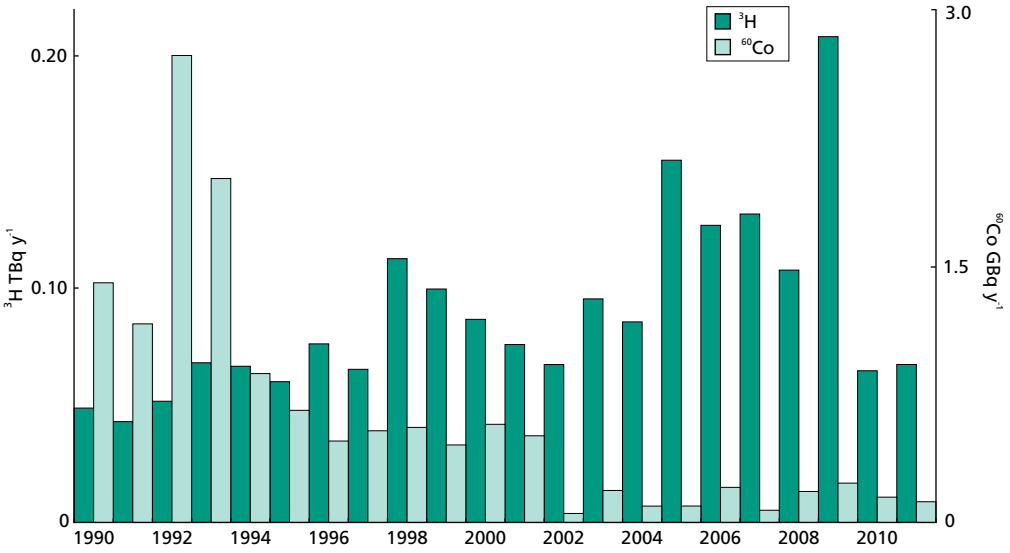


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2011

During August 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Rumney *et al*., *in press/a).* A slight increase in the mollusc consumption rate has been observed, together with a decrease in the occupancy rates; in comparison with those of the previous survey in 2006, no crustacean consumption was reported. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1 (Table X2.2).

The *total dose* from all pathways and sources of radiation was less than 0.005 mSv in 2011 (Table 5.1). The most exposed people were adults spending time on the shores of the loch, but as in 2010 the dose was less than 0.5 per cent of the dose limit for members of the public. Source specific assessments for high-rate consumers of fish and shellfish (using seafood concentrations based on earlier data) and consumers of locally grown food (based on limited data) give exposures that were also less than 0.005 mSv.

The routine monitoring programme consisted of the analysis of seawater, seaweed and sediment samples, and gamma dose rate measurements. Samples of non-migratory fish species were not available in 2011. Mollusc samples collected included the separate radioanalysis of mussel flesh and mussel shell (to assess the impact of utilising the latter as a fertiliser). The results are given in Tables 5.3(a) and (b) and were similar to those in 2010. Radionuclide concentrations were generally below the limits of detection, with caesium-137 concentrations in sediment 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.

5.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued during 2011 in order to determine the effects of past discharges from the US submarine support facilities which closed in 1992. Radionuclide concentrations were low (Table 5.3(a)). Gamma dose rate measurements from intertidal areas (Table 5.3(b)) were similar to those observed in 2010. The external radiation dose to people spending time on the loch shore was 0.007 mSv in 2011, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 5.1) and similar to the dose in 2010.

5.7 Rosyth, Fife

The site is operated by Babcock Marine, a division of Babcock International Group plc, 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 October 2008. Radioactive aqueous and gaseous wastes continue to be discharged in accordance with conditions in the same authorisation. In 2009, RRDL applied to vary its authorisation to allow the disposal of radioactive waste by transfer from RRDL to the processing facility operated by Studsvik SB in Sweden and an initial consignment was made in May 2009. Following volume reduction and the recovery of reusable metals, the radioactive waste was returned to Rosyth during 2011 for disposal to the Low Level Waste Repository.

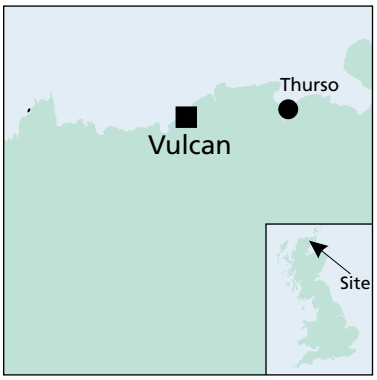
SEPA, and other stakeholders, are currently engaging with the MoD Nuclear Legacy Works Team at RRDL to identify the Best Practicable Environmental Option (BPEO) for managing radiologically contaminated Ion-exchange Resins held on the site. In March 2011, resin samples were sent for testing to assess whether the resins can be encapsulated in a cement-type matrix.

The *total dose* from all pathways and sources was less than 0.005 mSv in 2011 (Table 5.1), which is less than 0.5 per cent of the dose limit. The people most exposed were adults who consume fish at high rates; this represents a change from 2010 (adults spending time on shoreline sediments). The assessment of total dose is conservative, by estimating activity concentrations in seafood using reported environmental data in 2011. The source specific assessment for local fishermen (also by conservatively estimating seafood concentrations) and beach users gives an exposure that was also less than 0.005 mSv in 2011.

In 2011, authorised gaseous discharges from Rosyth were below the LoD. Liquid wastes are discharged via pipeline to the Firth of Forth. Tritium releases during 2011 were typical of the low levels discharged since 2000, and cobalt-60 discharges continued to decline. In all cases the activities in the liquid discharged were below authorised limits.

SEPA's routine monitoring programme included analysis of 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 2010, 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 2010 (Rumney *et al.*, *in press/b).*

5.8 Vulcan NRTE, Highland



The Vulcan Naval Reactor Test Establishment operated by the Defence Procurement Agency, acting as the test bed for prototype submarine nuclear reactors, is located adjacent to the DSRL Dounreay site and the impact of its discharges is considered along with those from Dounreay (in Section 3). The site continued operations in 2011 however in Written Parliamentary Statements made on 2nd of November 2011, it was stated that "the Vulcan NRTE site will not be required to support reactor core prototyping activity when the current series of PWR2 reactor core prototype tests are complete in 2015. Options for the future of the site are currently being assessed; these range from placing the prototype facilities into care and maintenance while retaining the site's strategic capabilities, to decommissioning the site and returning it to Nuclear Decommissioning Authority ownership".

Table 5.1. Individual radiation exposures - defence sites, 2011

Site	Exposed population[a,b]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways
Aldermaston and Burghfield							
Total dose - all sources	**Infant milk consumers**	**<0.005**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Anglers[c]	<0.005	<0.005	-	<0.005	-	-
	Infant consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005
	Workers at Silchester STW	<0.005	-	-	<0.005[d]	<0.005[e]	-
Derby							
Total dose - all sources	**Infant consumers of locally sourced water**	**<0.005**	**-**	**-**	**-**	**<0.005**	**-**
Source specific doses	Anglers consuming fish and drinking water[f]	<0.005	<0.005	-	<0.005	<0.005	-
Devonport							
Total dose - all sources	**Adult sea fish consumers**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**
Source specific doses	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
Faslane							
Total dose - all sources	**Adult occupants over sediment**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-	-
Holy Loch							
Source specific doses	Anglers	0.007	-	-	0.007	-	-
Rosyth							
Total dose - all sources	**Adult sea fish consumers**	**<0.005**	**<0.005**	**-**	**-**	**-**	**-**
Source specific doses	Fishermen and beach users	<0.005	<0.005	-	<0.005	-	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *None of the people represented in this table were considered to receive direct radiation from the sites listed*

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

[d] *External radiation from raw sewage and sludge*

[e] *Intakes of resuspended raw sewage and sludge*

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

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Flounder	Woolwich Reach	1		<25	*	0.06			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	*	<0.04	0.039	<0.00069	0.024
Sediment	Pangbourne	4[E]				4.1	13	<1.2	14
Sediment	Mapledurham	4[E]				7.2	11	<1.2	11
Sediment	Aldermaston	4[E]				2.3	8.8	<1.1	8.2
Sediment	Spring Lane	4[E]				<1.6	10	<1.1	11
Sediment	Stream draining south	4[E]				<1.4	27	<2.7	26
Sediment	Reading (Kennet)	4[E]				3.9	13	<1.2	13
Gullypot sediment	Falcon Gate	1[E]				2.1	16	<1.3	16
Gullypot sediment	Main Gate	1[E]		<8.0		0.52	14	<0.90	14
Gullypot sediment	Tadley Entrance	1[E]				17	15	<1.6	17
Gullypot sediment	Burghfield Gate	1[E]				1.7	13	<0.98	13
Freshwater	Pangbourne	4[E]		<3.7		<0.21	<0.0097	<0.0043	<0.0084
Freshwater	Mapledurham	4[E]		<3.9		<0.20	<0.012	<0.0040	0.0094
Freshwater	Aldermaston	4[E]		<5.2		<0.20	<0.0081	<0.0038	<0.0060
Freshwater	Spring Lane	4[E]		<4.0		<0.21	<0.0050	<0.0040	<0.0045
Freshwater	Reading (Kennet)	4[E]		<3.6		<0.20	<0.0082	<0.0037	<0.0053
Crude liquid effluent	Silchester treatment works	4[E]		<10		<0.20	<0.011	<0.0040	<0.0053
Final Liquid effluent	Silchester treatment works	4[E]		<11		<0.20	<0.010	<0.0055	<0.0050
Sewage sludge	Silchester treatment works	4[E]		<12		<0.53	0.19	<0.019	0.15

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Flounder	Woolwich Reach	1			<0.05				
Signal crayfish	Ufton Bridge - Theale	1	0.000016	0.000083	0.000092	*	*		
Sediment	Pangbourne	4[E]	<1.1	<0.85	<1.1			240	400
Sediment	Mapledurham	4[E]	<0.45	<0.70	<1.4			<170	<280
Sediment	Aldermaston	4[E]	<0.48	1.6	1.5			170	280
Sediment	Spring Lane	4[E]	<0.60	<2.0	<1.1			220	390
Sediment	Stream draining south	4[E]	<0.56	<0.58	<1.2			420	820
Sediment	Reading (Kennet)	4[E]	<0.48	<0.47	<0.99			150	370
Gullypot sediment	Falcon Gate	1[E]	<0.50	1.0	<0.62			230	650
Gullypot sediment	Main Gate	1[E]	<0.22	<0.33	<0.51			270	590
Gullypot sediment	Tadley Entrance	1[E]	<0.40	0.81	<1.5			230	530
Gullypot sediment	Burghfield Gate	1[E]	<0.68	0.55	<0.56			290	610
Freshwater	Pangbourne	4[E]	<0.0058	<0.0060	<0.0072			<0.065	0.31
Freshwater	Mapledurham	4[E]	<0.0055	<0.0050	<0.0075			<0.10	0.32
Freshwater	Aldermaston	4[E]	<0.0070	<0.0060	<0.0075			<0.15	0.20
Freshwater	Spring Lane	4[E]	<0.0052	<0.0050	<0.0078			<0.057	<0.13
Freshwater	Reading (Kennet)	4[E]	<0.0052	<0.0050	<0.0073			<0.047	<0.15
Crude liquid effluent	Silchester treatment works	4[E]	<0.015	<0.0060	<0.29			<0.17	0.79
Final Liquid effluent	Silchester treatment works	4[E]	<0.0065	<0.0050	<0.30			<0.090	0.68
Sewage sludge	Silchester treatment works	4[E]	<0.027	<0.028	<0.68			<2.7	<4.7

Table 5.2(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples									
Milk			6	<4.3		<0.19	<0.00075	<0.00055	<0.00075
Milk		max		<4.8		<0.20	0.0012	<0.00070	0.0015
Blackberries			1	<4.0		<0.10	0.0010	<0.00060	0.0010
Cabbage			1	<4.0		<0.20	0.0014	0.00020	0.0012
Honey			1	<7.0		<0.20	0.00080	<0.00040	0.0012
Onions			1	<4.0		<0.20	<0.00050	<0.00030	<0.00080
Rabbit			1	<5.0		<0.20	0.0027	0.00040	0.0016
Runner beans			1	<4.0		<0.20	<0.00070	<0.00030	<0.00080
Swede			1	<5.0		<0.20	0.0027	0.00040	0.0021
Wheat			1	<7.0		<0.20	0.0012	<0.00040	<0.00080
Grass	Location 7		1[E]	35	2.8	<0.99	0.40	<0.19	0.39
Grass	Opposite gate 26A		1[E]	28	1.8	<0.67	<0.32	<0.18	0.29
Soil			1[#]				5.7	0.26	5.8
Soil	Location 7		1[E]	<4.3		9.7	22	<1.1	24
Soil	Opposite gate 26A		1[E]	22		35	12	<2.4	12

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples							
Milk		6	<0.00010	<0.00010	<0.00012		
Milk	max				<0.00015		
Blackberries		1	<0.00020	<0.00010	<0.00020		
Cabbage		1	<0.00010	<0.00020	0.00040		
Honey		1	<0.00020	0.00020	<0.00020		
Onions		1	<0.00020	0.00020	<0.00020		
Rabbit		1	<0.00020	<0.00020	0.00030		
Runner beans		1	<0.00020	0.00020	0.00030		
Swede		1	<0.00010	<0.00020	0.00050		
Wheat		1	<0.00010	0.00010	<0.00030		
Grass	Location 7	1[E]	<0.18	0.14		13	240
Grass	Opposite gate 26A	1[E]	<0.10	0.13		<4.0	250
Soil	Location 7	1[E]	<0.65	0.96		290	640
Soil	Opposite gate 26A	1[E]	<0.61	1.7		220	450

* *Not detected by the method used*

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

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

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

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

Table 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2011

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	4	0.070
Mapledurham, riverbank	Grass and mud	3	0.067
Mapledurham, riverbank	Grass	1	0.063

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2011

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{58}Co	^{60}Co	^{106}Ru	^{110m}Ag	^{125}Sb	^{131}I
Barrow											
Grass	Barrow	2[F]		<5.0							
Derby											
Sediment	River Derwent, upstream	1					<0.50				
Sediment	Fritchley Brook	1					<1.1				
Sediment	River Derwent, downstream	4					<1.3				
Water	River Derwent, upstream	1					<0.24				
Water[c]	Fritchley Brook	1		<3.3			<0.23				
Water	River Derwent, downstream	4					<0.23				
Devonport											
Grey mullet	Plymouth Sound	1[F]			22	<0.05	<0.04	<0.35	<0.07	<0.09	*
Herring	Plymouth Sound	1[F]			25	<0.07	<0.07	<0.54	<0.11	<0.13	<0.30
Crabs	Plymouth Sound	2[F]			27	<0.11	<0.05	<0.52	<0.10	<0.13	*
Cockles	Southdown	1[F]				<0.52	<0.15	<1.7	<0.32	<0.32	*
Pacific oysters	Southdown	1[F]				<0.21	<0.07	<0.69	<0.14	<0.14	*
Pacific oysters	Lynher Estuary	1[F]			16	<0.15	<0.14	<1.3	<0.23	<0.30	<1.0
Mussels	River Lynher	2[F]	<25	<25		<0.12	<0.08	<0.78	<0.14	<0.17	*
Seaweed[d]	Kinterbury	2					<0.77				9.8
Sediment[e]	Kinterbury	2		<9.1			<1.5				
Sediment	Torpoint South	2		<11			<0.90				
Sediment	Lopwell	2		<17			<1.8				
Seawater	Torpoint South	2		<3.8	<11		<0.24				
Seawater	Millbrook Lake	2		<4.1	<7.3		<0.24				
Beetroot		1[F]		<4.0			<0.20	<0.50	<0.20		
Blackberries		1[F]		<4.0			<0.20	<1.3	<0.10		
Courgettes		1[F]		<4.0			<0.30	<1.2	<0.20		
Lettuce		1[F]		<4.0			<0.20	<1.2	<0.20		
Faslane											
Mussel shells	Shandon	1				<0.33	<0.10	<0.99	<0.13	<0.27	
Mussels	Shandon	1				<0.20	<0.10	<0.69	<0.10	<0.18	
Winkles	Garelochhead	1				<0.11	<0.11	<0.85	<0.11	<0.25	
Winkles	Helensburgh	1				<0.58	<0.10	<0.50	<0.10	<0.15	
Fucus vesiculosus	Rhu	1				<0.13	<0.10	<0.39	<0.10	<0.10	
Sediment	Carnban boatyard	1				<0.14	<0.10	<0.85	<0.16	<0.17	
Seawater	Carnban boatyard	2		1.8		<0.10	<0.10	<0.40	<0.10	<0.12	
Beef muscle	Faslane	1					<0.05	<0.36	<0.05		
Honey	Faslane	1					<0.06	<0.51	<0.07		
Grass	Auchengaich	1		<5.0			<0.09	<0.95	<0.11		
Grass	Lochan Ghlas Laoigh	1		<5.0			<0.05	<0.37	<0.06		
Soil	Auchengaich	1					<0.16	<1.7	<0.22		
Soil	Lochan Ghlas Laoigh	1					<0.07	<0.73	<0.12		
Freshwater	Helensburgh Reservoir	1		<1.0							
Freshwater	Loch Finlas	1		<1.0			<0.01	<0.09	<0.01		
Freshwater	Auchengaich	1		<1.0							
Freshwater	Lochan Ghlas Laoigh	1		<1.0			<0.01	<0.08	<0.01		
Freshwater	Loch Eck	1		<1.0							
Freshwater	Loch Lomond	1		<1.0			<0.01	<0.03	<0.01		
Holy Loch											
Sediment	Mid-Loch	1				<0.27	<0.10	<0.85	<0.14	<0.24	
Rosyth											
Fucus vesiculosus	East of dockyard	1				<0.32	<0.10	<0.84	<0.11	<0.20	
Sediment	East of dockyard	1				<0.14	<0.10	<0.81	<0.13	<0.25	
Sediment	Port Edgar	1				<0.15	<0.10	<0.93	<0.14	<0.24	
Sediment	West of dockyard	1				<0.10	<0.10	<0.29	<0.10	<0.10	
Sediment	East Ness Pier	1				<0.10	<0.10	<0.59	<0.10	<0.19	
Sediment	Blackness Castle	1				<0.10	<0.10	<0.53	<0.10	<0.17	
Sediment	Charlestown Pier	1				<0.10	<0.10	<0.52	<0.10	<0.16	
Seawater	East of dockyard	2		<1.0		<0.13	<0.10	<0.52	<0.10	<0.14	
Freshwater	Castlehill	1		<1.0			<0.01	<0.06	<0.01		
Freshwater	Holl Reservoir	1		1.2			<0.01	<0.06	<0.01		
Freshwater	Gartmorn	1		<1.0			<0.01	<0.05	<0.01		
Freshwater	Morton No. 2	1		<1.0							

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{134}Cs	^{137}Cs	^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Derby											
Sediment	River Derwent, upstream	1		2.7		22	<1.9	21		330	490
Sediment	Fritchley Brook	1				19	<1.4	20		180	630
Sediment	River Derwent, downstream	4		2.8		29	<2.0	27		380	650
Grass		4[F]				0.057	<0.0022	0.058			
Grass	max					0.11	0.0053	0.13			
Soil		4[F]				26	1.0	26			
Soil	max					37	1.5	36			
Water	River Derwent, upstream	1								<0.060	0.23
Water[c]	Fritchley Brook	1		<0.20		0.042	<0.0090	0.032		<0.080	0.19
Water	River Derwent, downstream	4								<0.093	0.28
Devonport											
Grey mullet	Plymouth Sound	1[F]	<0.04	0.10	<0.10				<0.10		
Herring	Plymouth Sound	1[F]	<0.07	<0.07	<0.11				<0.06		
Crabs	Plymouth Sound	2[F]	<0.05	<0.05	<0.12				<0.10		
Cockles	Southdown	1[F]	<0.17	<0.13	<0.22				<0.11		
Pacific oysters	Southdown	1[F]	<0.07	<0.05	<0.10				<0.05		
Pacific oysters	Lynher Estuary	1[F]	<0.14	<0.13	<0.20				<0.11		
Mussels	River Lynher	2[F]	<0.08	<0.07	<0.11				<0.06		
Sediment[e]	Kinterbury	2		4.4					0.85		
Sediment	Torpoint South	2		1.0							
Sediment	Lopwell	2		7.8							
Beetroot		1[F]	<0.20	<0.20							
Blackberries		1[F]	<0.20	<0.20							
Courgettes		1[F]	<0.20	<0.20							
Lettuce		1[F]	<0.20	<0.20							
Faslane											
Mussel shells	Shandon	1	<0.11	0.10	<0.26				<0.14		
Mussels	Shandon	1	<0.10	0.22	<0.16				<0.10		
Winkles	Garelochhead	1	<0.10	0.41	<0.22				<0.12		
Winkles	Helensburgh	1	<0.10	0.65	<0.13				<0.10		
Fucus vesiculosus	Rhu	1	<0.10	0.65	<0.10				<0.10		
Sediment	Carnban boatyard	1	<0.13	9.9	0.76				0.56		
Seawater	Carnban boatyard	2	<0.10	<0.10	<0.12				<0.10		
Beef muscle	Faslane	1	<0.05	0.09					<0.09		
Honey	Faslane	1	<0.06	0.55					<0.09		
Grass	Auchengaich	1	<0.10	<0.09					<0.12		
Grass	Lochan Ghlas Laoigh	1	0.14	9.2					<0.11		
Soil	Auchengaich	1	<0.10	1.4					<0.32		
Soil	Lochan Ghlas Laoigh	1	<0.09	27					0.68		
Freshwater	Helensburgh Reservoir	1		<0.01						<0.010	0.035
Freshwater	Loch Finlas	1	<0.01	<0.01					<0.01	<0.010	0.030
Freshwater	Auchengaich	1		<0.01						<0.010	0.017
Freshwater	Lochan Ghlas Laoigh	1	<0.01	<0.01					<0.01	<0.010	0.030
Freshwater	Loch Eck	1		<0.01						<0.010	<0.014
Freshwater	Loch Lomond	1	<0.01	<0.01					<0.01	<0.010	0.020
Holy Loch											
Sediment	Mid-Loch	1	<0.10	6.5	1.1				<0.31		
Rosyth											
Fucus vesiculosus	East of dockyard	1	<0.10	0.12	<0.19				<0.13		
Sediment	East of dockyard	1	<0.12	5.1	0.68				<0.34		
Sediment	Port Edgar	1	<0.13	14	1.5				1.5		
Sediment	West of dockyard	1	<0.10	1.7	0.61				<0.12		
Sediment	East Ness Pier	1	<0.10	16	0.71				<0.23		
Sediment	Blackness Castle	1	<0.10	3.4	0.43				<0.23		
Sediment	Charlestown Pier	1	<0.10	0.70	0.41				<0.26		
Seawater	East of dockyard	2	<0.10	<0.10	<0.13				<0.10		
Freshwater	Castlehill	1	<0.01	<0.01					<0.01	<0.010	0.020
Freshwater	Holl Reservoir	1	<0.01	<0.01					<0.01	<0.010	0.020
Freshwater	Gartmorn	1	<0.01	<0.01					<0.01	<0.010	0.090
Freshwater	Morton No. 2	1		<0.01						<0.010	<0.014

* *Not detected by the method used*

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

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

[c] *The concentrations of ^{228}Th, ^{230}Th and ^{232}Th were 0.011, <0.0060 and 0.0050 Bq l^{-1}*

[d] *The concentration of ^{99}Tc was <1.0 Bq kg^{-1}*

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

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

Table 5.3(b). Monitoring of radiation dose rates near defence establishments, 2011

Establishment	Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Devonport	Torpoint South	Mud and stones	1	0.10
Devonport	Torpoint South	Rock and mud	1	0.10
Devonport	Kinterbury Access Gate	Mud and stones	2	0.090
Devonport	Lopwell	Mud	2	0.092
Faslane	Garelochhead	Mud, sand and stones	2	0.054
Faslane	Gulley Bridge Pier	Sand and stones	2	0.059
Faslane	Rhu	Gravel	2	0.055
Faslane	Helensburgh	Sand	2	0.051
Faslane	Carnban boatyard	Gravel	2	0.074
Holy Loch	North Sandbank	Mud and sand	1	0.060
Holy Loch	Kilmun Pier	Sand and stones	1	0.063
Holy Loch	Mid-Loch	Sand	1	0.073
Rosyth	Blackness Castle	Mud and sand	2	0.052
Rosyth	Charlestown Pier	Sand	2	0.048
Rosyth	East Ness Pier	Sand	2	0.055
Rosyth	East of dockyard	Sand	2	0.055
Rosyth	Port Edgar	Mud	2	0.054
Rosyth	West of dockyard	Mud and rock	2	0.050

6. Radiochemical production

This section considers the results of monitoring by the Environment Agency and Food Standards Agency 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. In 2011, GE Healthcare occupied a building in one small area embedded within the Harwell licensed site. 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, 2010b).

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- Public radiation doses from all sources were less than 22 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Gaseous discharges of radon-222 increased (from the lowest reported value in 2010)
- Concentrations of radioactivity in terrestrial and aquatic samples, and gamma dose rates, were low and generally similar to those in 2010

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- Public radiation doses from all sources were less than 1 per cent of the dose limit. The highest exposure was due to external radiation emitted from radionuclides in intertidal sediment
- Gaseous and liquid discharges of tritium and carbon-14 decreased
- Tritium concentrations in most fish species continued their long-term decline; mean carbon-14 concentrations in fish also decreased

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 technetium-99m, for use in medicine and research. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 3.1. The most recent habits survey was undertaken in 2009 (Clyne *et al.*, 2010b).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.22 mSv, or 22 per cent of the dose limit (Table 6.1), and unchanged from 2010. This dose was primarily due to the relatively high level of direct radiation to local adult inhabitants at the site perimeter. Exposure from direct radiation varies around the boundary of the Grove Centre and therefore the *total dose* is determined as a cautious upper value. The trend in *total dose* over the period 2004 – 2011 is given in Figure 1.1. *Total doses* remained broadly similar with time and were dominated by direct radiation.

Source specific assessments for high-rate consumers of locally grown foods, for anglers, and for workers at Maple Lodge, give exposures that were less than the *total dose* in 2011 (Table 6.1). The dose for high rate consumers of locally grown foods which included a contribution from the gaseous plume related pathways was 0.022 mSv, or approximately 2 per cent of the dose limit to members of the public of 1 mSv. The increase in dose, from 0.012 mSv in 2010, was primarily due to the higher atmospheric discharges of radon-222 in 2011, this radionuclide 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 dose in 2011 to local anglers was 0.007 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table

6.1). In 2010, the dose was less than 0.005 mSv, and the increase in 2011 was due to small enhancements in gamma dose rates above the banks of the canal.

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 for anglers.

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 2011 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.

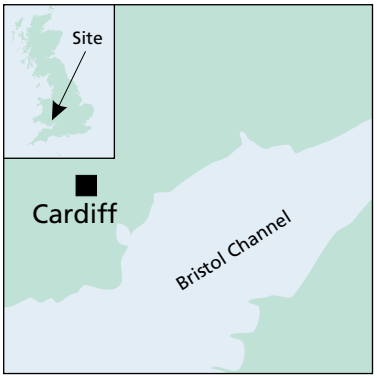
Gaseous discharges and terrestrial monitoring

The Amersham facility is permitted to discharge gaseous radioactive wastes via stacks on the site. Radon-222 discharges increased in comparison to 2010 due to unexpected releases in 2011 (see Table A2.4 for further information); other gaseous discharges were generally similar. Activity concentrations in terrestrial samples were generally below the limits of detection (Table 6.2). Sulphur-35 was positively detected at low concentrations in some crop and grass samples, and iodine-125 was detected just above the LoD in one sample (blackberries) in 2011. Caesium-137 activities were again detected in soil near the site, and this 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 given in Table 6.2. Activity concentrations in freshwater, and effluent and sludge from Maple Lodge STW, were below, or near, 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 (given in footnote, Table 6.2) above the banks of the canal remained low in 2011, but there was a small enhancement in rates in comparison to 2010.

6.2 Maynard Centre, Cardiff



GE Healthcare operates a second establishment, on the Forest Farm industrial estate near Whitchurch, Cardiff. GE Healthcare ceased manufacturing a range of radiolabelled products containing tritium in 2009 and products containing carbon-14 in 2010. The site is being decommissioned and the bulk of the site will be de-licensed (subject to approval from the ONR), leaving a small licensed area for storage of historic radioactive wastes. A revised permit was issued in August 2011 following a variation application for new solid waste transfer routes. Gaseous discharges from the Maynard Centre are now the result of out-gassing of tritium and carbon-14 from stored wastes with only small amounts originating from decommissioning.

GE Healthcare's custom radiolabelling division was acquired by Quotient Bioresearch, (a division of Quotient Bioscience) who operates from different premises in Cardiff (a purpose-built laboratory at Trident Park). This non-nuclear facility also discharges carbon-14 and tritium to atmosphere and to the Severn estuary near Orchard Ledges. These are at much reduced levels in comparison to when the Maynard Centre was manufacturing radiolabelled products. The effluents discharged from the site are also treated to ensure that organic matter present is destroyed prior to discharge.

The Food Standards Agency and the Environment Agency conduct a routine monitoring programme on behalf of the Welsh 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. The most recent habits survey was undertaken in 2003 (McTaggart *et al*., 2004a).

Past monitoring data from Cardiff has been reviewed in order to compare the apparent enhancement of tritium concentrations on uptake by marine biota with bioaccumulation at other UK sites (Hunt *et al*., 2010). 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).

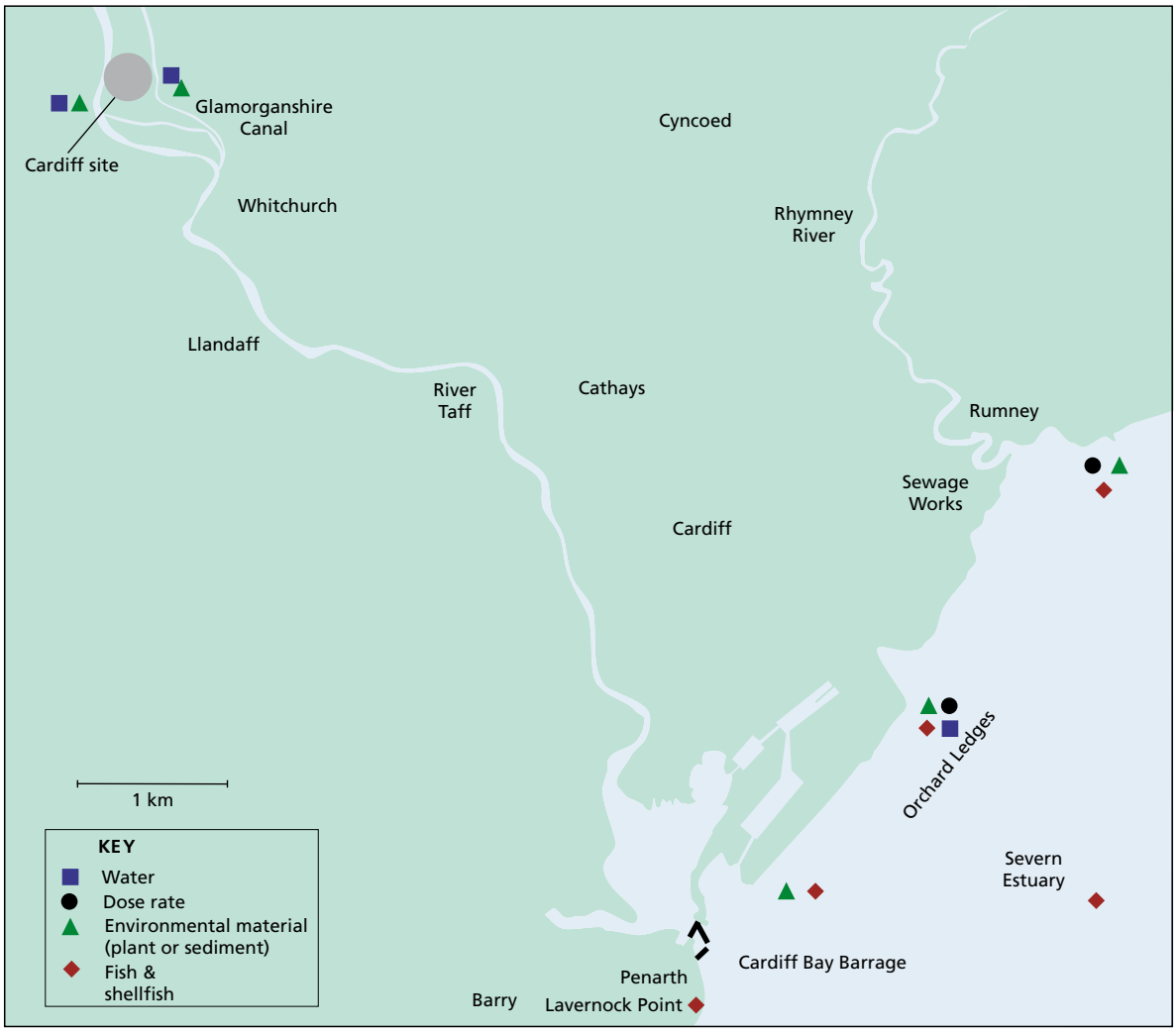


Figure 6.1. Monitoring locations at Cardiff, 2011 (not including farms)

Doses to the public

In 2011, the *total dose* from all pathways and sources was 0.006 mSv (Table 6.1), or approximately 0.5 per cent of the dose limit (as in 2010). This dose estimates take into account the increased dose coefficients for OBT derived for discharges from the Maynard Centre and includes consideration of prenatal children. The dominant contributions to this exposure were the low levels of external radiation emitted from radionuclides in intertidal sediment and mostly due to radioactive sources other than from the GE Healthcare site in Cardiff. The prenatal children of adults who spend time over intertidal sediments were the most exposed people. The contribution of tritium in fish to the *total dose* in 2011 was approximately half of the value in 2010 (~ 0.001 mSv). Trends in *total doses* in the Severn Estuary (and areas of the south coast) are shown in Figure 6.2. At Cardiff, the most significant reductions in the *total dose*, prior to 2007, were largely due to lower concentrations of tritium and carbon-14 in seafood. Since 2007, the *total doses* continued to decrease over time, and in recent years were consistently low.

Source specific assessments for consumers of locally grown foods (that consumed crops grown in soil treated with sludge pellets), for recreational users of the River Taff, and for workers at Cardiff East Waste Water Treatment Works, give exposures that were less than 0.005 mSv in 2011 (Table 6.1). The doses to consumers of locally grown foods and seafood, at high-rates, were 0.005 and 0.010 mSv, respectively (as in 2010). However, the latter dose (although unchanged from 2010) included an increased contribution from gamma dose exposure combined with a decreased contribution from seafood consumption (mostly tritium in fish).

The dose coefficients for OBT differ from those for tritiated water (see Appendix 1, A3.4) 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. An experimental study by Hunt *et al.* (2009) suggests that this raised dose coefficient is conservative, but it is retained for 2011 dose assessments on the advice of the HPA. For ingestion of other food, the ICRP dose coefficient for OBT is applied.

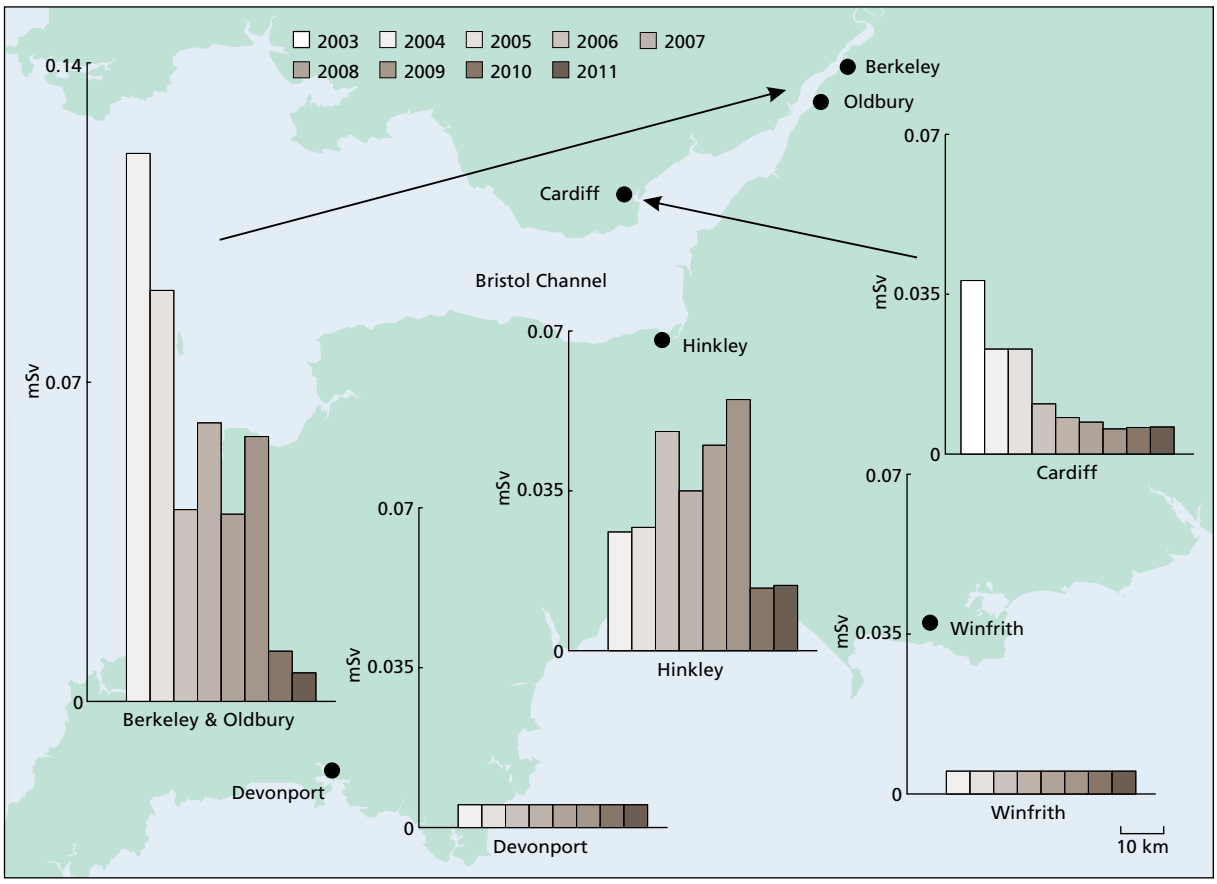


Figure 6.2. *Total dose* for major sites in the Severn Estuary and south coast, 2003-2011
(Small doses, less than or equal to 0.005 mSv, are recorded as being 0.005 mSv)

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. Following the significant decrease of tritium discharges in recent years, further reductions in releases of insoluble tritium occurred in 2011. This resulted from the reduced commercial operations, in relation to the site's planned shutdown. Carbon-14 discharges were also decreased in 2011, compared to those releases in 2010.

The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops, freshwater, soil and grass. 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.

Tritium concentrations in all terrestrial food samples were below the LoD in 2011 (Table 6.3(a)). These values are the lowest in over a decade and are consistent with progressive discharge reductions in recent years. Carbon-14 concentrations in foodstuffs were generally similar to those in 2010 (although lower in grass and silage samples in 2011). Low concentrations of sulphur-35, which is not discharged by the site, were detected in foods and are similar to those in 2010. Phosphorus-32 and iodine-125 were below the limits of detection in all terrestrial samples.

Samples of raw and treated sewage and associated products from Cardiff East WWTW were analysed for tritium and carbon-14 in 2011. The results (Table 6.3(a)) show enhanced concentrations of tritium in crude effluent and sludge pellets. However, the value for sludge pellets was significantly decreased from that in 2010 (by about an order of magnitude), and was the lowest reported value in recent years.

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 6.3. 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 over the whole time period. In 2011 (unlike in 2010), the

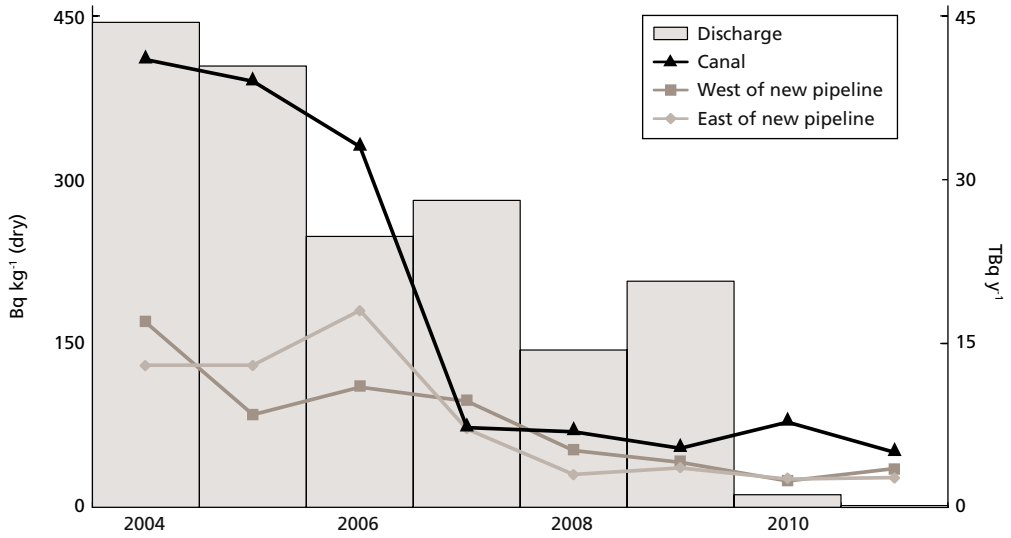


Figure 6.3. Tritium liquid discharge from Cardiff and mean concentrations in sediment near Cardiff, 2004-2011

tritium concentration from site run-off water into the River Taff was below the LoD.

Liquid waste discharges and aquatic monitoring

The Maynard Centre discharges liquid wastes into the Ystradyfodwg and Pontypridd (YP) public sewer. 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 2011 (as in 2010) was very low. Over the longer term the discharge rate of this nuclide has decreased substantially (Figure 6.4). Carbon-14 discharges also decreased again in 2011, continuing its recent and long-term downward trend (Figure 6.5).

Marine sampling included locally caught seafood, and indicator materials (e.g. seaweed). These were supported by external dose rate measurements over intertidal areas. The results of routine monitoring in 2011 are given in Tables 6.3(a) and (b). The effects of liquid discharges remained evident in enhanced tritium and carbon-14 concentrations in fish samples. Further analysis of these samples showed that a high proportion of the tritium was still 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. In 2011, tritium concentrations in most fish (cod, flounder, and sole and skates/rays) decreased significantly (whilst dogfish increased) as compared with concentrations of their respective species in 2010. 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 in recent years suggests that complex indirect uptake mechanisms continue to affect tritium concentrations in the region.

No mussel samples were collected from Cardiff in 2011 (as in 2010) due to the scarcity of the available species, leaving limpets as the only mollusc sample. Figure 6.4 indicates that the overall tritium concentrations in mollusc samples have decreased significantly over the last decade. Tritium was also detected in marine sediment samples at similar levels to those in 2010. The mean concentration of carbon-14 in fish (but not in molluscs) showed a small decrease consistent with the reduction in discharges in 2011. The longer term trend in concentrations and the relationship to discharges is shown in Figure 6.5 (concentrations in both species declining). 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. Overall, gamma dose rates over sediment were slightly higher than 2010 levels, but are not, in the main, attributable to discharges from the Maynard Centre.

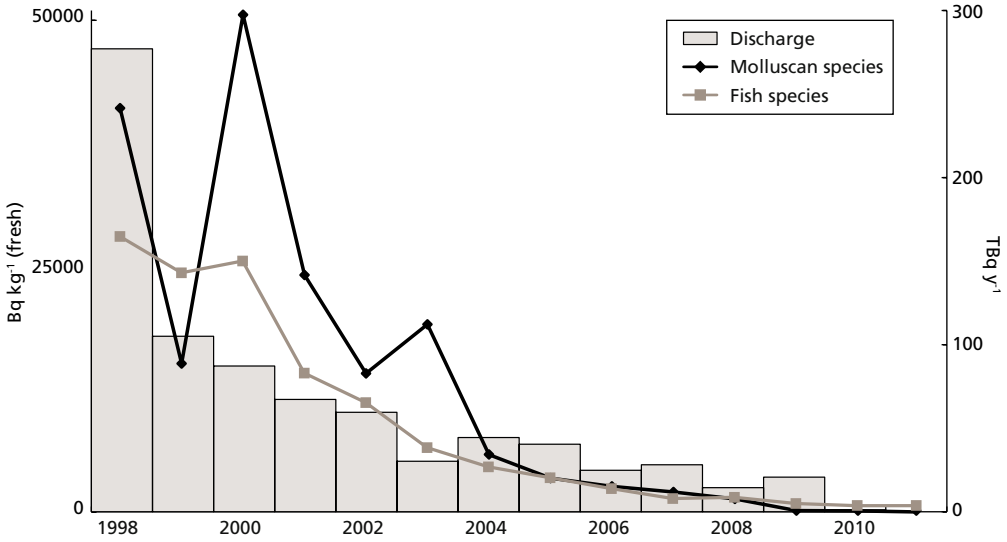


Figure 6.4. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2011 (species include all those reported in RIFE for the given year)

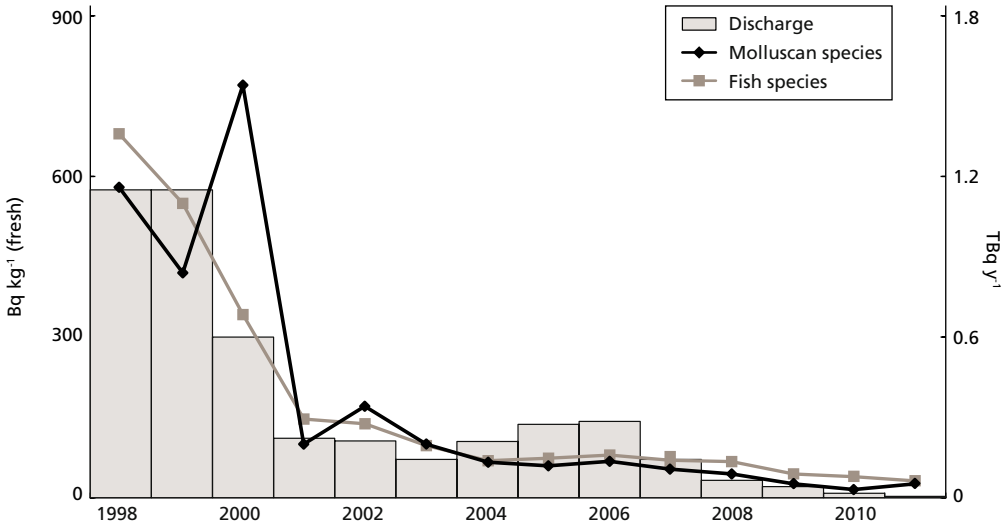


Figure 6.5. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2011 (species include all those reported in RIFE for the given year)

Table 6.1. Individual radiation exposures - radiochemical sites, 2011

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 or water	Gaseous plume related pathways	Direct radiation from site
Amersham								
Total dose - all sources	**Local adult inhabitants (0 - 0.25km)**	**0.22**	**-**	**<0.005**	**<0.005**	**-**	**0.007**	**0.22**
Source specific doses	Anglers	0.007	<0.005	-	0.007	-	-	-
	Infant consumers of locally grown food	0.022	-	<0.005	-	-	0.020	-
	Workers at Maple Lodge STW	<0.005	-	-	<0.005[b]	<0.005[c]	-	-
Cardiff								
Total dose - all sources	**Prenatal children of occupants over sediment**	**0.006**	**<0.005**	**-**	**0.005**	**-**	**-**	**-**
Source specific doses	Prenatal children of seafood consumers	0.010	<0.005	-	0.009	-	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-	-
	Infant consumers of locally grown food	0.005	-	0.005	-	-	<0.005	-
	Workers at Cardiff East WWTW	<0.005	-	-	<0.005[b]	<0.005[c]	-	-
	Prenatal children of consumers of crops grown in soil treated with sludge pellets	<0.005	-	<0.005	-	-	-	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *External radiation from raw sewage and sludge*

[c] *Intakes of resuspended raw sewage and sludge*

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2011[g]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{32}P	^{35}S	^{57}Co	^{65}Zn	^{125}I
Freshwater samples								
Flounder	Woolwich Reach	1	<25			<0.03	<0.15	
Sediment	River Colne (Grand Union Canal)	2[E]				<0.53	<3.0	<3.2
Sediment	Upstream of outfall (Grand Union Canal)	2[E]				<0.56	<3.3	<2.9
Freshwater	Maple Cross	2[E]	<5.0			<0.11	<0.44	<0.33
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<4.8			<0.11	<0.41	<0.33
Freshwater	River Chess	1[E]	<3.4			<0.11	<0.42	<0.23
Freshwater	River Misbourne - upstream	1[E]	<3.4			<0.11	<0.43	<0.24
Freshwater	River Misbourne - downstream	1[E]	<3.4			<0.11	<0.43	<0.23
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<7.4	<1.6	<0.51	<0.13	<0.59	<0.36
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<7.3	<2.3	<0.58	<0.12	<0.58	<0.38
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<9.4	<1.6	<0.53	<0.11	<0.49	<0.42

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{131}I	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Freshwater samples							
Flounder	Woolwich Reach	1	*	0.06	<0.05		
Sediment	River Colne (Grand Union Canal)	2[E]	<6.0	5.0		<130	200
Sediment	Upstream of outfall (Grand Union Canal)	2[E]	<6.3	8.3		190	370
Freshwater	Maple Cross	2[E]	<0.82	<0.18		<0.090	0.69
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<0.85	<0.20		<0.055	0.21
Freshwater	River Chess	1[E]	<0.45	<0.20		<0.050	<0.10
Freshwater	River Misbourne - upstream	1[E]	<0.48	<0.20		<0.070	<0.050
Freshwater	River Misbourne - downstream	1[E]	<0.46	<0.20		<0.060	<0.060
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<0.24	<0.31	<0.13	0.57
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]		<0.22	<0.28	<2.0	4.7
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]		<0.20	<0.29	<0.12	0.73

Table 6.2. continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{35}S	^{57}Co	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples										
Milk		2	<4.4	<0.23		<0.015	<0.0093	<0.20		
Milk	max		<4.5			<0.016	<0.013			
Apples		1	<4.0	<0.20		<0.028		<0.20		
Blackberries		1	<4.0	<0.20		0.061		<0.10		
Broad beans		1	<4.0	0.60		<0.027		<0.20		
Broccoli		1	<4.0	0.90		<0.0080		<0.20		
Cabbage		1	<4.0	<0.30		<0.031		<0.10		
Carrots		1	<4.0	0.20		<0.030		<0.20		
Potatoes		1	<5.0	0.50		<0.031		<0.20		
Wheat		1	<7.0	1.3		<0.053		<0.20		
Grass	Next to site	1[E]		1.3	<0.48	<0.97	<1.9	<1.1	<2.0	220
Grass	Orchard next to site	1[E]		2.5	<0.43	<0.91	<1.7	<0.88	<2.2	230
Grass	Water Meadows (River Chess)	1[E]		<1.6	<0.26	<0.46	<0.89	<0.71	<2.5	300
Soil	Next to site	1[E]			<0.43	<2.5	<2.2	11	310	770
Soil	Orchard next to site	1[E]			<0.47	<2.2	<2.5	4.3	280	480
Soil	Water Meadows (River Chess)	1[E]			<0.49	<2.5	<8.1	11	120	300

* *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 ^{3}H as tritiated water was <4.7 Bq l^{-1}*

e *The concentration of ^{3}H as tritiated water was <3.5 Bq l^{-1}*

f *The concentration of ^{3}H as tritiated water was <3.6 Bq l^{-1}*

g *The gamma dose rates in air at 1m over grass and mud, and grass on the bank of the Grand Union Canal were 0.069 and 0.066 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, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{125}I	^{131}I	^{137}Cs
Marine samples									
Cod	East of new pipeline	1		92		34		*	0.22
Flounder	East of new pipeline	4	230	250		32		<0.45	0.30
Sole	East of new pipeline	2		710		31		*	0.19
Mullet	East of new pipeline	1		<25		24		*	0.27
Lesser spotted dogfish	Off Orchard Ledges	2	940	1000		34		*	0.49
Skates/Rays	Off Orchard Ledges	1	47	53		30		*	0.65
Thornback Ray	Off Orchard Ledges	1	180	180		50		*	0.87
Limpets	Lavernock Point	2	<25	<25		26		*	0.33
Seaweed[d]	Orchard Ledges	2[E]		29	8.4	26	<0.75		<0.55
Sediment	East of new pipeline	2[E]		27		6.0	<8.4		23
Sediment	West of new pipeline	2[E]		35	<5.5	<9.3	<7.7		12
Seawater	Orchard Ledges	2[E]		<7.3	<4.3	<12	<0.47		<0.20

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{35}S	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples												
Milk[g]		6	<4.3	<4.3		17	<0.37	<0.016		<0.20		
Milk[g]	max		<4.6	<4.5		18	0.45	<0.018				
Barley		1		<7.0		96	1.6	<0.087		<0.20		
Blackberries		1	<4.0	<4.0		15	<0.20	<0.046		<0.30		
Cabbage		1	<4.0	<4.0		2.0	<0.30	<0.026		<0.20		
Honey		1		<8.0		84	<0.20	<0.020		<0.20		
Leeks		1	<4.0	<4.0		10	0.30	<0.035		<0.20		
Onions		1	<4.0	<4.0		8.0	0.30	<0.030		<0.20		
Potatoes		1	<5.0	<5.0		15	0.50	<0.037		<0.20		
Rape		1		<10		16	3.6	<0.037		<0.30		
Strawberries		1	<4.0	<4.0		12	<0.20	<0.041		<0.20		
Swede		1	<4.0	<4.0		6.0	0.70	<0.032		<0.20		
Grass		5	<5.6	<5.6		20				<0.20		
Grass	max		<8.0	8.0		21				0.20		
Silage		2	<5.5	<5.5		30						
Silage	max		<6.0	6.0		33						
Soil		3								5.1		
Soil	max									7.1		
Sediment	Canal	2[E]		51		19		<8.8		8.3		
Freshwater	River Taff upstream	2[E]		<17	<5.0	<4.5		<0.42	<0.34	<0.20	<0.070	0.30
Freshwater	River Taff downstream	1[E]		<18	<4.2	<4.5		<0.43	<0.36	<0.20	<0.070	0.22
Freshwater	Canal	2[E]		<19	11	<4.3		<0.27	<0.73	<0.30	<0.060	0.14
Crude effluent	Cardiff East WWTW	1[E]	190	190	<3.3	<3.5						
Final effluent	Cardiff East WWTW	1[E]	<8.6	<8.6	17	<3.5						
Sludge pellets	Cardiff East WWTW	1[E]		140		<130						

* *Not detected by the method used*

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

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

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

[d] *The concentration of ^{99}Tc was 4.8 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 ^{32}P 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, 2011

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	1	0.085
East of Pipeline	Mud and rock	1	0.077
West of Pipeline	Mud	1	0.088
West of Pipeline	Mud and sand	1	0.11
Peterstone Wentlooge	Mud and salt marsh	1	0.081
Peterstone Wentlooge	Salt marsh	1	0.085

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.

Key points

LLWR, near Drigg

- No disposals of solid waste were made in 2011
- A variation to the site's discharge permit was effective in 2011 to allow for new waste transfer routes
- Concentrations and dose rates at LLWR were similar to those in 2010
- Doses near Drigg were dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven

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
- Permits were granted relating to the disposal of LLW
- Very small discharges from the Studsvik Metals Recycling Facility were made in 2011
- Enhancement in natural radionuclides at Whitehaven from phosphate processing are now very difficult to detect, however the radiation dose from the enhancement, taken with effects of disposal of other local wastes, was estimated to be 18 per cent of the dose limit
- The investigation into the radium-226 contamination near Dalgety Bay, Fife continued in 2011
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in regulations

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 most waste is grouted within containers before disposal. Wastes are now disposed of in engineered concrete vaults on land, whereas prior to the early 1990s waste was disposed of in open clay lined trenches. The site is operated by LLW Repository Limited on behalf of the NDA. From 1 April 2008, a consortium, UK Nuclear Waste Management Limited (UKNWM), took over as the Parent Body Organisation for LLW Repository Limited. The operators submitted an Environmental Safety Case (ESC) to the Environment Agency in May 2011. The purpose of this submission is to demonstrate to the Environment Agency that the continued use of the site, and in particular the disposal of waste into vault 9, is safe for people and the environment both now and in the long term.

The Environment Agency is providing significant effort into its review of the LLWR ESC submitted by the operators in May 2011. Once the technical review is completed, the Environment Agency expects LLW Repository Limited to seek a variation to their permit to allow further disposals at the site. At that point the Environment Agency will consult widely. As part of the technical review the Environment Agency has identified a number of areas where further information is required. Therefore, full completion of the review is not anticipated until around the end of 2012 (subject to provision of further suitable information). These timescales will impact upon any final decision date on permitting further disposals, which would not now be expected until at least the end of 2013. Further information is available at: www.environment-agency.gov.uk/llwr

A report published by the Environment Agency provides 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 Environment Agency re-issued the permit, effective from 1 January 2011, which included the allowance for new waste transfer routes, but did not change gaseous, liquid or solid

discharge limits. These additional routes were used during the year for the disposal of LLW to appropriately permitted sites.

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 Sellafield and any effects of LLWR discharges in the marine environment could not, in 2011, be distinguished from those due to Sellafield.

In 2011, there were no disposals of solid waste at the LLWR near Drigg due to a combination of the only permitted disposal capacity in Vault 8 being nearly full and also maintenance work being undertaken on the waste grouting facility. Future disposals will depend on the outcome of the ESC review process and permitting of further disposal capacity.

During 2010, the LLWR near Drigg reported some negative figures for the disposal of solid low level waste by burial on the site (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2011). These negative figures reflect an exercise undertaken in February 2010 in which a number of waste containers were transferred from a disposal vault (Vault 8) to a storage vault (Vault 9), or to positions within a vault currently identified as for storage only (higher stacked waste in Vault 8). Insufficient further waste was disposed of in the disposal vault, during the remainder of 2010, to restore the total radioactivity of some groups of radionuclides within this vault to positive disposal figures. This resulted in negative overall disposal figures during the year for the site. These transfers were undertaken to optimise the limited remaining disposal capacity for the receipt of 'overweight' containers in the disposal vault, with the intent of minimising the risk that 'overweight' containers would need to be moved in the future, given that these movements can be problematic.

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 2010. 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 in 2010 have shown that the 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 close to the limit of detection. No sample was available for analysis in 2011.

The monitoring programme of terrestrial foodstuffs at the site was primarily directed at the potential migration of radionuclides from the waste burial site via groundwater. Results for 2011 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 2011, as it was in 2010. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 2). The *total dose* from all pathways and sources, including a component due to Chernobyl and weapon test fallout, was 0.18 mSv, or 18 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). This was 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, and the sources of exposure from the LLWR are considered, the people most exposed were represented by children aged 1 year spending time near the site. Their *total dose* in 2011 was 0.033 mSv (Table 1.2), mostly due to direct radiation. Source specific assessments of exposures for consumers of water from Drigg stream and of locally grown terrestrial food were less than 0.013 mSv.

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. In Northern Ireland, this type of waste is transferred to Great Britain for incineration. 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 2011 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 (e.g. Clifton Marsh), and at a few other landfill sites where disposals of radioactive waste are ongoing. In June 2011, the Environment Agency conducted a public consultation, on an application made by Sita (Lancashire) Limited, to allow Clifton Marsh landfill to

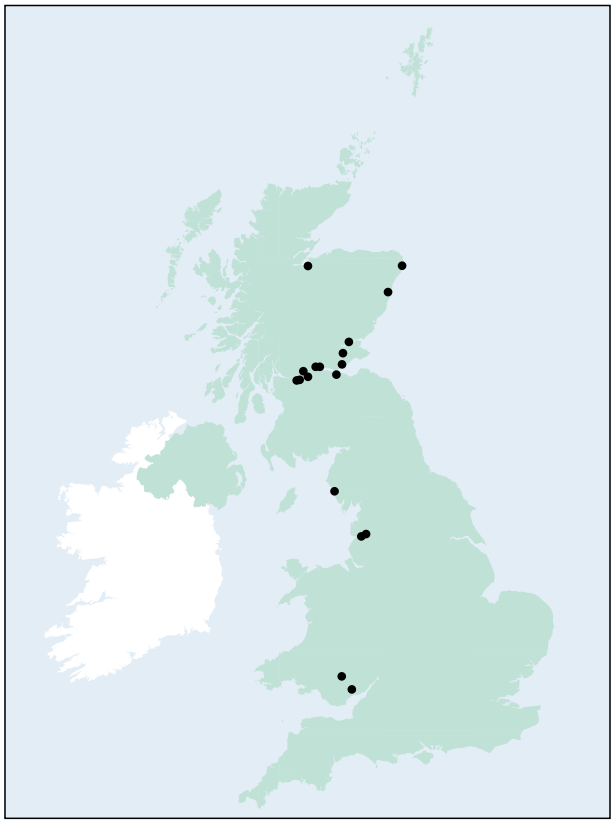


Figure 7.1. Landfill sites monitored in 2011

accept waste containing low levels of radioactivity from a range of sources.

The results, in common with previous years, showed very low concentrations of caesium-137 in leachate and evidence for migration of tritium from some of the discharge sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al*., 1998). Inadvertent ingestion of leachate (2.5 l per year) from the site with the highest observed concentration of tritium 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). Similarly the dose from ingestion of uranium isotopes in leachate from Clifton Marsh was also less than 0.005 mSv. Clifton Marsh has been used for solid waste disposal from the Springfields nuclear site in the past (see Section 2.2).

In March 2007, the Government introduced a more flexible framework for the disposal of certain categories of LLW to landfill. Further details and information are provided on the DECC website: http://www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/radioactivity/waste/low/low.aspx

The Environment Agency website describes how the agency regulates radioactive waste going to landfill: http://www.environment-agency.gov.uk/business/sectors/100241.aspx

Landfill companies and nuclear operators have to apply to the Environment Agency for permits to dispose of LLW. This Government policy has led to a number of applications to dispose of LLW to landfill, particularly wastes from nuclear sites being decommissioned. During 2011, the Environment Agency issued two such permits, as follows:

- Waste Recycling Group (WRG) Limited. On 6 April 2011, a permit to WRG Limited to dispose of up to 26,000 cubic metres of very low level radioactive waste at their Lillyhall Landfill Site in Cumbria.
- Augean. On 25 May 2011, a permit to Augean for the disposal of low level radioactive waste at the East Northants Resource Management Facility, near Kings Cliffe, Northamptonshire.

Neither of the sites received radioactive waste for disposal in 2011. The Environment Agency will consider the need to extend their environmental monitoring in the vicinity of these sites once any such disposals take place.

SEPA has also started a programme of monitoring at the Stoneyhill Landfill Site in Aberdeenshire. The purpose of the programme is to gather data on the environmental baseline around the site prior to the landfill consigning conditioned Naturally occurring radioactive material (NORM) waste from the oil and gas industry.

NORM is found within oil and gas reserves and is consequently extracted along with the oil and gas. The NORM can precipitate onto oil and gas industry equipment creating an insoluble scale (NORM scale). The presence of this scale reduces the efficiency of the equipment and must be removed. Sita UK Limited, who operates Stoneyhill Landfill, has constructed a descaling facility adjacent to the landfill in partnership with Nuvia Limited. This facility will descale oil and gas industry equipment, such as pipes, using pressurised water. The solid scale removed from the equipment will then be grouted into drums and consigned to Stoneyhill Landfill in accordance with their authorisation granted in May 2012.

The SEPA monitoring programme involves the collection and analysis of landfill leachate, groundwater and surface water on a quarterly basis prior to the landfill accepting conditioned NORM waste so that an environmental baseline can be established. This programme is complementary to, but independent of, the operator monitoring programme.

Further details of the authorisation and SEPA's decision document can be found on the Radioactive Substances pages of the SEPA website. The results of the monitoring programme will be included in next year's RIFE.

7.3 Metals Recycling Facility, Lillyhall, Cumbria

The Metals Recycling Facility (MRF), operated by Studsvik UK Limited, first commenced operations in September 2009. The facility is located on the north-eastern edge of the Lillyhall Industrial Estate, about 4 km south-east of Workington. The main function of the MRF is to receive, sort, segregate, monitor and size reduce metallic low level radioactive waste (LLW) before either treating it on site by surface decontamination, or sending the metal to a sister plant in Sweden for melting. The intent of the process is, as far as possible, to decontaminate the metal, such that it can be returned to the open market as exempt from control as radioactive waste, for recycling. Secondary wastes from the metal treatment containing radioactivity, as either LLW or very low level waste (VLLW), are disposed of to the LLWR or to landfills.

A permit for disposal of radioactive waste from the site was issued by the Environment Agency in March 2008, although no radioactive waste disposals were made until September 2009. The permit allows discharges of gaseous waste to the environment via a main stack and aqueous waste to the sewer. Low discharge limits are set for both aqueous and gaseous discharges. Very small discharges were made during 2011 (Appendix 2). The permit includes conditions requiring Studsvik UK Limited to monitor discharges and undertake environmental monitoring.

7.4 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 2011 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 were 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 some changes in concentrations of polonium-210 in local samples in 2011 compared with 2010. 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 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 was internal irradiation, due to the ingestion of naturally-occurring radioactivity in local fish and shellfish. Centred on the Sellafield site to the south of Whitehaven, the group included 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 is subtracted. Consumption rates for people who eat at high-rates were reviewed and revised in 2011. The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

The *total dose* to local high rate consumers of seafood was 0.18 mSv in 2011 (Table 7.1), below the dose limit for members of the public of 1 mSv and the same value as for 2010. The dose includes the effects of all sources near the site, enhanced naturally-occurring radionuclides from the non-nuclear industrial activity (i.e. TNORM), and Sellafield operations. The source specific assessment of dose, targeted directly at high-rate seafood consumers confirmed the *total dose* assessment and gives a similar result, 0.26 mSv. The contribution to the *total dose* from enhanced natural radionuclides was 0.11 mSv in 2011, compared with 0.047 mSv in 2010. The change was largely due to (i) an increase in the concentration of polonium-210 in locally caught fish and (ii) an increase in the consumption rate of fish taken to be representative of those most exposed. The longer term trend in dose, shown in Figure 7.4, is one of a steady reduction in exposures.

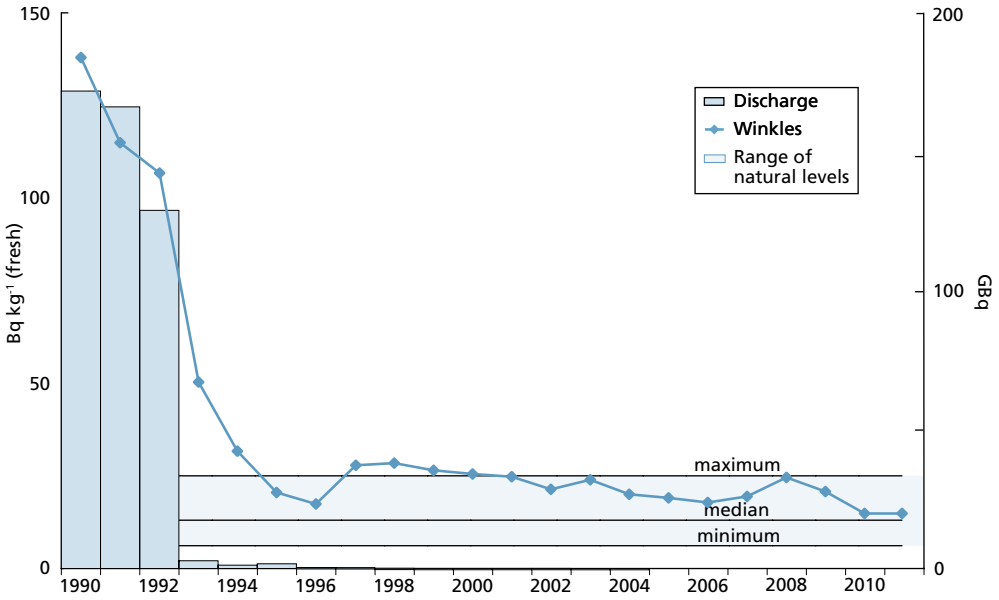


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2011

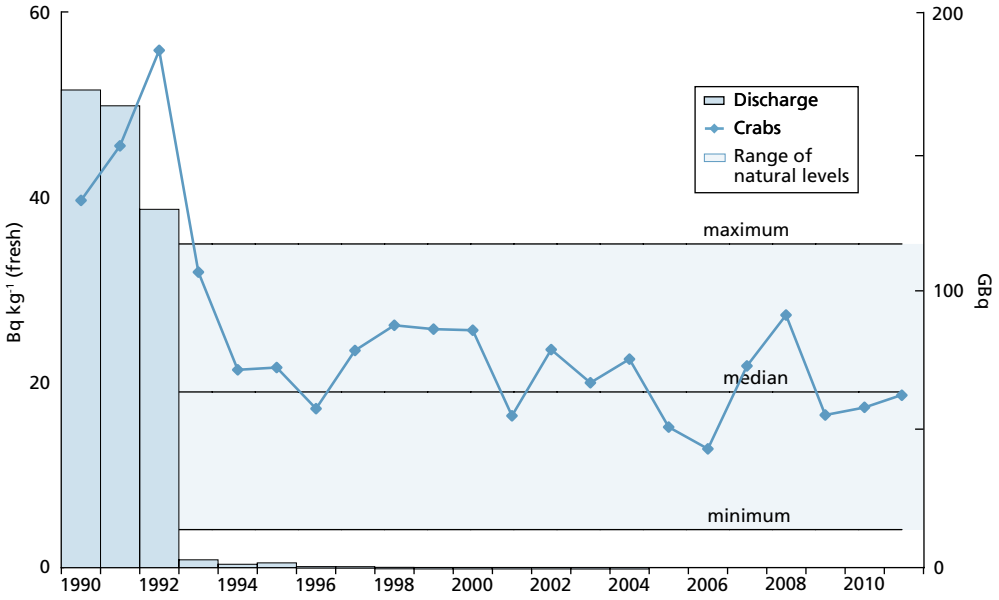


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2011

7.5 Aberdeen

Scotoil operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. Prior to their operations, a fertiliser manufacturing process was operated on the site, which made discharges to sea.

In 2008, SEPA issued a variation to Scotoil's authorisation requiring that the discharge of solid radioactive waste into the sea must cease by October 2011. Scotoil has developed a waste treatment facility for the separation and solidification of their radioactive waste. The discharge of liquid effluent from the site to the sea near Aberdeen harbour continues although with significantly reduced levels of radioactivity in solution. The primary discharge is of radium-226 and radium-228, with lead-210 and polonium-210 in smaller quantities. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring.

Monitoring data for seaweed and sediment samples taken from Aberdeen harbour (2007 – 2011) are given in Table 7.9. Technetium-99 was detected in seaweed over the period, but broadly in line with the expected effect from Sellafield discharges (as the releases become diluted or mixed in moving further afield). Gamma-emitting radionuclides were at, or below, the LoD. In 2011, the dose rate on sediment was 0.14 μGy h^{-1} and continued to be enhanced above

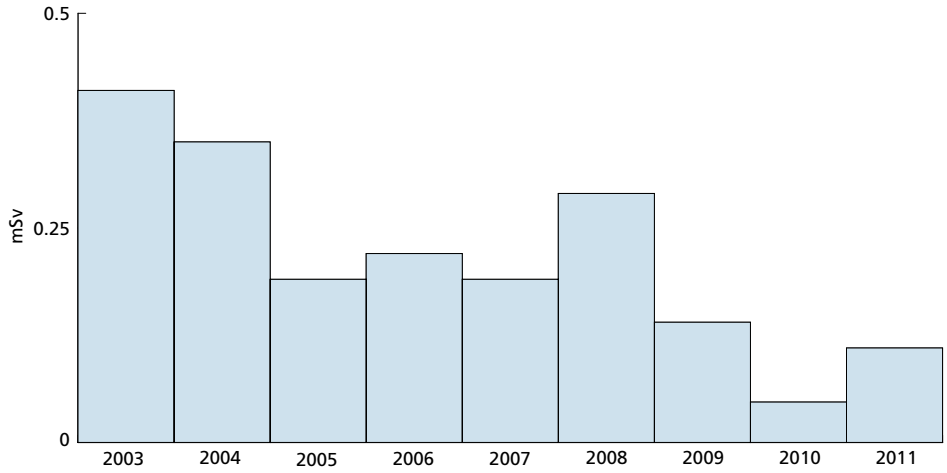


Figure 7.4. Trend in *total dose* to seafood consumers from naturally-occurring radionuclides near Whitehaven, 2003-2011

background. The dose rate was generally similar to those results in previous years, reflecting the effects of current and earlier discharges.

7.6 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected at Dalgety Bay in Fife since at least 1990. Contamination has been associated with historic disposals of waste from past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959 and upon which large areas of the town of Dalgety Bay have been built. 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 by reclaiming land from the sea. Following years of erosion at the site the contamination is being exposed on and adjacent to the foreshore. Some of the incinerated material contained items such as dials and levers 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.

In 2011, work to determine the primary source and extent of the contamination continued and SEPA began an investigation into the headland area of Dalgety Bay to determine whether it is a potential source of the particles that continue to repopulate the beach. The headland was initially surveyed using ground penetrating radar to identify areas of interest for further investigation. A surface gamma survey was then conducted to identify any possible areas of contamination. Using the results of these surveys areas for further investigation were delineated. These areas were then subject to in-situ gamma spectrometry both at the surface and at depth after cores/pits had been excavated. This work has shown that radium-226 contamination is present both at the surface and at depth in the headland meaning that this area could be a potential source of the particles that continue to repopulate the beach. A report on this programme of work is available on SEPA's website (www.sepa.org.uk).

During the headland investigation the MoD deployed its contractor to undertake a further monitoring and recovery exercise of the beach, using more sensitive equipment than SEPA possessed, which resulted in the removal of further particles. Further monitoring of the area by SEPA resulted in the recovery of over 1000 additional particles. In comparison recent annual find rates at Dalgety Bay were in the low tens of particles. In addition, a number of high activity particles which posed an unacceptable hazard to the public were detected and recovered by SEPA from an area of the beach North of the headland. The activities of these particles were 76MBq (estimated), 10MBq, 1.8MBq and 1.3MBq. A further high activity source was found in front of the headland with an activity of 2MBq. The finding of the increased number of particles coupled with the discovery of the high activity particles resulted in the erection of extra signage to inform the public and the demarcation of the section of the beach where the high activity particles were found. In addition, the Food Standards Agency in Scotland has placed a FEPA Order on Dalgety Bay prohibiting the collection of seafood from the area and SEPA has started a programme of shellfish monitoring. These public protection measures will remain in place until either remediation has been achieved or a full risk assessment can be conducted.

In order to provide SEPA with information on the potential hazards to the public at Dalgety Bay, SEPA commissioned work

for the characterisation of a sample of the particles recovered during 2011. This analysis involved the measuring of physical size, mass and activity of the selected particles. In addition, some were subject to a solubility analysis using simulated stomach acid and intestine solutions to inform on the potential ingestion hazard. This has shown that the solubility of particles can range from 0 – 25% which is consistent with previous studies. For those particles subjected to this solubility work, the committed effective dose to a 3-month old infant (age range zero to one year old) could have been around 205 mSv and 72 mSv to a one year old (age range 1 to 2 years). The former exceeds the Radioactive Contaminated Land criteria, as specified in the Radioactive Contaminated Land (Scotland) Regulations 2007 (as amended) and associated Statutory Guidance, which considers a potential total effective dose of greater than 100mSv to be significant regardless of the probability of exposure.

In response to the recent survey findings the Dalgety Bay Particles Advisory Group (DBPAG) was formed which met for the first time in December 2011. The remit of the group is to provide impartial scientific advice to SEPA and other parties on actions which are needed to ensure that the public and environment are adequately protected and to provide comment on the work being undertaken and the results being obtained.

Work to characterise the extent of the contamination at Dalgety Bay continues and the MoD has committed to a monthly monitoring programme using a system set to the detection criteria as specified by the DBPAG. This is providing a level of protection to members of the public whilst the MoD conduct their site investigation of Dalgety Bay. Details of their site investigation plan, as well the work of SEPA and DBPAG, can be found on at www.sepa.org.uk/radioactive_substances/dalgety_bay.aspx .

7.7 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, 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 limited because of the relatively low impact of the discharges. However, programmes are carried out to confirm that impacts are low and, when these occur, they are described in this report.

In 2011, 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 from the River Clyde and sludge pellets from a sewage treatment works. The results are given in Table 7.8 and show the expected effects of Sellafield discharges at this distance. The results were generally similar to those in 2010. 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.

In 2011, SEPA continued with a surveillance programme of the impact of the non-nuclear industry on the environment by undertaking a year-long study at a major Sewage Treatment Works (STW) in Glasgow. The purpose of this programme was to study the impact of discharges from primarily hospitals and research establishments and how the radionuclides from these discharges are transported through the STW. The programme initially involved the collection and analysis of proportional samples of sewage influent, liquid effluent and solid sludge pellets over a 2 week period. The sampling of solid sludge pellets was extended and samples were taken at regular intervals over the course of a year between May 2011 and May 2012. This extended sampling allows the impact of sporadic discharges, sewage transit time and seasonality to be taken into account. A report detailing the results of the monitoring and assessment of impact will be published on the SEPA website in due course.

Table 7.1. Individual radiation exposures - industrial and landfill sites, 2011

Site	Exposed population[a,b]	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
***Total dose* - all sources**							
Sellafield, Whitehaven and LLWR	**Adult consumers of marine plants and algae**	**0.18[d]**	**0.046**	**0.11**	**-**	**0.022**	**-**
Source specific doses							
LLWR near Drigg	Infant consumers of locally grown food	0.013	-	-	0.013	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers[c]	<0.005	-	-	-	-	<0.005
Whitehaven (habits averaged 2006-10)	Seafood consumers	0.26[d]	0.12	0.11	-	0.036	-

[a] *The total dose is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The total dose for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. Adults are the most exposed group unless otherwise stated*

[b] *None of the people represented in this table were considered to receive direct radiation from the sites listed*

[c] *Infants*

[d] *Includes the effects of discharges from the adjacent Sellafield site*

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2011

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<4.0	17	<0.15	0.040	<0.35	<0.30	0.0060	<1.4	<0.35
Beetroot		1	<4.0	11	<0.30	0.51	<0.30	<0.30		<1.7	<0.50
Blackberries		1	<4.0	17	<0.20	0.22	<0.40	<0.20		<1.5	<0.40
Cabbage		1	<4.0	4.0	<0.20	0.67	<0.20	<0.20	<0.022	<1.3	<0.40
Deer muscle		1	<5.0	33	<0.10	0.024	<0.20	<0.20	<0.020	<0.90	<0.30
Duck		1	<7.0	31	<0.20	0.033	<0.20	<0.10	<0.023	<0.90	<0.20
Eggs		1	<6.0	30	<0.20	0.028	<0.30	<0.20		<1.6	<0.50
Potatoes		1	<5.0	18	<0.20	0.095	<0.20	<0.10	<0.028	<1.2	<0.40
Sheep muscle		1	<5.0	31	<0.10	0.034	<0.30	<0.20	<0.020	<1.5	<0.40
Sheep offal		1	<7.0	21	<0.20	0.86	<0.30	<0.20	<0.020	<1.1	<0.40
Grass		2							0.089		
Grass	max								0.13		
Sediment	Drigg Stream	4[E]			<0.57	<5.1	<1.4	<0.44		<4.9	<2.6
Freshwater	Drigg Stream	4[E]	<5.0		<0.24	<0.072					

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{129}I	^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.012	<0.20	<0.20		<0.95				
Beetroot		1	<0.027			0.26	<1.0				
Blackberries		1	<0.022			0.090	<0.80				
Cabbage		1	<0.026			0.15	<0.70				
Deer muscle		1	<0.024			1.0	<0.70				
Duck		1	<0.067			0.23	<0.60				
Eggs		1	<0.029			0.11	<1.1				
Potatoes		1	<0.027			0.37	<0.80				
Sheep muscle		1	<0.054			0.70	<0.70				
Sheep offal		1	<0.041			0.58	<0.60				
Sediment	Drigg Stream	4[E]		<0.52	270		<2.6	12	20	15	13
Freshwater	Drigg Stream	4[E]		<0.22	<0.20			<0.0055	<0.0082	<0.0055	<0.0050

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1				<0.00010	<0.00020	<0.032	<0.00010		
Beetroot		1				<0.00010	<0.00030	<0.042	0.00040		
Blackberries		1				0.00020	<0.00030	<0.039	0.00080		
Cabbage		1				<0.00020	<0.00030	<0.044	0.00060		
Deer muscle		1				<0.00010	<0.00050	0.21	0.00040		
Duck		1				<0.00010	<0.00040	0.12	0.00070		
Eggs		1				<0.00020	<0.00020	<0.039	<0.00010		
Potatoes		1				<0.00010	0.00020	<0.063	0.00070		
Sheep muscle		1				0.00020	<0.00030	<0.099	0.0018		
Sheep offal		1				0.0052	0.030	0.14	0.037		
Grass		2	0.021	0.00085	0.018						
Grass	max		0.034	0.0012	0.027						
Soil		1	10	0.45	10						
Sediment	Drigg Stream	4[E]	54	<3.2	47	17	110	510	140	690	1200
Freshwater	Drigg Stream	4[E]	<0.010	<0.0045	<0.010	<0.0062	<0.0062	<0.13	<0.0075	<0.065	0.57

[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, 2011

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	14	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	140	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	320	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	14	<15	<0.05	<0.05
Dunbartonshire	Birdstone	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	<5.0	<15	<0.05	<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	52	<15	<0.05	<0.05
Fife	Melville Wood	1	270	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	330	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	340	<15	<0.05	0.06

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2011

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1}						
			Total ^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{137}Cs	^{228}Th
Glamorgan									
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	440	370	<4.4				
Trecatti Landfill, Merthyr Tydfil	Treated Leachate	2	350	320	<3.1				
Lancashire									
Clifton Marsh	Borehole 6	2		<8.7		<4.2	<0.22	<0.20	<0.0075
Clifton Marsh	Borehole 19	2		5.9		<4.0	<0.23	<0.20	0.011
Clifton Marsh	Borehole 40	2		<4.2		<4.0	<0.23	<0.20	<0.010
Clifton Marsh	Borehole 59	2		9.5		<4.4	<0.24	<0.20	<0.012
Ulnes Walton	Pond	1		<4.0		<4.3	<0.24	<0.20	0.0050
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2		18	<3.0	<5.0	<0.28	<0.22	

Location	Sample source	No. of sampling observ-ations	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	<0.0050	<0.0075	0.10	<0.0055	0.097	<0.29	2.6
Clifton Marsh	Borehole 19	2	<0.0055	<0.0055	0.026	<0.0035	0.023	<0.72	4.1
Clifton Marsh	Borehole 40	2	<0.0050	<0.0050	<0.0055	<0.0020	<0.0045	<0.12	1.5
Clifton Marsh	Borehole 59	2	<0.0065	<0.0050	<0.0035	<0.0025	<0.0035	<0.26	2.1
Ulnes Walton	Pond	1	<0.0050	<0.0050	0.054	<0.0070	0.056	<0.20	0.48
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2						<0.14	1.2

[a] *As tritiated water*

[b] *The concentrations of ^{125}I and ^{131}I were <0.41 and <0.50 Bq l^{-1} respectively*

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2011

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Phosphate processing, Whitehaven										
Winkles	Saltom Bay	4	9.2	2.2						
Winkles	Parton	4	15	1.5	0.62	0.82	0.42	0.97	0.033	0.89
Winkles	North Harrington	1	9.6							
Winkles	Nethertown	4	13							
Winkles	Drigg	1			0.62	0.54	0.40			
Winkles	Tarn Bay	1	11							
Mussels	Parton	4	39	1.3						
Mussels	Nethertown	4	41	2.0						
Limpets	St Bees	2	7.9							
Cockles	Ravenglass	2	26							
Crabs	Parton	4	19	0.18	0.097	0.014	0.0072	0.038	0.00081	0.030
Crabs	Sellafield coastal area	4	13	0.22						
Lobsters	Parton	4	8.0	0.15	0.044	0.010	0.0051	0.023	0.00092	0.020
Lobsters	Sellafield coastal area	4	10	0.18						
Cod	Parton	2	0.88	0.17	0.044	<0.00013	<0.00015	0.0029	<0.00015	0.0030
Dab	Whitehaven	1	3.2							
Other samples										
Winkles	South Gare (Hartlepool)	2	10	1.6						
Winkles	Kirkcudbright	1	5.1							
Mussels	Ribble Estuary	1			0.26	0.24	0.11			
Limpets	Kirkcudbright	1	11							
Cockles	Ribble Estuary	1			0.55	0.51	0.33			
Cockles	Southern North Sea	1			0.39	0.19	0.25			
Cockles	Flookburgh	2	18							
Crabs	Kirkcudbright	1	4.8							
Lobsters	Kirkcudbright	1	1.2							
Shrimps	Ribble Estuary	2			0.011	0.0078	0.0054			
Wildfowl	Ribble Estuary	1			0.0037	0.0045	0.0012			
Seaweed	Isle of Man	1						1.7	<0.17	1.6
Sediment	Kirkcudbright	1						12	0.43	12
Sediment	Rascarrel Bay	1						9.4	0.45	9.4

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

Table 7.6. Discharges of gaseous radioactive wastes from non-nuclear establishments in the United Kingdom, 2010[a]

PLEASE NOTE CHANGE OF UNITS TO BECQUERELS

	Discharges during 2010, Bq								
	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	2.2E+08						5.5E+12		
^{13}N							3.4E+10		
^{14}C	2.0E+06			2.1E+06			8.5E+12	2.9E+08	8.2E+09
^{18}F	3.9E+11						1.6E+11		
^{35}S							3.9E+08		
^{85}Kr				3.2E+11			1.9E+11		
^{99m}Tc				2.0E+09					
^{125}I	4.5E+05			4.9E+07			3.5E+08		
^{129}I							4.0E+03		1.3E+07
^{131}I				6.0E+08			2.7E+08		
^{131m}Xe				1.1E+08					
^{137}Cs							4.8E+00		
^{222}Rn							2.0E+09		
Plutonium Alpha							2.4E+02		
Uranium Alpha							1.2E-01		
^{241}Am							4.4E+02		
Other Alpha particulate							1.1E+11		
Other Beta/Gamma					3.2E+11				
Other Beta/Gamma Particulate	1.2E+12		1.3E+09	4.2E+08		2.0E+09	5.9E+12		1.1E+10

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland and Scotland discharge data refer to 2011*

Table 7.7. Discharges of liquid radioactive waste from non-nuclear establishments in the United Kingdom, 2010[a]

PLEASE NOTE CHANGE OF UNITS TO BECQUERELS

	Discharges during 2010, Bq										
	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	Scotland
^{3}H	4.0E+10	2.8E+07		7.0E+08	2.7E+08		5.8E+12		4.5E+08		
^{14}C	4.1E+09	9.5E+06	6.8E+08	1.7E+09		2.9E+08	6.5E+11	1.9E+10	1.3E+08		
^{18}F	6.0E+11		9.2E+10	1.9E+12	2.6E+11	2.7E+11	1.6E+12				
^{22}Na							7.3E+04				
^{32}P	1.8E+10	5.4E+07	3.9E+09	7.9E+09	2.9E+07	2.2E+09	9.2E+09	6.5E+08			
^{33}P	1.1E+09		1.1E+10	1.1E+08			5.5E+09	1.4E+10			
^{35}S	2.0E+10	1.2E+07	2.9E+09	2.6E+09			6.1E+09	5.1E+08			
^{51}Cr	6.7E+09			4.9E+10	7.4E+08	2.9E+09	1.4E+09				
^{57}Co	2.7E+03			1.6E+08	2.2E+04		3.8E+03				
^{58}Co					4.0E+03						
^{60}Co	1.4E+04						1.3E+07				
^{67}Ga				2.5E+10	3.6E+07	4.5E+08	3.2E+08				
^{75}Se	4.2E+07			1.2E+09		3.7E+07	7.6E+06				
^{89}Sr				2.2E+10		4.7E+09	2.1E+06				
^{90}Sr	7.0E+07			4.4E+07			2.0E+07				
^{90}Y	2.7E+06			3.9E+11	1.0E+07		7.0E+01				
^{95}Nb							1.0E+07				
^{95}Zr							2.9E+06				
^{99}Tc	3.4E+07					1.0E+09	3.5E+06				
^{99m}Tc	1.3E+09			5.4E+13	1.7E+12	5.2E+12	1.1E+12				
^{106}Ru	5.0E+01						1.3E+05				
^{111}In	2.0E+09			3.3E+11	1.1E+10	3.5E+10	3.7E+09				
^{123}I				1.1E+12	7.0E+10	1.5E+11	3.3E+10				
^{125}Sb	2.1E+01						3.8E+04				
^{125}I	4.2E+09	1.2E+08	2.6E+08	1.5E+09	3.7E+07	7.5E+08	6.2E+10		1.7E+08		
^{129}I	5.1E+03						1.4E+03				
^{131}I	5.5E+08		4.3E+09	1.0E+13	1.3E+10	8.9E+11	1.3E+11				
^{134}Cs	6.5E+01						2.0E+05				
^{137}Cs	3.2E+06						1.9E+07				
^{144}Ce							1.1E+06				
^{153}Sm				4.0E+10	1.3E+09						
^{201}Tl				2.0E+11		2.8E+10	3.1E+08				
^{230}Th							2.0E-01				
^{232}Th							2.9E+09				
Plutonium Alpha	4.5E+02						4.2E+06				
Uranium Alpha	3.9E+05						5.2E+09				
^{237}Np	2.2E+00						2.8E+03				
^{241}Am	4.5E+04						5.9E+04				
^{241}Pu	1.5E+04						2.6E+07				
^{242}Cm							6.9E+02				
Total Alpha	5.8E+06			9.7E+08			2.6E+10			3.4E+09	8.0E+09
Total Beta/Gamma (Excl Tritium)	7.0E+11		1.2E+11	5.7E+13		5.9E+12	2.5E+12	4.2E+09		2.4E+09	3.2E+09
Other Alpha particulate	9.8E+02			6.9E+08			9.6E+07				
Other Beta/ Gamma[b]	4.3E+10		1.8E+07	5.2E+11	2.2E+05	4.8E+08	3.5E+10				
Other Beta/ Gamma particulate								5.6E+09			

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland and Scotland discharge data refers to 2011*

[b] *Excluding specific radionuclides*

Table 7.8. Monitoring in the River Clyde and near Glasgow, 2011[a]

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{32}P	^{54}Mn	^{90}Sr	^{99}Tc
Between Finlaystone and Woodhall	Mussels	1		32	<2.6	<0.10		24
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1		<15	<3.1	<0.10		52
14 km downstream of Dalmuir	Sediment	1		<15	<2.6	<0.10		
Downstream of Dalmuir	Freshwater	4			<0.055	<0.10		
River Clyde	Freshwater	4	<1.1				<0.010	
Daldowie	Sludge pellets	4				<0.10		

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{131}I	^{125}Sb	^{137}Cs	^{155}Eu	^{241}Am	Gross beta
Between Finlaystone and Woodhall	Mussels	1		<0.20	0.21	<0.20	<0.11	
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1		<0.10	0.72	<0.10	<0.10	
14 km downstream of Dalmuir	Sediment	1		<0.23	15	0.79	1.1	
Downstream of Dalmuir	Freshwater	4		<0.17	<0.10	<0.15	<0.11	
River Clyde	Freshwater	4			<0.10			0.70
Daldowie	Sludge pellets	4	420	<0.30	<4.2	1.8	<0.38	

[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*

Table 7.9 Monitoring in Aberdeen harbour, 2007-2011[a]

Material and selection	No. of sampling observations	Year	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}			
			^{99}Tc	^{137}Cs	^{155}Eu	Gamma dose rate
Fucus vesiculosus	1	2007	70	<0.10	<0.18	
Fucus vesiculosus	1	2008	55	0.10	<0.10	
Fucus vesiculosus	1	2009		<0.10	<0.10	
Fucus vesiculosus	1	2010	<0.12	0.29	<0.22	
Fucus vesiculosus	1	2011	19	0.12	0.14	
Sediment	1	2008				0.12
Sediment	1	2009				0.22
Sediment	1	2010				0.19
Sediment	1	2011				0.14

[a] *Results are available for other radionuclides detected by gamma spectrometry, All such results are less than the limit of detection*
[b] *Except for gamma doses where units are μGy h^{-1}*

8. Overseas incidents

8.1 Chernobyl (1986)

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, where heavy rain fell in the days following the accident. Restrictions were put in place on moving, selling and slaughtering sheep from the affected areas to prevent animals 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, from entering the food chain.

A programme of monitoring live animals, known as the Mark and Release Scheme, was put in place to protect the safety of food, while allowing established sheep farming practices to continue. A farmer wishing to move sheep out of a restricted area had to have them tested using an external monitor held against the sheep. Any sheep that was assessed to have levels of contamination exceeding 1,000 Bq kg^{-1} was marked on the back of the head with coloured paint. Painted sheep could be moved off restricted areas, but could not be sold for slaughter nor returned to the restricted areas for a minimum of three months, allowing time for the radiocaesium to pass out of the body.

Key points

- Contamination of sheep and fish with caesium-137 from Chernobyl in 1986 remained at low but still detectable levels. Concentrations in fish are now less than 10 per cent of those observed in the immediate aftermath of the accident. Restrictions on farms due to Chernobyl caesium in sheep meat have now been withdrawn due to the low consumer risks involved
- The UK governments reacted quickly to the Fukushima Dai-ichi accident in 2011 to ensure the safety of UK citizens, especially those overseas, and to monitor the effects in the UK. These effects were found to be of no radiological significance in the UK
- Monitoring at ports of entry to the UK for non-specific contamination detected a single unacceptable shipment of wild mushrooms, which was excluded from the market as unfit for consumption

In January 2011, 338 farms or part farms (eight in England, and 330 in Wales) and 190,000 sheep were still subject to restrictions. This represented 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 and the final controls were removed in Scotland in 2010.

In 2011, the Food Standards Agency reviewed the controls to assess whether these protective measures were still required to maintain food safety (Food Standards Agency, 2011a). The review included an assessment of the potential radiation dose to people eating sheep meat. In summer 2010 and 2011, surveys were carried out to monitor sheep on selected farms in the restricted areas of England and Wales to provide data to inform this dose assessment.

The data from this survey were input into a probabilistic dose model to estimate the distribution of dose to those people that were more highly exposed to radiation by eating sheep meat from farms in the restricted areas. The model produced a realistic assessment of consumer risks, whereas the previous approach, used to define policy, only considered the radiocaesium concentration in sheep. The distribution of doses for a range of consumer habits was also modelled to demonstrate a sound understanding of potential doses in different scenarios.

The main advantage of using a probability distribution was that not every sheep had to be monitored. Representative monitoring provided enough information about the distribution of radiocaesium in the whole flock.

Figure 8.1 shows the distribution of doses that an adult consuming sheep meat at high-rates would receive if they were to consume their annual supply from each monitored farm in Cumbria and North Wales.

The results of the dose assessment showed that doses to the representative person ranged from < 0.05 to 0.21 mSv per year, with an average of < 0.09 mSv per year. This was significantly below the 1 mSv per year limit for members of the public exposed to radiation from routine planned exposures and the 1 mSv per year reference level typically used in existing exposure situations.

The results of the sheep monitoring survey and the consumer dose assessment demonstrate that, although there were still low levels of radiocaesium in sheep throughout the restricted areas of Cumbria and North Wales, the risks to consumers were very low.

In November 2011, the Food Standards Agency launched a public consultation based on the results of this risk assessment, where it proposed to remove all remaining post-Chernobyl sheep controls (Food Standards Agency, 2011b). After carefully

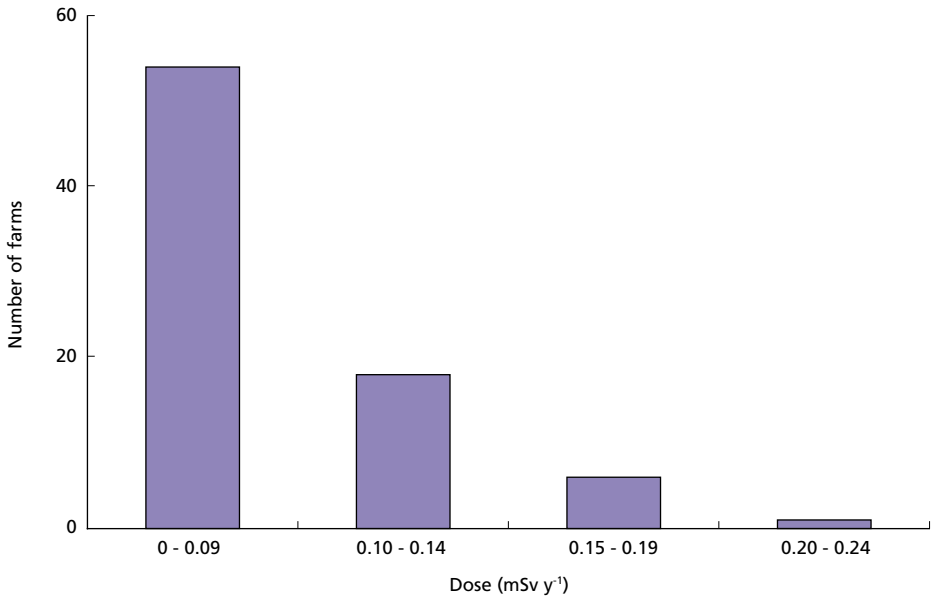


Figure 8.1. Distribution of doses to the representative person from consuming sheep meat from each monitored farm in Cumbria and North Wales

considering the consultation responses it received, the Food Standards Agency Board met on 20 March 2012 and agreed to accept this proposal (Food Standards Agency, 2012). As a result, all post-Chernobyl restrictions on farm holdings in the UK were lifted on 31 May 2012.

Sampling locations for freshwater fish affected by Chernobyl are now limited to Cumbria in England, which had areas of relatively high fallout from the accident. Samples from areas of low deposition in England were also obtained for comparison. Table 8.1 shows concentrations of caesium-134 and caesium-137 in fish. Other artificial radionuclides from the Chernobyl accident are no longer detectable. In 2011, the highest concentration of caesium-137 was 130 Bq kg^{-1} in perch from Devoke Water; the same as in 2010. Levels in fish from other locations were generally similar to those in recent years, and substantially less (by orders of magnitude) than the 1,000 Bq kg^{-1} level reached shortly after the accident. Caesium-134 concentrations were below or near to 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. Monitoring results for Devoke Water for perch and trout, over the period 1986 – 2011, are shown in Figure 8.2.

A cautious assessment has been made of the dose received from consuming fish contaminated with radiocaesium following the Chernobyl accident. A consumption rate of 37 kg a year, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposure. Actual exposure is likely to be much lower, not only because this consumption rate is higher than expected (Leonard *et al*., 1990), but also because, in practice, people are likely to eat mostly hatchery-reared or farmed fish that have a much lower radiocaesium concentration. In 2011, estimated doses were less than 0.1 mSv.

8.2 Fukushima Dai-ichi (2011)

On 11 March 2011 Japan suffered its worst recorded earthquake (Tohoku, magnitude 9.0). The epicentre was 110 miles east-northeast from the Fukushima Dai-ichi (Fukushima-1) nuclear power site. The three operating reactors at Fukushima Dai-ichi were shut down safely during the earthquake. Within an hour, a 14m tsunami caused by the earthquake inundated the site. This resulted in the loss of all but one diesel generator, some direct current supplies and essential instrumentation, and caused massive damage around the site. The reactors were still very hot with residual heat and needed ongoing cooling by circulating water for a number of weeks. Emergency batteries continued to circulate cooling water for some hours, but, because of the tsunami damage, it was neither possible to restart the generators nor reconnect to the electricity grid before the batteries failed. Despite the efforts of the operators, back-up cooling was eventually lost. This meant that the three reactors that had been operating at the time of the earthquake began to overheat. Reactor 1 lost its cooling water first. There were several pressure releases from the reactors followed by hydrogen explosions. The fuel melted, leading to fission products being released into the atmosphere, followed later by contaminated water leaking into the sea. Fission products released into the atmosphere included iodine-131, caesium-137, caesium-134 and tellurium-132. These began to circulate globally, with small amounts reaching Western Europe and the UK towards the end of March. This section reports on the monitoring carried out in the UK and the levels detected.

This incident was rated as Level 7 (the highest level) under the International Nuclear and Radiological Event Scale (INES) rating scheme, showing that this was a very serious nuclear accident. Tens of thousands of people were evacuated from a zone extending 20km from the site and remain so over a year after the event.

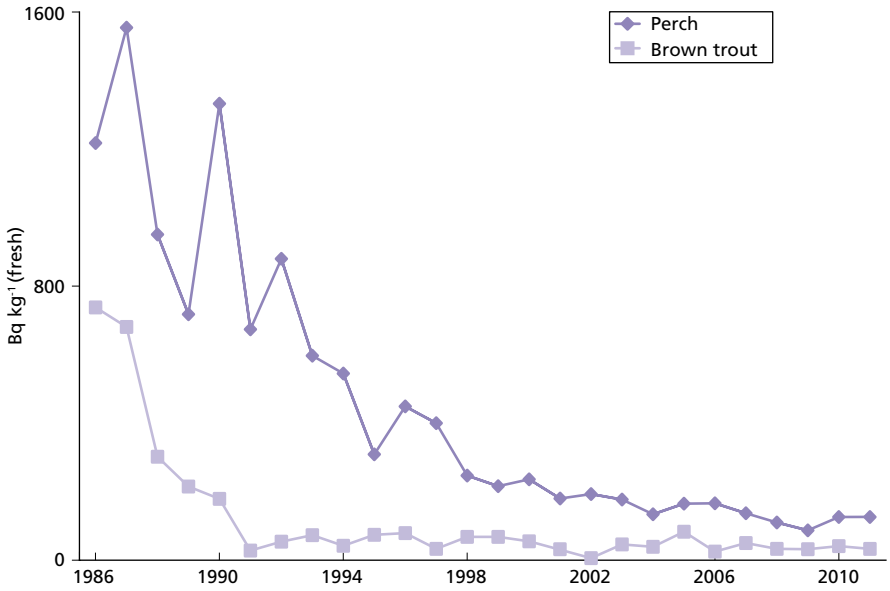


Figure 8.2. Caesium-137 concentrations in freshwater fish from Devoke Water, Cumbria 1986-2011

In the UK, the situation was kept under review at the highest level in Government, and the Cabinet Office Briefing Room (COBR) was set up, meeting for the first time on 11 March 2011. COBR was supported by the Scientific Advisory Group in Emergencies (SAGE), which included experts from the UK Environment Agency and the Food Standards Agency. The main focus was to give UK citizens living or visiting Japan advice on:

- Restrictions on access to contaminated areas;
- Restrictions on eating locally produced food;
- Keeping and disposing of contaminated items.

Actions taken in the UK included:

- Implementing EU controls on importing food from Japan;
- Enhanced monitoring across the UK, measuring air, rain, grass and food to check for the effects of atmospheric transport and deposition from Japan.

In addition, the Secretary of State for Energy and Climate Change asked the Chief Inspector of the Office for Nuclear Regulation to take a broad view of the lessons learned from the Fukushima Dai-ichi accident, and his report was issued in October 2011 (Weightman, 2011). That analysis revealed no fundamental safety weaknesses in the UK's nuclear industry, but concluded that by learning lessons it could be made even safer. The report identified 38 areas where further work should be carried out. These included reliance on off-site infrastructure such as the electrical grid supply in extreme events, emergency response arrangements, layout of plant, risks associated with flooding, planning controls around nuclear facilities and prioritising safety reviews. This work is now underway and a further report will be issued giving details of the progress made.

As a result of the Fukushima Dai-ichi accident in Japan in March 2011, the environment agencies and the Food Standards Agency increased their routine surveillance to assess the consequences of the accident and release. As a result of this increased surveillance, elevated concentrations of iodine-131 were first detected in Glasgow, Scotland on 29 March 2011 (http://www.sepa.org.uk/about_us/news/2011/low_level_iodine_detected_in_g.aspx). The concentrations detected were extremely low and consistent with those detected elsewhere in Europe.

Following the detection of iodine-131 in the UK, many organisations carried out further specific monitoring throughout the UK to provide reassurance that the consequences of the accident were negligible. These included all of the UK environment agencies (Environment Agency, NIEA and SEPA), the Food Standards Agency and HPA.

This monitoring used sites from the routine surveillance programmes and this allowed direct comparisons to be made between measurements made before and after the accident. Specific measurements to determine the effect of the accident were made over several months, returning back to routine frequency in July 2011. In addition, other measurements were made to inform advice given by these organisations to the UK population.

The measurements carried out by the UK environment agencies, HPA and the Food Standards Agency were compiled by HPA and regularly published on the HPA website during April, May and June with the last report in July 2011, together with information on the current situation and the radiological impact of the incident.

The results of the increased monitoring SEPA carried out across Scotland were published in a report in September 2011, which is available on the SEPA website. (http://www.sepa.org.uk/radioactive_substances/publications/other_reports.aspx)

Figure 8.3 shows the locations where measurements were made and Table 8.2 gives a summary of the types of measurements made at each location.

At the time of the incident the majority of UK dairy cows were not grazing on pasture. The Food Standards Agency and SEPA have a robust milk sampling and analysis programme, with between two and 15 farms sampled around each nuclear site. Most samples are collected weekly then bulked into either quarterly or annual samples for analysis. It was expected that UK food, including milk, would not be significantly affected by releases from Fukushima. To check on this assumption milk samples from 15 farms were collected in the week after the plume reached the UK (i.e. the week beginning 11 April 2011). Very low levels of iodine-131 were detected in some samples. The milk sampling carried out by SEPA at ten locations across Scotland did not detect any iodine-131, tellurium-132, caesium-134 and caesium-137 in any of the samples. The Environment Agency and HPA took additional grass samples at a number of locations in England and Wales during April 2011. Trace levels of iodine-131 were found at four locations.

Figure 8.4 shows the weekly activity concentrations in air of iodine-131, tellurium-132, caesium-134 and caesium-137 measured across the UK. Figure 8.5 shows the measured iodine-131 concentrations in milk made by the Food Standards Agency across the UK as part of its routine surveillance programme, alongside the iodine-131 activity concentrations in air measured across the UK. This illustrates a very small increase in activity levels in milk following the arrival of the radioactive plume in the UK.

The levels of radioactivity detected were very low and significantly below any action levels. A simple dose assessment for members of the public living in the UK based on the measurement data has been undertaken (Brown and Eslava-Gomez, *in press*). The committed effective doses received were very small and less than 1 μSv.

On 25 March 2011, the European Commission (EC) implemented controls on the import of food and feed originating in or consigned from Japan (Regulation 297/2011). All food and feed imported from Japan has to be certified by the Japanese authorities. This certification has to declare that either the product originates outside the specified prefectures (regions) of Japan known to have been affected by radioactive contamination or, for products originating within the specified prefectures, that the product has been tested to confirm contamination is below the maximum permissible levels for caesium-134, caesium-137 and iodine-131.

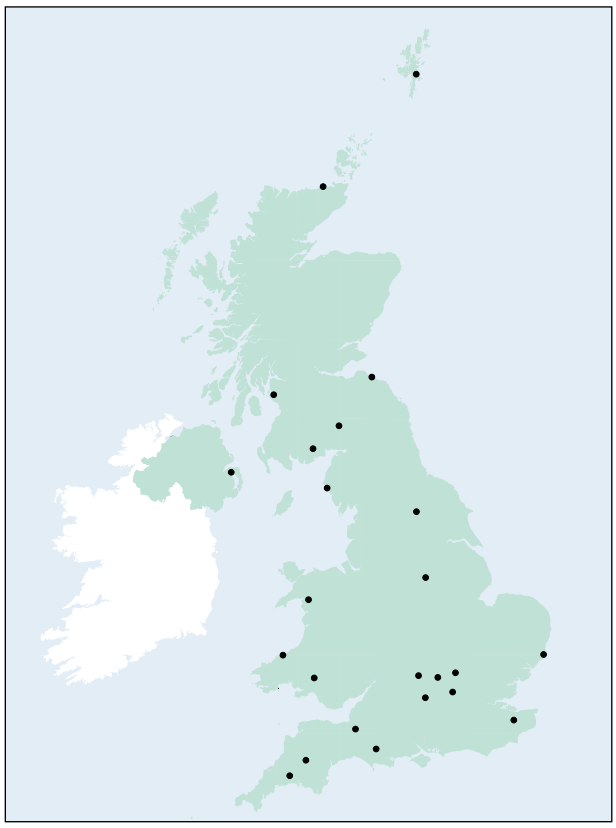


Figure 8.3. Fukushima Dai-ichi sampling locations, 2011

The EC Regulations were amended several times during 2011 to revise both the list of specified prefectures and the maximum permissible levels as more information became available. From 11 April, the maximum permissible levels for import into the EU were aligned with those used internally by the Japanese authorities to provide consistency for Japanese producers (Regulation 351/2011). At that time, the maximum permissible levels for general foods (other than milk and dairy products, liquid foods and foods for infants) and feed was 500 Bq kg^{-1} for caesium-134 and caesium-137 and 2000 Bq kg^{-1} for iodine-131*. Regulation 297/2011 was consolidated and replaced by Regulation 961/2011 on 27 September. Regulation 961/2011 was further amended on 21 December and the requirement to test for iodine-131 was removed, as the short half-life of this radionuclide (approximately eight days) meant it was no longer a concern (Regulation 1371/2011)#.

* *Maximum permissible levels for milk and dairy products and liquid foods were 200 Bq kg^{-1} and 300 Bq kg^{-1} and infant foods were 100 and 200 Bq kg^{-1} for caesium 134/137 and iodine-131 respectively.*

\# *In 2012, the Japanese authorities revised their maximum permissible levels for caesium-134 and caesium-137 to 10 Bq kg^{-1} for mineral water and drinks brewed from unfermented leaves, 50 Bq kg^{-1} for milk and dairy products and infant foods and 100 Bq kg^{-1} for all other foods. Maximum permissible levels in feed range from 40 to 160 Bq kg^{-1}. These revised levels were adopted by the EC on 29 March 2012 in Regulation 284/2012, which revoked Regulation 961/2011 and its amendments. Regulation 284/2012 was further amended on 27 June 2012 (Regulation 561/2012) to update the list of specified prefectures.*

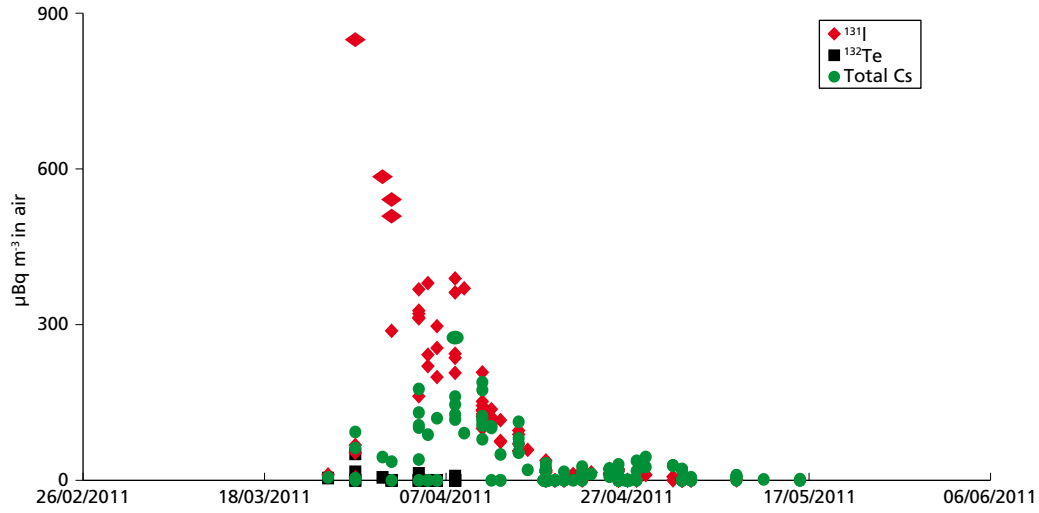


Figure 8.4. Activity concentrations in air measured across the UK following the Fukushima Dai-ichi incident in Japan in March 2011

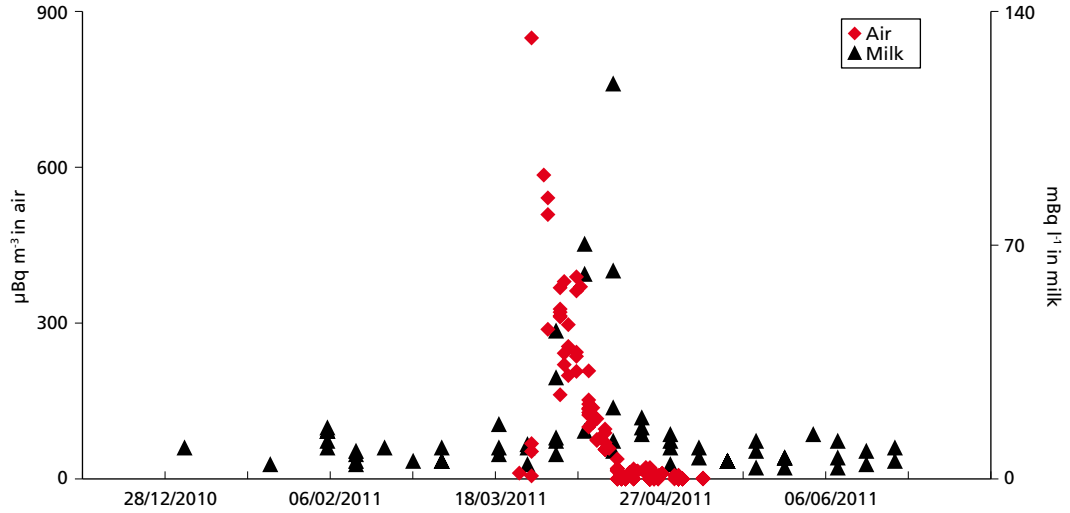


Figure 8.5. Activity concentrations of iodine-131 in air and milk measured across the UK following the Fukushima Dai-ichi incident in Japan in March 2011 (data before the end of March and after late April are consistent with the normal range observed in milk)

In addition, a percentage of Japanese imports into the EU are monitored at ports of entry. Some imports of seafood from other nations from the region where contamination might be expected in the western Pacific were also monitored. The results of monitoring Japanese imports to the UK have been published by the EC (http://ec.europa.eu/energy/nuclear/radiation_protection/fukushima_en.htm). None of the imports to the UK have contained radioactivity exceeding the maximum permissible levels; most results have been below the limits of detection, with a few being around 10 Bq kg^{-1}. The doses received due to the imports were of negligible radiological significance.

8.3 General monitoring at importation points of entry to the UK

Screening instruments are used at importation points of entry to the UK as a general check on possible contamination from unknown sources. In 2011, the instruments were triggered at an importation point by the presence of caesium-137 in a consignment of food being brought into the UK. The sample of wild dried mushrooms from Bulgaria was analysed and the activity concentration was 4951 Bq kg^{-1}. The Food Standards Agency recommended that the consignment should not be placed on the market and was unfit for human consumption.

Table 8.1. Concentrations of radiocaesium in the freshwater environment, 2011

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Rainbow trout	1	<0.05	0.18
Cogra Moss	Rainbow trout	2	<0.08	0.41
Narborough[a]	Rainbow trout	1	<0.08	0.28
Devoke Water	Brown trout	1	0.35	33
Devoke Water	Perch	1	0.68	130
Gilcrux	Rainbow trout	1	<0.06	0.17

[a] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}$Pu, ^{241}Am and ^{242}Cm were 35, <0.00016, 0.000075, 0.000069 and 0.00019 Bq kg^{-1} respectively*

Table 8.2. Fukushima Dai-ichi incident related monitoring, 2011

Location	Type of sample	Organisation
Channel Islands		
Jersey	Air	HPA
England and Wales		
Berkshire	Grass	Environment Agency
Buckinghamshire	Grass and milk	Environment Agency and Food Standards Agency
Ceredigion	Air and rainwater	Environment Agency
Cornwall	Milk	Food Standards Agency
Cumbria	Air and milk	Food Standards Agency and Health Protection Agency
Derbyshire	Grass	Environment Agency
Devon	Milk	Food Standards Agency
Dorset	Grass and milk	Environment Agency and Food Standards Agency
Gwynedd	Grass	Environment Agency
Hertfordshire	Milk	Food Standards Agency
Kent	Milk	Food Standards Agency
Middlesex	Milk	Food Standards Agency
Oxfordshire	Air, grass, soil and rainwater	Environment Agency and Health Protection Agency
Powys	Grass	Environment Agency
Somerset	Milk	Food Standards Agency
Suffolk	Air and rainwater	Environment Agency
Yorkshire	Air and rainwater	Environment Agency
Northern Ireland		
Co. Down	Air	Northern Ireland Environment Agency
Scotland		
Ayrshire (3 locations)	Air, milk and surface water	SEPA
Caithness (3 locations)	Air, grass, milk, soil and surface water	SEPA
Central (1 location)	Air and rainwater	SEPA
Dumfries and Galloway (3 locations)	Air, milk, rainwater and surface water	SEPA
Lothian (2 locations)	Air, milk and surface water	SEPA
Shetland (1 location)	Air	SEPA

9. Regional monitoring

Regional monitoring in areas remote from nuclear sites has continued in 2011 (i) to establish long distance transport of radioactivity from UK and other nuclear sites, (ii) to indicate general contamination of the food supply and the environment and (iii) to provide data under UK obligations under Article 36 of the Euratom Treaty and the OSPAR Convention.

The component parts of this programme are:

- Channel Islands, the Isle of Man and Northern Ireland
- General diet
- Milk and crops
- Airborne particulates, rain, drinking water and groundwater
- Seawater

Key points

- Monitoring in areas remote from nuclear sites continued (i) to establish long distance transport of radioactivity from UK and other nuclear sites, (ii) to indicate general contamination of the food supply and the environment and (iii) to provide data under UK obligations under Article 36 of the Euratom Treaty and the OSPAR Convention
- Sampling of marine life from the Channel Islands continued to monitor possible effects from French nuclear facilities discharging radioactivity into the English Channel. Doses were less than one 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 one 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
- Surveys of seas around the UK supported international assessments for the OSPAR Treaty and showed the extent of tritium and caesium-137 contamination. In the Irish Sea, caesium-137 concentrations were generally similar to those reported in the previous Irish Sea survey in 2009. Tritium concentrations in samples taken close to these installations in the Bristol Channel were the lowest in recent years

9.1 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 La Hague and the power station at Flamanville. It also monitors 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 to determine exposure from the internal radiation pathway; sediment is analysed for external exposures. Seawater and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers. A review of marine radioactivity in the Channel Islands from 1990 to 2009 has been published (Hughes *et al*., 2011).

Table 9.1 shows analysis results for 2011. 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. Apportioning this to different sources, including fallout from weapon testing, 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 large amounts of fish and shellfish was carried out. In 2011, they were estimated to receive less than 0.005 mSv, which is 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 9.2 and 9.3, respectively, and form part of the programmes considered in Sections 9.5 and 9.6.

9.2 Isle of Man

The Food Standards Agency carries out an ongoing programme of radioactivity monitoring on behalf of the Department of Environment, Food and Agriculture (DEFA) on the Isle of Man for a range of food grown on the land (Table 9.4). 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 of this report because of their significance in relation to Sellafield, but are also included here for completeness (Table 9.4).

Radioactivity is monitored on the island for two reasons. Firstly, to monitor the continuing effects of radiocaesium deposition resulting from the Chernobyl accident in 1986. Secondly, 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 carried out 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, strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites. The results demonstrate that there was no significant impact on Manx foodstuffs from the operation of mainland nuclear installations in 2011.

Table 2.18 shows radiation doses to people on the Isle of Man from different exposure pathways. The dose to local people from consuming large amounts of food grown on the land monitored in 2011 was 0.006 mSv (0.009 mSv in 2010). This is less than one 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 less than 0.005 mSv in 2011, which is unchanged from the 2010 dose. Residents that spent a typical amount of time on sandy beaches were assessed to receive 0.009 mSv from external exposure to radionuclides entrained on the sand.

9.3 Northern Ireland

The Northern Ireland Environment Agency monitors the far-field effects of liquid discharges from Sellafield into the Irish Sea. The programme involves sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 9.1). The external exposure pathway is studied by monitoring gamma dose rates over intertidal areas. The results are presented in Tables 9.5(a) and (b).

In 2011, the main effect of discharges from Sellafield was concentrations of technetium-99 in shellfish and seaweed

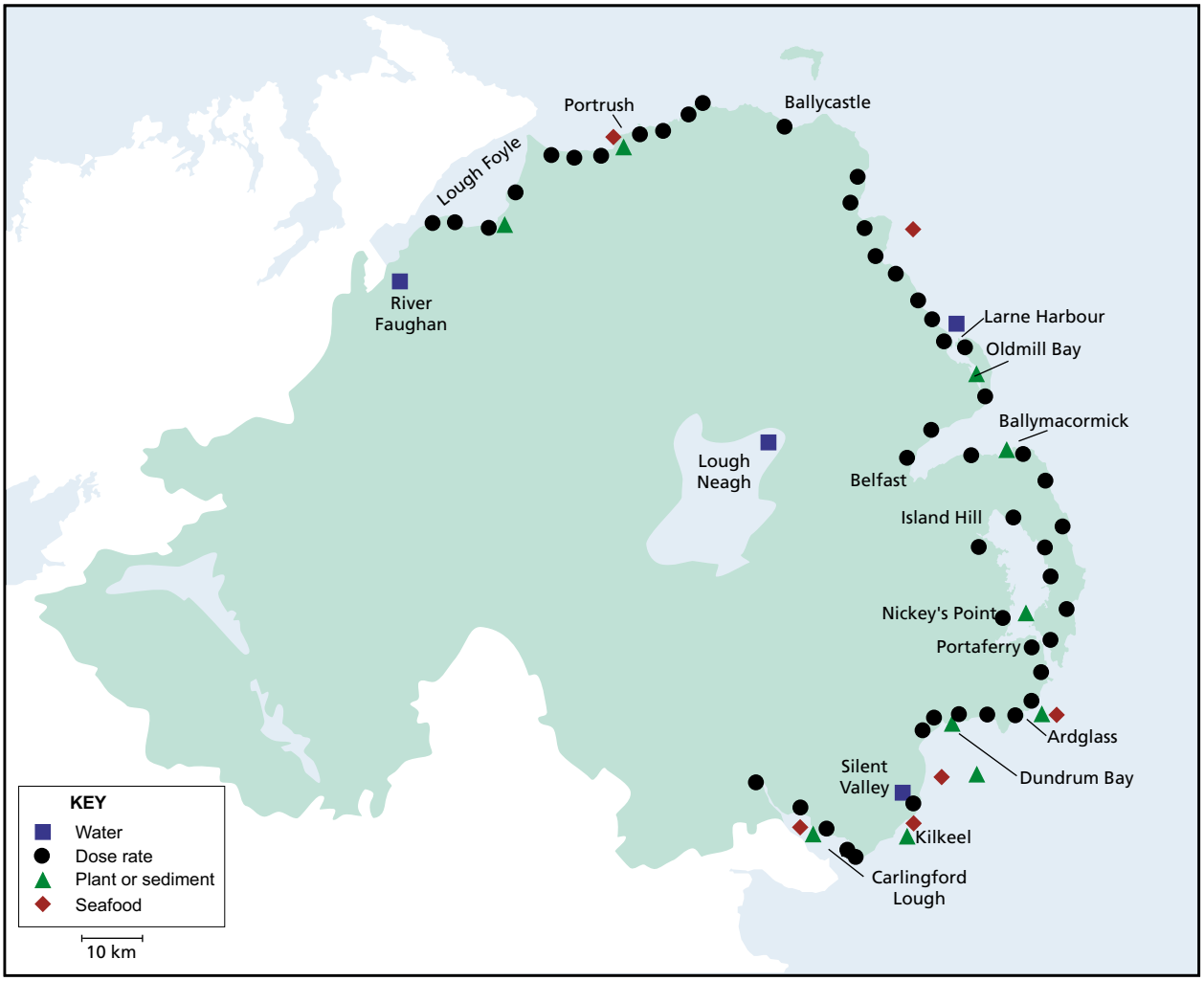


Figure 9.1. Monitoring locations in Northern Ireland, 2011

samples. These were generally similar to those in 2010, reflecting the considerably decreased inputs to the Irish Sea in recent years, although there was some limited evidence for local increases in levels in seaweed (see also Section 2.3.3). Caesium-137 concentrations were low and similar to 2010 levels, and trace amounts of transuranic nuclides were detected. Observed concentrations were less than those found nearer to Sellafield. The radiation dose rates over intertidal areas were similar to those in previous years.

A survey of consumption and occupancy in coastal regions of Northern Ireland (Smith *et al.*, 2002) established habits representative of people consuming large quantities of fish and shellfish. Based on the monitoring results from the marine environment in 2011, the dose to the people most exposed was 0.010 mSv, which is one per cent of the dose limit for members of the public.

Monitoring results for the terrestrial environment of Northern Ireland are given in the following parts of Section 9.

9.4 General diet

As part of the UK governments' general responsibility for food safety, concentrations of radioactivity are determined in regional diets. This data (and data on other dietary components in Sections 9.5 and 9.6) forms the basis of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with data from other EU member states (for example, Joint Research Centre, 2009). Concentrations of radioactivity in the general diet 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 on behalf of the Food Standards Agency.

In 2011, the concentrations found in a survey of radioactivity in diet as represented by canteen meals collected across the UK (Table 9.6) were very low or typical of natural sources. Similar values were observed in 2010.

9.5 Milk

The programme of milk sampling across dairies in the UK continued in 2011. Its aim is to collect and analyse samples on a monthly basis for their radionuclide content. This programme, together with the programme for crops presented in Section 9.6, 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 is 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 (for example, Joint Research Centre, 2009).

The results are summarised in Table 9.2. The majority of measurements, where comparable, are similar to those in previous years. Carbon-14 concentrations are very close to the expected background concentration in milk (see Appendix 1, Annex 4). Tritium results were again below detection limits. The mean concentration of strontium-90 detected was about 0.04 Bq l^{-1}. In the past, the concentrations of radiocaesium in milk were highest from those 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 though at levels of negligible radiological significance.

Radiation dose from consuming milk at average rates was assessed for various age groups. In 2011, 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 (for example, 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.

9.6 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2011 as a check on general food contamination (Table 9.3). 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. 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 2010.

9.7 Airborne particulate, rain, freshwater and groundwater

Radioactivity in rainwater and air was monitored at several UK locations as part of the programme of background sampling managed by the Environment Agency. This data is reported on behalf of the Department of Energy and Climate Change (DECC), NIEA and the Scottish Government, as part of the UK submission to the EC under Article 36 of the Euratom Treaty (for example, Joint Research Centre, 2009). The results are given in Table 9.7. 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 (see Section 8.1).

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 2010. Concentrations in air and rainwater were very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2011 (Figure 9.2). This water data is 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 (for example, Joint Research Centre, 2009). Sampling was designed to represent the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples were representative of natural waters before treatment and supply to the public water system. The results in Tables 9.8, 9.9 and 9.10 show that concentrations of tritium were all substantially below the EU indicator limit of 100 Bq l^{-1}. The highest value in Scotland was found at Gullielands Burn, which is near to the Chapelcross nuclear site. The origin of the local source is being investigated (see Section 4). 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 consuming drinking water in the UK was assessed as 0.027 mSv in 2011 (Table 9.11). 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 Silent Valley in Co. Down.

Separately, in 2011, SEPA took a series of groundwater samples from across Scotland and the results are displayed in Table 9.12. All samples contained levels below the limit of detection and are consistent with those in 2010.

9.8 Seawater surveys

The UK governments are 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 (for example, OSPAR, 2010b). In 2006, OSPAR adopted the Periodic Evaluation of the Progress in Implementing the OSPAR Radioactive Substances Strategy (concerning progressive and

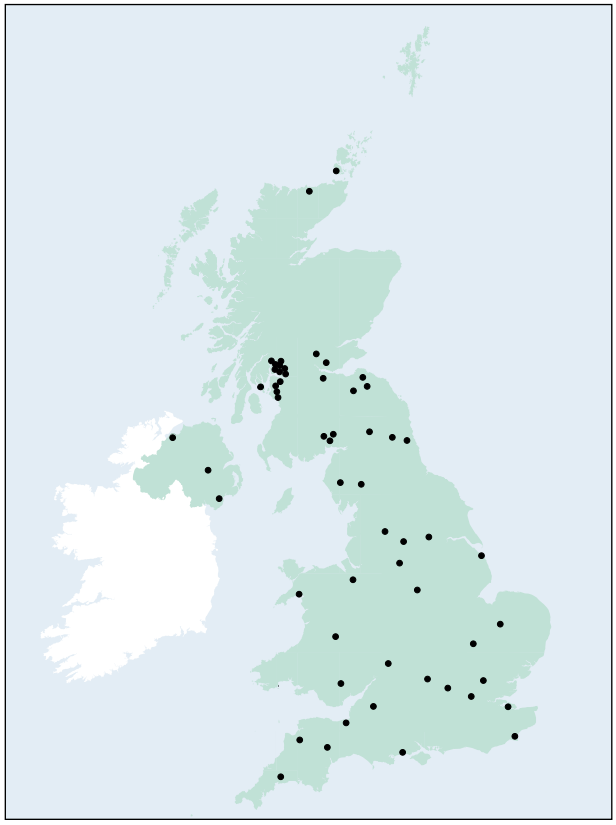


Figure 9.2. Drinking water sampling locations, 2011

substantial reductions in discharges of radioactive substances, as compared with the agreed baseline) (OSPAR, 2009b). 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 (for example, Kershaw and Baxter, 1995). Data has 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 achieving 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 comprised annual surveys of the Bristol Channel/western English Channel and biennial surveys of the Irish Sea and the North Sea. The results obtained in 2011 are given in Figures 9.3 – 9.7. Shoreline sampling was also carried out around the UK, and the data are given in Table 9.13. Much of the shoreline sampling was 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 carried out in 2011. The caesium-137 data from this survey (Figure 9.3) shows a band of higher concentrations along the coast to the north and south of Sellafield, with levels decreasing with distance from the coast. Caesium-137 concentrations were reasonably uniform in a large part of the Irish Sea. Overall, concentrations were generally similar to those reported in the previous Irish Sea survey in 2009 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a). Caesium-137 concentrations in the Irish Sea were only a small percentage of those prevailing in the late 1970s (typically up to 30 Bq l^{-1}, Baxter *et al.*, 1992), when discharges were substantially higher.

The predominant source 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 9.8). Longer time series showing peak concentrations in the Irish Sea and, with an associated time-lag, the North Sea are also shown in Figure 9.8.

In 2010, very low concentrations of caesium-137 (0.01 Bq l^{-1}) were found throughout most of the North Sea survey area (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2011), and these were only slightly above those observed for global fallout levels in surface seawaters (0.0001 – 0.0028 Bq l^{-1}, Povinec *et al.*, 2005).

Concentrations of caesium-137 in the western English Channel (Figure 9.4) near the Channel Islands were higher in 2011 compared to those in 2010, but were lower than concentrations in both the Irish and North Seas. Near the Channel Islands the activity concentrations may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague in France. Elsewhere, concentrations were not distinguishable from the background levels of global fallout (within experimental error).

A full assessment of long-term trends of caesium-137 in surface waters of Northern European seas is provided elsewhere (Povinec *et al.*, 2003).

Figure 9.5 shows tritium concentrations in Irish Sea seawater in September 2011. As expected, these were higher than those observed in the North Sea in 2010 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2011) due to the influence of discharges from Sellafield and other nuclear sites. The samples to the south and west of the Isle of Man contained tritium concentrations below the limit of detection.

In the Bristol Channel, the combined effect of tritium discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is shown in Figure 9.6. Overall, the general level of tritium concentrations in the Bristol Channel was very low. Tritium concentrations in samples taken close to these installations were the lowest in recent years and most measurements were below the limits of detection. Tritium concentrations in the western English Channel were also very low (Figure 9.6).

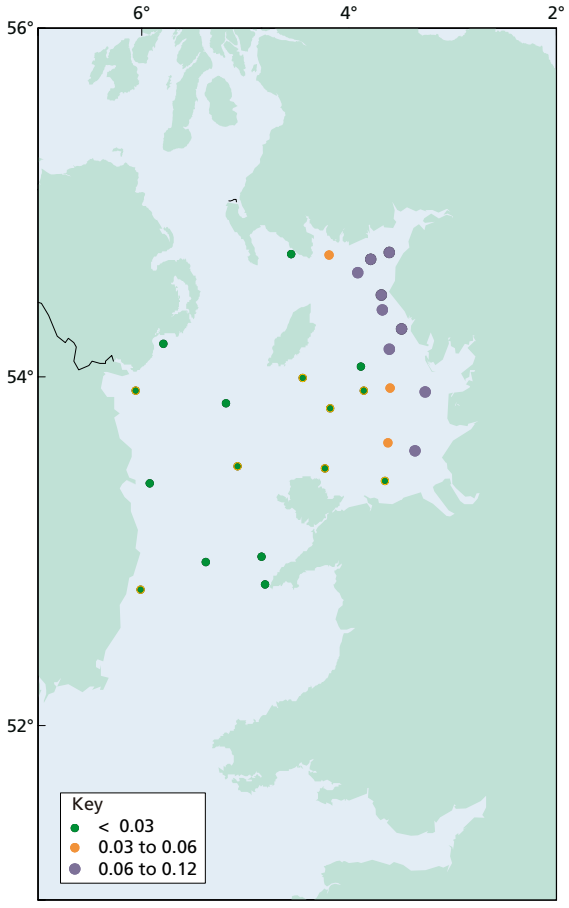


Figure 9.3. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water fom the Irish Sea, September 2011

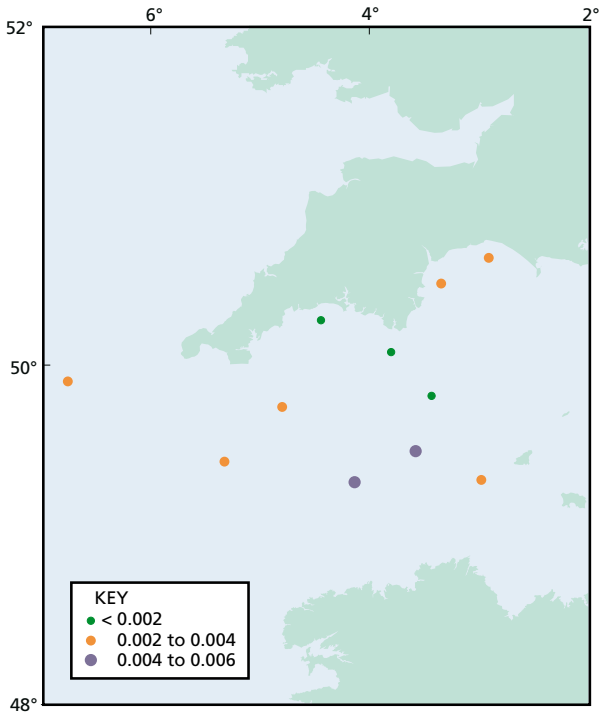


Figure 9.4. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the western English Channel, March 2011

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). Full reviews 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; 2010b).

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 9.13. Most radionuclides are below limits of detection, and tritium and caesium-137 levels are consistent with those in Figures 9.3 – 9.7.

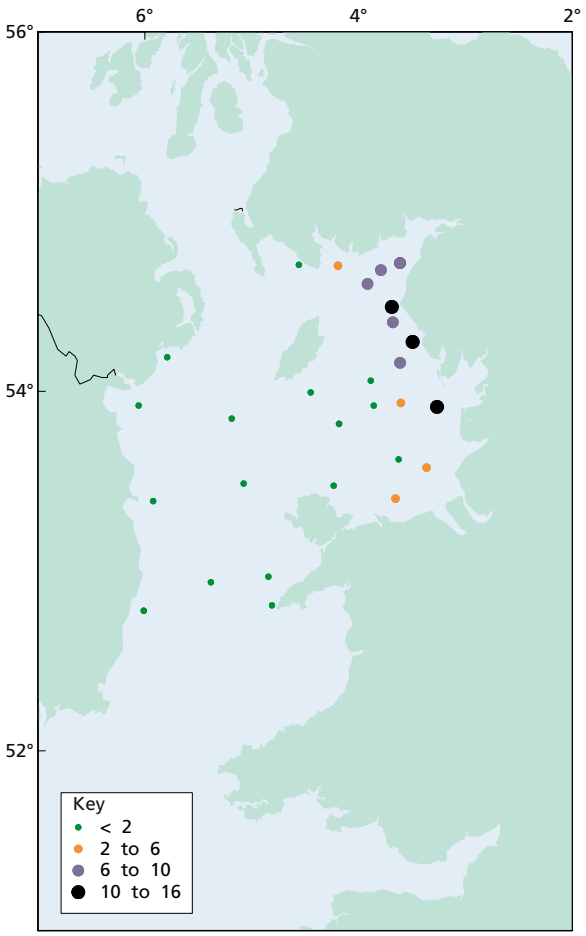


Figure 9.5. Concentrations (Bq l^{-1}) of tritium in surface water fom the Irish Sea, September 2011

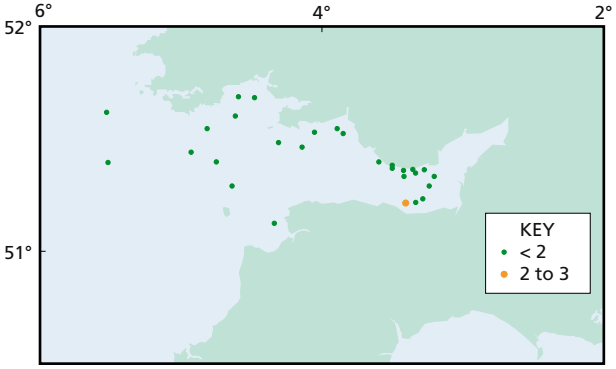


Figure 9.6. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September 2011

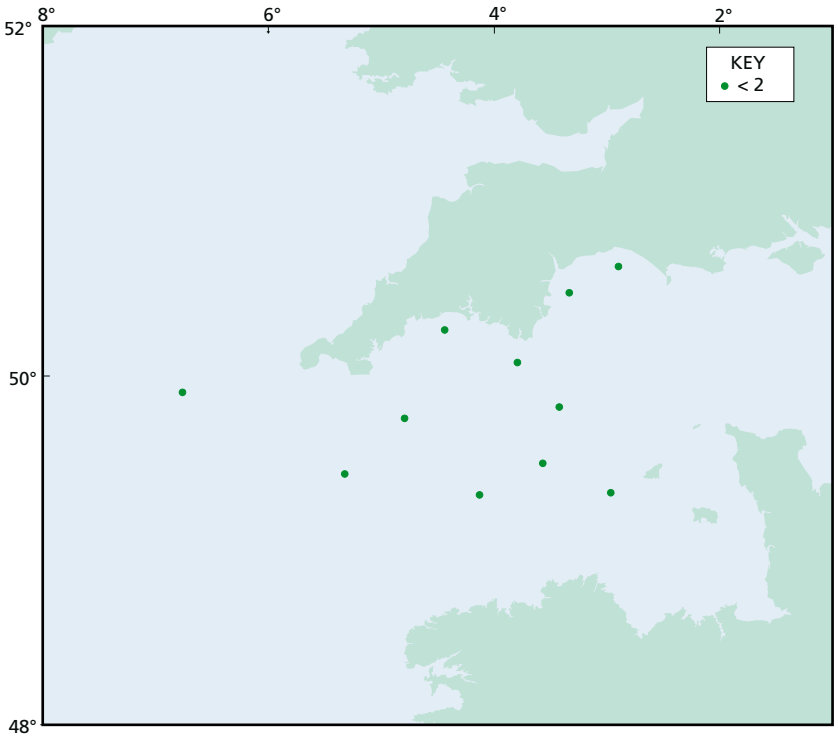


Figure 9.7. Concentrations (Bq l^{-1}) of tritium in surface water from the western English Channel, September 2011

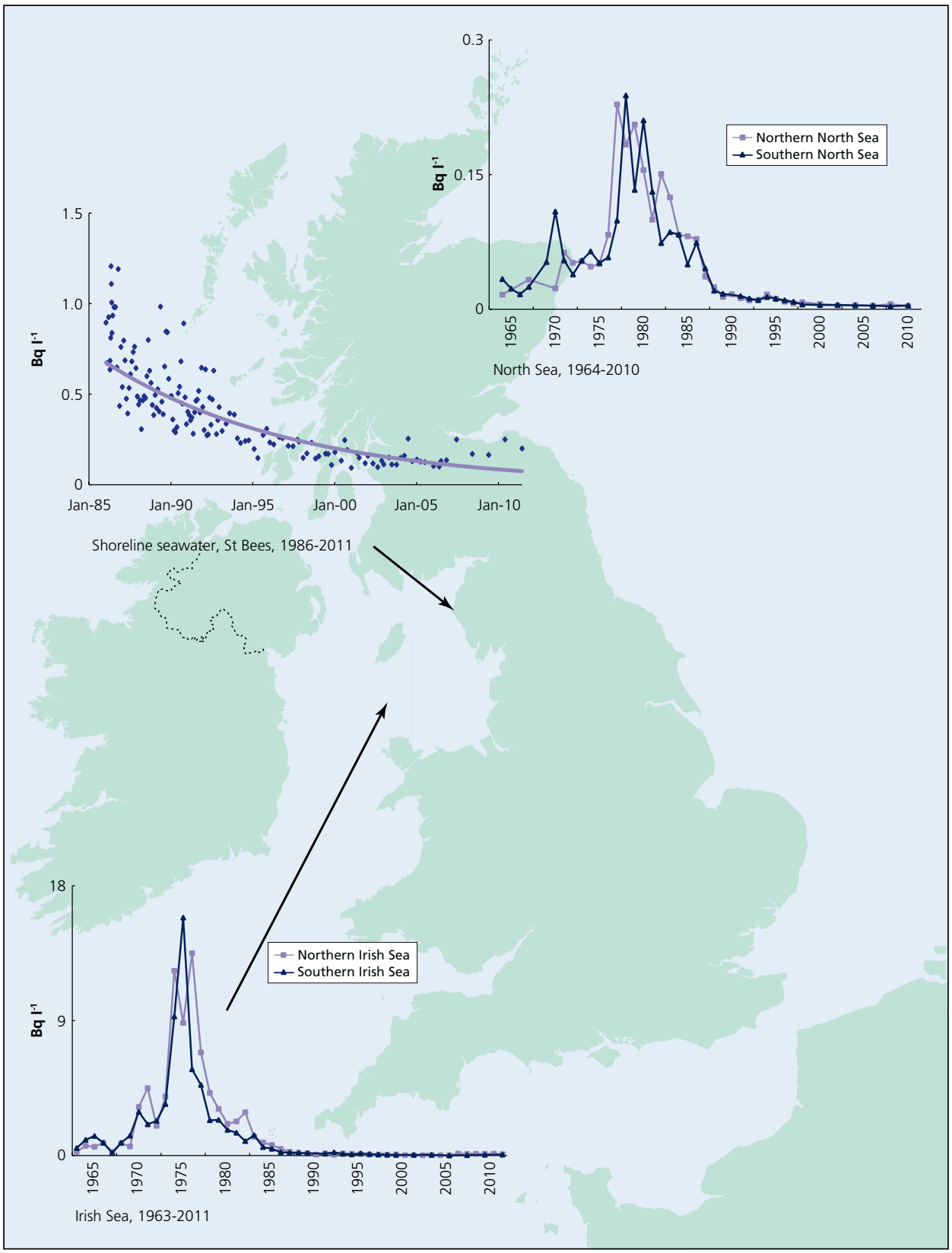


Figure 9.8. Concentration of caesium-137 in the Irish sea, North sea and in shoreline seawater close to Sellafield (at St. Bees)

Table 9.1. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2011

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	^{108m}Ag	^{129}I
Guernsey											
	Mackerel	1				<0.08			<0.68		
	Bass	1				<0.06			<0.57		
	Crabs	1				<0.05			<0.41		
	Lobsters	1				<0.06			<0.53	0.08	
	Limpets	1				<0.16			<1.8		
	Scallops	1				<0.03			<0.29		
	Ormers	1				<0.07			<0.68		
Fermain Bay	*Porphyra*	2				<0.07			<0.67		
Fermain Bay	*Fucus serratus*	2				<0.05	<0.079	3.6	<0.42		
St. Sampson's Harbour	Mud and sand	1				<0.16			<1.7		
	Seawater	3									
Jersey											
	Mackerel	1				<0.07			<0.61		
	Pollack	2				<0.07			<0.58		
	Bass	1				<0.07			<0.60		
	Crabs	1				<0.06			<0.50		
	Spiny spider crabs	1				<0.06			<0.44		
	Lobsters	1				<0.15		1.2	<1.4		
	Scallops	2				<0.08			<0.41	0.06	
La Rocque	Oysters	1				<0.05			<0.39		
La Rozel	Limpets	1				<0.06			<0.56		
Plemont Bay	*Porphyra*	2				<0.07			<0.53		
La Rozel	*Fucus vesiculosus*	4				<0.07	<0.079	17	<0.45		
Gorey	*Fucus vesiculosus*	1				<0.06			<0.46		
Gorey	*Ascophyllum nodosum*	2				<0.05			<0.33		
Gorey	*Fucus* spp.	1				<0.07			<0.55		
St Helier	Mud	1				1.9			<3.3		
Alderney											
	Crabs	2	<25	<25	61	<0.06		<0.25	<0.47		
	Spiny spider crabs	1				<0.27			<2.0		
	Lobsters	1				<0.06			<0.53		
	Toothed winkles	1	<25	<25	18	<0.20	0.12		<1.9		
	Fucus vesiculosus	2									0.65
Quenard Point	*Fucus serratus*	4				<0.06	0.050	8.1	<0.45		
Quenard Point	*Laminaria digitata*	4				<0.07			<0.57		
Little Crabbe Harbour	Sand	1				<0.20			<2.0		
	Seawater	4		<2.4							

Table 9.1. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Guernsey										
	Mackerel	1	0.08	<0.17	0.000057	0.00031	0.00035	*	*	160
	Bass	1	0.18	<0.15	0.000029	0.00013	0.00026	*	*	170
	Crabs	1	<0.04	<0.09	0.00021	0.00085	0.0030	*	0.00025	86
	Lobsters	1	<0.05	<0.10			<0.05			92
	Limpets	1	<0.14	<0.22			<0.11			99
	Scallops	1	<0.03	<0.09	0.00077	0.0030	0.0019	*	0.00015	98
	Ormers	1	<0.06	<0.17			<0.20			120
Fermain Bay	*Porphyra*	2	<0.06	<0.11	0.0016	0.0050	0.0098	*	0.00076	110
Fermain Bay	*Fucus serratus*	2	<0.05	<0.12	0.0028	0.011	0.0060	0.000040	0.00062	170
St. Sampson's Harbour	Mud and sand	1	0.46	<0.40	0.036	0.15	0.19	*	0.019	540
	Seawater	3	0.002							
Jersey										
	Mackerel	1	0.13	<0.16	0.000033	0.000080	0.000099	*	*	
	Pollack	2	0.21	<0.13			<0.12			190
	Bass	1	0.23	<0.11			<0.06			150
	Crabs	1	<0.05	<0.09	0.00034	0.0012	0.0028	*	0.00026	120
	Spiny spider crabs	1	<0.04	<0.06			<0.04			140
	Lobsters	1	<0.13	<0.20	0.00033	0.0012	0.0058	0.00012	0.00064	88
	Scallops	2	0.06	<0.10	0.0092	0.033	0.041	0.00091	0.0035	140
La Rocque	Oysters	1	<0.04	<0.11	0.0014	0.0047	0.0058	*	0.00048	70
La Rozel	Limpets	1	<0.05	<0.14	0.0017	0.0050	0.0074	0.00011	0.00056	97
Plemont Bay	*Porphyra*	2	<0.09	<0.09			<0.06			290
La Rozel	*Fucus vesiculosus*	4	<0.06	<0.12	0.0069	0.023	0.019	0.00023	0.00095	270
Gorey	*Fucus vesiculosus*	1	0.12	<0.11			<0.07			430
Gorey	*Ascophyllum nodosum*	2	<0.04	<0.06			<0.04			230
Gorey	*Fucus* spp.	1	<0.06	<0.15			<0.18			210
St Helier	Mud	1	1.6	<0.92	0.36	0.95	2.0	*	0.17	650
St Catherine's Bay	Seawater	1	0.003							
Alderney										
	Crabs	2	<0.05	<0.06	0.00021	0.00053	0.0023	*	0.00025	110
	Spiny spider crabs	1	<0.18	<0.29	0.00014	0.0043	0.0056	0.000041	0.00083	160
	Lobsters	1	<0.05	<0.13	0.00017	0.00071	0.0080	*	0.0011	110
	Toothed winkles	1	<0.16	<0.26	0.0071	0.024	0.043	0.00020	0.0039	120
Quenard Point	*Fucus serratus*	4	<0.05	<0.11	0.0058	0.019	0.014	0.00040	0.0010	180
Quenard Point	*Laminaria digitata*	4	<0.05	<0.14	<0.15					370
Little Crabbe Harbour	Sand	1	1.5	<0.58			<0.56			850
	Seawater	4	0.002							

* *Not detected by the method used*

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

Table 9.2. Concentrations of radionuclides in milk remote from nuclear sites, 2011

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	14	0.018	0.14
Co. Armagh		1	<4.0	15	0.019	0.080
Cambridgeshire		1	<2.1	14	0.016	0.061
Ceredigion		1	<4.0	14	0.030	0.082
Cheshire		1	<4.5	16	0.016	0.094
Clwyd		1	<2.1	16	0.022	0.066
Cornwall		1	<4.5	11	0.022	0.074
Devon		1	<4.0	17	0.026	0.069
Dorset		1	<4.5	14	0.016	0.077
Co. Down		1	<4.0	14	0.024	0.14
Dumfriesshire		1	<5.0	<16	<0.10	<0.05[c]
Essex		1	<4.0	11	0.014	0.061
Co. Fermanagh		1	<4.0	14	0.020	0.096
Gloucestershire		1	<4.5	13	0.022	0.071
Guernsey		1	<2.1	12	0.017	0.072
Gwynedd		1	<4.0	11	0.027	0.082
Hampshire		1	<4.0	14	0.024	0.076
Humberside		1	<4.0	17	0.019	0.069
Kent		1	<5.0	19	0.017	0.079
Lanarkshire		1			<0.030	<0.03[c]
Lancashire		1	<4.0	19	0.022	0.079
Leicestershire		1	<4.5	13	0.020	0.063
Middlesex		1	<4.5	9.5	0.018	0.059
Midlothian		1	<5.0	<14	<0.10	<0.05[c]
Nairnshire		1	<5.0	<16	<0.10	<0.05[c]
Norfolk		1	<4.5	15	0.020	0.067
North Yorkshire		1			0.021	0.065
Renfrewshire		1	<5.0	<15	<0.10	<0.05[c]
Co. Tyrone		2	<2.4	17	0.020	0.11
Co. Tyrone	max		<4.0	18		0.12
Mean Values						
Channel Islands			<2.1	12	0.017	0.072
England			<4.2	14	0.020	0.071
Northern Ireland			<3.7	15	0.020	0.11
Wales			<3.4	14	0.026	0.077
Scotland			<5.0	<15	<0.086	<0.05[c]
United Kingdom			<4.1	<15	<0.038	<0.078

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

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

[c] *^{137}Cs only*

Table 9.3. Concentrations of radionuclides in animals and crops remote from nuclear sites, 2011[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
Bedfordshire									
Flitton	Carrots	1	<4.0	7.0	0.022	0.024	0.069	0.010	0.034
	Lettuce	1	<5.0	<3.0	0.094	0.071	0.24	0.13	0.097
Ceredigion									
Sarnau	Lettuce	1	<4.0	<3.0	0.27	0.14	0.12	0.099	0.035
	Potatoes	1	<3.0	13	0.050	0.11	<0.040	0.0054	0.039
Channel Islands									
Guernsey	Blackberries	1	4.0	13	0.072	0.070	<0.044	0.056	0.025
	Lettuce	1	<4.0	4.0	0.065	0.054	0.10	0.0097	0.014
Jersey	Potatoes	1	<4.0	15	0.017	0.070			
	Strawberries	1	<4.0	6.0	0.041	0.047			
Cheshire									
Malpas	Kale	1	<5.0	12	1.1	0.058	0.12	0.063	0.0070
	Potatoes	1	<3.0	11	0.059	0.046	<0.043	0.0053	0.012
Cornwall									
Hayle	Cabbage	1	<4.0	<3.0	0.038	0.025	<0.041	0.0020	0.012
	Potatoes	1	<5.0	8.0	0.010	0.056	<0.049	0.0071	0.0080
Cumbria									
Kendal	Chard	1	<4.0	4.0	0.27	0.086	0.29	0.013	0.18
	Potatoes	1	<5.0	21	0.042	0.050	<0.034	0.0074	0.039
Denbighshire									
Wrexham	Cabbage	1	<4.0	6.0	0.10	0.025	<0.046	0.0065	0.0080
	Strawberries	1	<4.0	12	0.047	0.013	<0.043	0.012	0.020
Dumfriesshire									
Dumfries	Mixed diet	4			<0.15	<0.05[b]			
East Lothian									
North Berwick	Mixed diet	4			<0.10	<0.05[b]			
Northamptonshire									
Peterborough	Cabbage	1	<4.0	8.0	0.090	0.023	<0.035	0.011	0.019
	Strawberries	1	<4.0	10	0.028	0.040	0.043	0.013	0.016
North Yorkshire									
Kirbymoorside	Cabbage	1	<4.0	10	0.28	0.13	<0.048	0.021	0.030
	Potatoes	1	<4.0	17	0.044	0.075	<0.045	0.0071	0.014
Oxfordshire									
Banbury	Cabbage	1	<4.0	7.0	0.099	0.055	<0.047	0.0095	0.018
Oxford	Strawberries	1	<4.0	9.0	0.019	0.027	0.047	0.0096	0.022
Renfrewshire									
Paisley	Mixed diet	4			<0.10	<0.05[b]			
Ross-shire									
Dingwall	Mixed diet	4			<0.10	<0.05[b]			
Shropshire									
Shrewsbury	Lettuce	1	<5.0	<3.0	0.12	0.077	<0.043	0.073	0.017
	Soft fruit	1	<4.0	19	0.084	0.049	0.073	0.060	0.013
Somerset									
Taunton	Spinach	1	<4.0	6.0	0.29	0.045	0.36	0.16	0.058
	Strawberries	1	6.0	5.0	0.042	0.017	0.11	0.024	0.026
South Yorkshire									
Wortley	Potatoes	1	<5.0	15	0.024	0.080	<0.043	0.0035	0.0070
	Spinach	1	<4.0	8.0	0.26	0.12	0.30	0.17	0.028
Suffolk									
Sudbury	Cabbage	1	<5.0	7.0	0.14	0.035	<0.036	0.020	0.021
	Strawberries	1	<4.0	7.0	0.039	0.054	<0.036	0.015	0.022
Surrey									
Weybridge	Beef Kidney	1	<8.0	37	0.13	0.40			
	Beef Liver	1	<8.0	26	0.075	0.70			
	Beef Muscle	1	14	27	0.027	0.45			
	Sheep Kidney/Liver	1	<7.0	52	0.17	0.23			
	Sheep Muscle	1	6.0	51	0.0080	0.12			
Sussex									
Brighton	Cabbage	1	<4.0	12	0.020	0.61	0.071	0.033	0.091
	Potatoes	1	<5.0	14	0.012	0.027	<0.047	0.0058	0.019
Warwickshire									
Warwick	Lettuce	1	<4.0	6.0	0.14	0.13	0.27	0.11	0.013
	Strawberries	1	<4.0	10	0.011	0.061	<0.045	0.013	0.020
Wiltshire									
Chippenham	Cabbage	1	<4.0	5.0	0.060	0.050	0.091	0.029	0.013
	Potatoes	1	<5.0	14	0.026	0.056	0.15	0.010	0.0080
Worcestershire									
Evesham	Beetroot	1	<4.0	10	0.025	0.052	<0.039	0.0063	0.022
	Cabbage	1	<4.0	9.0	0.33	0.053	0.22	0.11	0.061
Mean Values[c]									
Channel Islands			<4.0	9.5	0.049	0.060	<0.072	0.033	0.020
England			<4.9	<14	0.12	0.12	<0.10	0.038	0.032
Wales			<3.8	<8.5	0.12	0.072	<0.062	0.031	0.026
Scotland					<0.11	<0.05[b]			
Great Britain			<4.4	<11	<0.12	<0.081	<0.081	0.035	0.029

Table 9.3. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Bedfordshire									
Flitton	Carrots	1	0.0046						
	Lettuce	1	0.059	0.045	0.0020	0.042			
Ceredigion									
Sarnau	Lettuce	1	0.016						
	Potatoes	1	<0.00070						
Channel Islands									
Guernsey	Blackberries	1	0.00090				0.00010	<0.00020	0.00020
	Lettuce	1	0.0019				0.00010	<0.00020	<0.00020
Jersey	Potatoes	1					<0.00010	<0.00020	0.00030
	Strawberries	1		0.0011	0.00010	0.00060	<0.00010	<0.00020	<0.00020
Cheshire									
Malpas	Kale	1	<0.0015						
	Potatoes	1	0.0018						
Cornwall									
Hayle	Cabbage	1	0.00070						
	Potatoes	1	<0.0016	0.0045	<0.00040	0.0035			
Cumbria									
Kendal	Chard	1	0.010	0.0069	<0.00050	0.0053			
	Potatoes	1	0.0039						
Denbighshire									
Wrexham	Cabbage	1	<0.0011						
	Strawberries	1	0.0017	0.0011	<0.00040	<0.0010			
Northamptonshire									
Peterborough	Cabbage	1	0.0013						
	Strawberries	1	<0.00070						
North Yorkshire									
Kirbymoorside	Cabbage	1	<0.00080						
	Potatoes	1	0.0050	0.0041	0.00050	0.0052			
Oxfordshire									
Banbury	Cabbage	1	0.0018						
Oxford	Strawberries	1	0.00080						
Shropshire									
Shrewsbury	Lettuce	1	0.0018						
	Soft fruit	1	0.0042	0.0069	0.00060	0.0053			
Somerset									
Taunton	Spinach	1	0.011	0.0073	<0.00040	0.0057			
	Strawberries	1	<0.00070						
South Yorkshire									
Wortley	Potatoes	1	0.0012	<0.00070	<0.00020	0.0010			
	Spinach	1	0.0064						
Suffolk									
Sudbury	Cabbage	1	0.0023						
	Strawberries	1	0.0022						
Surrey									
Weybridge	Beef kidney	1		0.0011	<0.00020	0.0012	<0.00010	<0.00020	0.00090
	Beef liver	1					0.00010	<0.00030	0.00040
	Beef muscle	1					0.00010	<0.00020	0.00030
	Sheep kidney/liver	1					<0.00010	<0.00020	0.00050
	Sheep muscle	1					<0.00010	<0.00020	0.00040
Sussex									
Brighton	Cabbage	1	0.0019	0.0088	<0.00070	0.0063			
	Potatoes	1	0.0012						
Warwickshire									
Warwick	Lettuce	1	0.0057						
	Strawberries	1	<0.0010						
Wiltshire									
Chippenham	Cabbage	1	0.0015						
	Potatoes	1	0.0028						
Worcestershire									
Evesham	Beetroot	1	<0.0013	<0.00060	<0.00040	0.0010			
	Cabbage	1	0.0038						
Mean Values[c]									
Channel Islands			0.0014	0.0011	0.00010	0.00060	<0.00010	<0.00020	<0.00023
England			<0.0048	<0.0086	<0.00059	0.0077	<0.00010	<0.00022	0.00050
Wales			<0.0049	<0.0011	<0.00040	<0.0010			
Great Britain			<0.0049	<0.0049	<0.00050	<0.0044	<0.00010	<0.00022	<0.00050

[a] *Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection*
[b] *^{137}Cs only*
[c] *Great Britain mean excludes Channel Islands. Mean values include crops and animals*

Table 9.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2011[a]

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Cod	4	<0.06	<0.14	<0.12		<0.52	<0.13	<0.06	1.7
Mackerel	3	<0.08	<0.24	<0.24		<0.77	<0.18	<0.08	0.63
Herring	1	<0.10	<0.24	<0.18		<1.1	<0.29	<0.11	0.38
Lobsters	4	<0.06	<0.24	<0.49	18	<0.56	<0.13	<0.06	0.24
Scallops	4	<0.07	<0.16	<0.14		<0.63	<0.16	<0.07	0.27
Seaweed[c]	4[E]	<0.72	<1.1	<0.49	110	<4.3	<2.4	<0.59	<0.56
Sediment	1[E]	<0.34	<0.84	<0.28		<2.1	<1.1	<0.32	6.6

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Aquatic samples									
Cod	4	<0.23	0.00021	0.0011	0.0021	*	0.000012		
Mackerel	3	<0.31			<0.08				
Herring	1	<0.63	0.00012	0.00075	0.0011	*	*		
Lobsters	4	<0.25			<0.12				140
Scallops	4	<0.29	0.024	0.15	0.041	*	*		
Seaweed[c]	4[E]	<1.8			<0.61				
Sediment	1[E]	<1.4			1.6			<100	460

Material or selection[d]	No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Terrestrial samples								
Milk	2	<4.1	16	<0.39	<0.18	0.028	0.0050	<0.93
Milk max		<4.3	17	<0.48		0.031		
Apples	1	<4.0	15	<0.20	<0.20	0.031		<0.70
Beetroot	1	<4.0	11	0.20	<0.20	0.039	<0.021	1.4
Cabbage	1	<4.0	8.0	0.60	<0.30	0.092	<0.021	<1.3

Material or selection[d]	No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{125}Sb	^{129}I	Total Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples								
Milk	2	<0.36	<0.0080	0.070	0.00010	<0.00010	<0.031	0.00020
Milk max		<0.40						
Apples	1	<0.50		0.095				
Beetroot	1	<0.40	<0.024	0.13	0.00010	<0.00020	<0.053	<0.00020
Cabbage	1	<0.40	<0.022	0.067	<0.00010	0.00030	<0.058	0.00020

* *Not detected by the method used*

[a] *The gamma dose rate in air at 1m over sand and stones at Ramsey[E] was 0.086 μGy h^{-1}*

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

[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 1.7, <0.17 and 1.6 Bq kg^{-1} respectively*

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

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

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

Table 9.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2011[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Cod	Kilkeel	4	33	<0.04		<0.09	<0.04	0.61
Plaice	Kilkeel	4		<0.06		<0.13	<0.06	0.42
Haddock	Kilkeel	4		<0.07		<0.14	<0.06	0.52
Herring	Ardglass	2		<0.09		<0.22	<0.09	0.64
Skates / rays	North coast	4		<0.14		<0.30	<0.14	2.0
Skates / rays	Kilkeel	4		<0.17		<0.35	<0.17	1.2
Witch	Kilkeel	1		<0.19		<0.38	<0.18	0.98
Crabs	Kilkeel	2		<0.05		<0.11	<0.05	0.18
Lobsters	Ballycastle	1		<0.12	23	<0.28	<0.13	0.15
Lobsters	Kilkeel	2		<0.05	21	<0.10	<0.05	0.15
Nephrops	Kilkeel	4		<0.11	6.4	<0.23	<0.11	0.55
Winkles	Minerstown	3		<0.09		<0.22	<0.09	0.17
Toothed winkles	Minerstown	1		<0.06		<0.18	<0.06	0.58
Mussels	Carlingford Lough	1		<0.11	8.0	<0.31	<0.14	0.42
Scallops	Co. Down	2		<0.05		<0.11	<0.05	0.29
Ascophyllum nodosum	Ardglass	1		<0.06		<0.10	<0.06	0.34
Ascophyllum nodosum	Carlingford Lough	2		<0.07	110	<0.13	<0.07	0.45
Fucus spp.	Carlingford Lough	2		<0.09		<0.17	<0.10	0.39
Fucus spp.	Portrush	4		<0.06		<0.11	<0.06	0.12
Fucus vesiculosus	Ardglass	3		<0.09	190	<0.18	<0.09	0.59
Rhodymenia spp.	Portaferry	4		<0.07	1.1	<0.14	<0.07	0.63
Mud	Carlingford Lough	2		<0.68		<2.3	<1.0	53
Mud	Dundrum Bay	2		<0.54		<1.7	<0.82	25
Mud	Oldmill Bay	2		<0.67		<1.7	<0.86	30
Mud	Strangford Lough-Nicky's point	2		<0.45		<1.3	<0.63	21
Mud	Ballymacormick	2		<0.43		<1.3	<0.60	15
Mud	Carrichue	1		<0.54		<1.3	<0.70	2.3
Mud, sand and stones	Carrichue	1		<0.33		<0.99	<0.46	1.0
Sand	Portrush	2		<0.37		<1.0	<0.46	0.60
Seawater	North of Larne	12			0.0028		*	0.01

Table 9.5(a). continued

Material	Location	No. of sampling observ-ations	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	<0.08			<0.06		
Plaice	Kilkeel	4	<0.11			<0.07		
Haddock	Kilkeel	4	<0.13			<0.13		
Herring	Ardglass	2	<0.20			<0.14		
Skates / rays	North coast	4	<0.20			<0.10		
Skates / rays	Kilkeel	4	<0.23			<0.12		
Witch	Kilkeel	1	<0.24			<0.13		
Crabs	Kilkeel	2	<0.08			0.15		
Lobsters	Ballycastle	1	<0.17			0.29		
Lobsters	Kilkeel	2	<0.08			<0.05		
Nephrops	Kilkeel	4	<0.17	0.0022	0.013	0.034	0.000046	0.000052
Winkles	Minerstown	3	<0.20	0.035	0.21	0.15	*	0.00017
Toothed winkles	Minerstown	1	<0.16			0.29		
Mussels	Carlingford Lough	1	<0.26			<0.22		
Scallops	Co. Down	2	<0.10			<0.11		
Ascophyllum nodosum	Ardglass	1	<0.07			0.09		
Ascophyllum nodosum	Carlingford Lough	2	<0.10			<0.06		
Fucus spp.	Carlingford Lough	2	<0.27			<0.20		
Fucus spp.	Portrush	4	<0.11			<0.09		
Fucus vesiculosus	Ardglass	3	<0.14			0.24		
Rhodymenia spp.	Portaferry	4	<0.10	0.075	0.45	0.81	*	0.0011
Mud	Carlingford Lough	2	<2.4	2.1	13	9.0	*	*
Mud	Dundrum Bay	2	<2.2			<6.4		
Mud	Oldmill Bay	2	<1.6			10		
Mud	Strangford Lough- Nicky's point	2	<1.8			6.9		
Mud	Ballymacormick	2	<1.4			12		
Mud	Carrichue	1	<1.3	0.071	0.55	0.91	*	0.00083
Mud, sand and stones	Carrichue	1	<1.3			<1.7		
Sand	Portrush	2	<1.1			<1.1		

* *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 9.5(b). Monitoring of radiation dose rates in Northern Ireland, 2011[a]

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lishally	Mud	1	0.062
Eglington	Shingle	1	0.051
Carrichue	Mud	1	0.071
Bellerena	Mud	1	0.060
Benone	Sand	1	0.057
Castlerock	Sand	1	0.059
Portstewart	Sand	1	0.058
Portrush, Blue Pool	Sand	1	0.055
Portrush, White Rocks	Sand	1	0.059
Portballintrae	Sand	1	0.054
Giant's Causeway	Sand	1	0.059
Ballycastle	Sand	1	0.058
Cushendun	Sand	1	0.060
Cushendall	Sand and stones	1	0.064
Red Bay	Sand	1	0.067
Carnlough	Sand	1	0.058
Glenarm	Sand	1	0.052
Half Way House	Sand	1	0.054
Ballygally	Sand	1	0.057
Drains Bay	Sand	1	0.056
Larne	Sand	1	0.056
Whitehead	Sand	1	0.063
Carrickfergus	Sand	1	0.057
Jordanstown	Sand	1	0.060
Helen's Bay	Sand	1	0.059
Groomsport	Sand	1	0.064
Millisle	Sand	1	0.066
Ballywalter	Sand	1	0.068
Ballyhalbert	Sand	1	0.065
Cloghy	Sand	1	0.064
Portaferry	Shingle and stones	1	0.091
Kircubbin	Sand	1	0.070
Greyabbey	Sand	1	0.071
Ards Maltings	Mud	1	0.071
Island Hill	Mud	1	0.068
Nicky's Point	Mud	1	0.094
Strangford	Shingle and stones	1	0.097
Kilclief	Sand	1	0.067
Ardglass	Mud	1	0.075
Killough	Mud	1	0.082
Rocky Beach	Sand	1	0.072
Tyrella	Sand	1	0.072
Dundrum	Sand	1	0.085
Newcastle	Sand	1	0.089
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.081
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.076
Rostrevor	Sand	1	0.10
Narrow Water	Mud	1	0.087

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

Table 9.6. Concentrations of radionuclides in canteen meals, 2011[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	8	33	99	<0.080	<0.05
Northern Ireland	5	42	100	0.10	<0.05
Scotland	12[S]	38		<0.037	<0.02
Scotland	2	50	85	<0.17	0.10
Wales	5	34	100	<0.052	<0.04

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

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

Table 9.7. Concentrations of radionuclides in rainwater and air 2011

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	<0.93	1.3			<0.016
		Air	4		0.0015			<1.7 10^{-6}
Co. Down								
	Conlig	Rainwater	4		0.90			<0.018
		Air	4		7.5 10^{-4}			<9.9 10^{-7}
Dumfries and Galloway								
	Eskdalemuir	Rainwater	4	<0.93	1.4			<0.013
		Air	4		0.0010			<1.5 10^{-6}
Glasgow								
	Glasgow	Air	9					<0.010
North Yorkshire								
	Dishforth	Rainwater	4		1.1			<0.016
		Air	3		5.6 10^{-4}			<9.9 10^{-7}
Oxfordshire								
	Chilton	Rainwater	4		0.86	2.2	<0.0020	<0.022
		Air	12		8.1 10^{-4}			<7.5 10^{-7}
Shetland								
	Lerwick	Rainwater	4		1.3			<0.016
		Air	4		9.8 10^{-4}			<1.5 10^{-6}
Suffolk								
	Orfordness	Rainwater	4	<0.92	1.5			<0.018
		Air	3		0.0011			<8.1 10^{-7}

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]					
				^{137}Cs[d]	^{238}Pu[c]	^{239}Pu+ ^{240}Pu[c]	^{241}Am[c]	Gross alpha[d]	Gross beta[d]
Ceredigion									
	Aberporth	Rainwater	4		<2.0 10^{-6}	4.0 10^{-6}	1.3 10^{-5}		
		Air	4		<3.0 10^{-9}	<3.9 10^{-9}	<3.0 10^{-9}		
Glasgow									
	Glasgow	Air	9						<0.0020
Oxfordshire									
	Chilton	Rainwater	4	<7.0 10^{-4}				<0.033	0.040

[a] *Bq l^{-1} for rainwater and Bq kg^{-1} for air. 1.2 kg air occupies 1m^3 at standard temperature and pressure*

[b] *Bulked from 4 quarterly samples*

[c] *Separate annual sample for rain, annual bulked sample for air*

[d] *Bulked from 12 monthly samples*

Table 9.8. Concentrations of radionuclides in sources of drinking water in Scotland, 2011

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Angus	Loch Lee	4	<1.0	<0.0050	<0.01	<0.010	0.034
Argyll and Bute	Auchengaich	1	<1.0		<0.01	<0.010	0.017
Argyll and Bute	Helensburgh Reservoir	1	<1.0		<0.01	<0.010	0.035
Argyll and Bute	Loch Ascog	1	<1.0		<0.01	<0.010	0.10
Argyll and Bute	Loch Eck	1	<1.0		<0.01	<0.010	<0.014
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.0		<0.01	<0.010	0.030
Argyll and Bute	Loch Finlas	1	<1.0		<0.01	<0.010	0.030
Clackmannanshire	Gartmorn	1	<1.0		<0.01	<0.010	0.090
Dumfries and Galloway	Black Esk	1	<1.0		<0.01	<0.010	0.020
Dumfries and Galloway	Gullielands Burn	1	35		<0.01	<0.010	0.15
Dumfries and Galloway	Purdomstone	1	<1.0		<0.01	<0.010	0.056
Dumfries and Galloway	Winterhope	1	1.6		<0.01	<0.010	0.024
East Lothian	Hopes Reservoir	1	<1.0		<0.01	0.024	0.035
East Lothian	Thorters Reservoir	1	<1.0		<0.01	0.019	0.060
East Lothian	Whiteadder	1	<1.0		<0.01	0.011	0.031
East Lothian	Thornton Loch Burn	1	<1.0		<0.01	<0.010	0.069
Fife	Holl Reservoir	1	1.2		<0.01	<0.010	0.020
Highland	Loch Baligill	1	<1.0		<0.01	<0.010	0.040
Highland	Loch Calder	1	<1.0		<0.01	0.016	0.051
Highland	Loch Glass	4	<1.0	<0.0050	<0.01	<0.011	0.031
Highland	Loch Shurrerey	1	<1.0		<0.10	<0.010	0.026
North Ayrshire	Camphill	1	<1.0		<0.01	<0.010	0.014
North Ayrshire	Knockendon Reservoir	1	<1.0		<0.01	<0.010	0.020
North Ayrshire	Munnoch Reservoir	1	<1.0		<0.01	<0.010	0.044
North Ayrshire	Outerwards	1	<1.0		<0.01	<0.010	0.027
Orkney Islands	Heldale Water	1	<1.0		<0.01	<0.010	<0.010
Perth and Kinross	Castlehill	1	<1.0		<0.01	<0.010	0.020
Scottish Borders	Knowesdean	4	<1.0	<0.0050	<0.01	<0.010	0.023
Stirling	Loch Katrine	12	<1.0	0.0029	<0.002	<0.010	<0.021
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0		<0.01	<0.010	0.020
West Lothian	Morton No 2	1	<1.0		<0.01	<0.010	<0.014

Table 9.9. Concentrations of radionuclides in sources of drinking water in England and Wales, 2011

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{40}K	^{90}Sr	^{125}I
England						
Buckinghamshire	Bourne End, groundwater	4	<4.0	0.048	<0.0010	
Cambridgeshire	Grafham Water	4	<4.0	0.33	0.0021	
Cheshire	River Dee, Chester	1	<4.0	0.15	0.0026	
Cornwall	River Fowey	4	<4.0	0.060	0.0018	<0.0027
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.036	0.0026	
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.035	0.0044	
County Durham	River Tees, Darlington	4	<4.0	0.028	0.0026	<0.0028
Cumbria	Ennerdale Lake	4	<4.0	<0.011	0.0018	
Cumbria	Haweswater Reservoir	4	<4.0	<0.024	0.0022	
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	<0.024	0.0016	
Derbyshire	Matlock, groundwater[a]	4	<4.0	0.029	<0.0010	
Devon	River Exe, Exeter	4	<4.0	<0.14	<0.0015	<0.019
Gloucestershire	River Severn, Tewkesbury	4	<4.0	0.13	0.0021	<0.0033
Greater London	River Lee, Chingford	4	<4.0	0.32	<0.0010	0.0035
Hampshire	River Avon, Christchurch	4	<4.0	0.054	<0.0010	<0.0029
Humberside	Littlecoates, groundwater	4	<4.0	0.051	<0.0020	
Kent	Chatham, deep groundwater	4	<4.0	<0.029	<0.0010	
Kent	Denge, shallow groundwater	4	<4.0	0.13	0.0027	
Lancashire	Corn Close, groundwater	4	<4.0	0.044	<0.0010	
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.084	0.0011	<0.0019
Northumberland	Kielder Reservoir	4	<4.0	<0.035	0.0038	
Oxfordshire	River Thames, Oxford	3	<4.0	0.13	0.0013	<0.0022
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.13	<0.0013	
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0017	
Surrey	River Thames, Chertsey	4	<4.0	0.22	<0.0012	<0.0021
Surrey	River Thames, Walton	4	<4.0	0.22	0.0012	<0.0022
Yorkshire	Chellow Heights, Bradford	4	<4.0	<0.015	0.0047	
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<4.0	0.15	0.0011	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England						
Buckinghamshire	Bourne End, groundwater	4	<0.0010	<0.020	0.053	<0.050
Cambridgeshire	Grafham Water	4	<0.0010	0.028	0.49	0.31
Cheshire	River Dee, Chester	1	<0.0011			
Cornwall	River Fowey	4	<0.0010	0.021	0.097	0.063
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.0010	<0.020	0.093	0.058
County Durham	Honey Hill Water Treatment Works, Consett	4	0.0047	0.076	0.16	0.10
County Durham	River Tees, Darlington	4	<0.0010	0.021	0.076	0.050
Cumbria	Ennerdale Lake	4	<0.0010	<0.020	<0.050	<0.050
Cumbria	Haweswater Reservoir	4	<0.0010	0.022	0.059	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<0.0010	<0.020	<0.050	<0.050
Derbyshire	Matlock, groundwater[a]	4	<0.0010	0.088	0.097	0.060
Devon	River Exe, Exeter	4	<0.0045	0.019	0.097	0.060
Gloucestershire	River Severn, Tewkesbury	4	<0.0010	0.055	0.27	0.17
Greater London	River Lee, Chingford	4	<0.0010	<0.024	0.40	0.25
Hampshire	River Avon, Christchurch	4	<0.0011	<0.020	0.11	0.069
Humberside	Littlecoates, groundwater	4	<0.0026	0.023	0.14	0.094
Kent	Chatham, deep groundwater	4	<0.0011	0.017	0.098	0.059
Kent	Denge, shallow groundwater	4	<0.0010	<0.020	0.16	0.10
Lancashire	Corn Close, groundwater	4	<0.0010	<0.020	0.093	0.058
Norfolk	River Drove, Stoke Ferry	4	<0.0010	<0.020	0.16	0.097
Northumberland	Kielder Reservoir	4	<0.0015	0.018	<0.053	<0.050
Oxfordshire	River Thames, Oxford	3	<0.0010	<0.024	0.19	0.12
Somerset	Ashford Reservoir, Bridgwater	4	<0.0010	0.023	0.15	0.094
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.0010	0.025	0.17	0.11
Surrey	River Thames, Chertsey	4	<0.0010	<0.025	0.29	0.18
Surrey	River Thames, Walton	4	<0.0010	<0.022	0.33	0.20
Yorkshire	Chellow Heights, Bradford	4	<0.0010	<0.020	0.051	<0.050
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	3	<0.0023	<0.020	0.096	0.060

Table 9.9. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}		
			^{3}H	^{40}K	^{90}Sr
Wales					
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.018	0.0032
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.013	0.0032
Powys	Elan Valley Reservoir	4	<4.0	<0.015	0.0033

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.0010	<0.020	<0.050	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.0010	0.020	0.050	<0.050
Powys	Elan Valley Reservoir	4	<0.0010	<0.020	<0.050	<0.050

1 *Using ^{137}Cs standard*
2 *Using ^{40}K standard*
a *The concentrations of ^{210}Po, ^{226}Ra, ^{234}U, ^{235}U and ^{238}U were 0.0093, 0.012, 0.044, <0.010 and 0.023 Bq l^{-1} respectively*

Table 9.10. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2011

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{90}Sr	^{137}Cs	^{210}Po	^{226}Ra	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Co. Londonderry	R Faughan	4	<1.0	0.0027	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.080
Co. Antrim	Lough Neagh	4	<1.0	<0.0023	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.12
Co. Down	Silent Valley	4	<1.0	<0.0026	<0.05	<0.010	<0.020	<0.010	<0.010	<0.010	0.023	0.070

Table 9.11. Estimates of radiation exposure from radionuclides in drinking water, 2011[a]

Region	Mean exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides[b,c]	Naturally occurring radionuclides[b]	All radionuclides	Location	All radionuclides
England	<0.001	0.027	0.027	Matlock, groundwater, Derbyshire	0.027
Wales[d]	<0.001			Elan Valley Reservoir, Powys	<0.001[d]
Northern Ireland	<0.001	0.027	0.028	Silent Valley, Co. Down	0.029
Scotland[d]	<0.001			Gullielands Burn, Dumfries and Galloway	<0.001[d]
UK	<0.001	0.027	0.027	Silent Valley, Co. Down	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] *Analysis of naturally occurring radionuclides was not undertaken*

Table 9.12. Analysis of groundwater in Scotland, 2011

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Aberdeenshire	Lumsden	1	<1.0	<0.10	<0.10	<0.10
Angus	Forfar, borehole	1	<1.0	<0.10	<0.10	<0.10
Argyll and Bute	Carradale, borehole	1	<1.0	<0.10	<0.10	<0.10
Argyll and Bute	Carradale, borehole	1	<1.0	<0.10	<0.10	<0.10
Ayrshire	Kilmarnock, borehole	1	<1.0	<0.10	<0.10	<0.10
Fife	Falkland	1	<1.0	<0.10	<0.10	<0.10
Highlands	Tomatin, borehole	1	<1.0	<0.10	<0.10	<0.10
Invernesshire	Tomich, borehole	1	<1.0	<0.10	<0.10	<0.10
Midlothian	Nr Selkirk, shallow borehole	1	<1.0	<0.10	<0.10	<0.10
Orkney	Shapinsay, borehole	1	<1.0	<0.10	<0.10	<0.10

Table 9.13. Concentrations of radionuclides in seawater, 2011

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag
Dounreay (Sandside Bay)	4^{S}	<1.0		<0.10			<0.60	<0.10
Dounreay (Brims Ness)	4^{S}	<1.0		<0.10			<0.52	<0.10
Rosyth	2^{S}	<1.0		<0.10			<0.52	<0.10
Torness	2^{S}	<20		<0.10			<0.52	<0.10
Hartlepool (North Gare)	2	<5.8		<0.24			<2.0	<0.27
Sizewell	2	<4.4		<0.24			<1.9	<0.25
Bradwell	2			<0.23			<1.9	<0.27
Dungeness south	2	<5.0		<0.24			<1.9	<0.27
Winfrith (Lulworth Cove)	1			<0.24			<2.1	<0.23
Alderney	5^{F}	<2.4						
Devonport (Millbrook Lake)	2	<4.1	<7.3	<0.24				
Devonport (Tor Point South)	2	<3.8	<11	<0.24				
Hinkley	2			<0.27	<0.050		<2.2	<0.30
Berkeley and Oldbury	2			<0.33			<2.6	<0.34
Cardiff (Orchard Ledges)[a]	2	<7.3	<12	<0.23				
Holyhead	4^{D}	<1.5						
Wylfa (Cemaes Bay)	2	<3.8		<0.24			<1.9	<0.26
Wylfa (Cemlyn Bay West)	2			<0.25			<1.9	<0.27
Heysham (inlet)	2	110		<0.23			<1.9	<0.25
Seascale (particulate)	2			<0.05	<0.0080		<0.39	<0.06
Seascale (filtrate)	2			<0.24	<0.060	<0.25	<1.8	<0.26
St. Bees	4	15				<0.24		
St. Bees (particulate)	2			<0.05	<0.016		<0.40	<0.07
St. Bees (filtrate)	2	19		<0.24	<0.050	<0.17	<1.8	<0.25
Seafield	4^{S}	<3.2		<0.10			<0.58	<0.10
Southerness[b]	4^{S}	5.9		<0.10			<0.54	<0.10
Auchencairn	4^{S}	3.6		<0.10			<0.58	<0.10
Knock Bay	4^{S}	<1.8		<0.10			<0.62	<0.10
Knock Bay	4^{D}	<2.1						
Hunterston[c]	2^{S}	13		<0.10			<0.66	<0.10
Hunterston (south of pipeline)[d]	2^{S}	2.7		<0.10			<0.52	<0.10
North of Larne	12^{N}					0.0028		
Faslane (Carnban)	2^{S}	1.8		<0.10			<0.40	<0.10

Table 9.13. continued

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}					
		^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	4[S]	<0.10	<0.10	<0.39	<0.11		
Dounreay (Brims Ness)	4[S]	<0.10	<0.10	<0.32	<0.10		
Rosyth	2[S]	<0.10	<0.10	<0.33	<0.10		
Torness	2[S]	<0.10	<0.10	<0.37	<0.10		
Hartlepool (North Gare)	2	<0.23	<0.20	<1.0	<0.30	<4.5	15
Sizewell	2	<0.23	<0.20	<0.98	<0.30	<5.5	19
Bradwell	2	<0.21	<0.21	<0.97	<0.29	<12	14
Dungeness south	2	<0.23	<0.20	<0.98	<0.28	<6.0	16
Winfrith (Lulworth Cove)	1	<0.24	<0.19	<1.1	<0.30	<4.7	10
Alderney	5[F]	*	0.002				
Jersey	1[F]	*	0.003				
Guernsey	4[F]	*	0.002				
Hinkley	2	<0.26	<0.22	<1.0	<0.28	<4.5	8.7
Berkeley and Oldbury	2	<0.31	<0.25	<1.1	<0.32	<2.3	6.5
Cardiff (Orchard Ledges)[a]	2		<0.20				
Holyhead	4[D]	*	0.02				
Wylfa (Cemaes Bay)	2	<0.23	<0.20	<1.0	<0.30	<4.1	10
Wylfa (Cemlyn Bay West)	2	<0.23	<0.20	<1.0	<0.29	<5.0	12
Llandudno	1[D]	*	0.03				
Prestatyn	1[D]	*	0.04				
New Brighton	1[D]	*	0.03				
Ainsdale	1[D]	*	0.04				
Rossall	1[D]	*	0.07				
Heysham (inlet)	2	<0.22	<0.20	<0.95	<0.30	<4.5	14
Half Moon Bay	1[D]	*	0.05				
Silecroft	1[D]	*	0.05				
Seascale (particulate)	2	<0.05	<0.04	<0.15	<0.13	0.35	0.13
Seascale (filtrate)	2	<0.22	<0.21	<0.97	<0.30	<4.5	8.8
St. Bees	4	<0.23	<0.20				
St. Bees (particulate)	2	<0.05	<0.13	<0.17	0.52	<0.25	<0.17
St. Bees (filtrate)	2	<0.23	<0.21	<0.89	<0.30	<3.5	11
Whitehaven	1[D]	*	0.07				
Maryport	1[D]	*	0.06				
Silloth	1[D]	*	0.06				
Seafield	4[S]	<0.10	<0.11	<0.35	<0.11		
Southerness[b]	4[S]	<0.10	<0.13	<0.36	0.0021		
Auchencairn	4[S]	<0.10	<0.10	<0.35	<0.12		
Ross Bay	1[D]	*	0.04				
Isle of Whithorn	1[D]	*	0.03				
Drummore	1[D]	*	0.03				
Knock Bay	4[S]	<0.10	<0.10	<0.43	<0.12		
Knock Bay	4[D]	*	0.02				
Hunterston[c]	2[S]	<0.10	<0.10	<0.43	<0.11		
Hunterston (south of pipeline)[d]	2[S]	<0.10	<0.10	<0.38	<0.10		
North of Larne	12[N]	*	0.01				
Faslane (Carnban)	2[S]	<0.10	<0.10	<0.27	<0.10		

* *Not detected by the method used*

[a] *The concentrations of ^{3}H as tritiated water and ^{125}I were <4.3 Bq l^{-1} and <0.47 Bq l^{-1} respectively*

[b] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00027 and 0.0015 Bq l^{-1} respectively*

[c] *The concentration of ^{35}S was <0.58 Bq l^{-1}*

[d] *The concentration of ^{35}S was <0.50 Bq l^{-1}*

[D] *Measurements labelled "D" are made by Cefas on behalf of Defra*

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

[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*

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(Includes references from Appendix 1: CD supplement)

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APPENDIX 1. Sampling, measurement, presentation and assessment methods and data

This Appendix contains information on the methods of sampling, measurement, presentation and assessment used in the Radioactivity in Food and the Environment report. It is provided in a separate file to the main report at http://www.cefas.defra.gov.uk/publications-and-data/scientific-series/radioactivity-in-food-and-the-environment-(rife).aspx

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2011

PLEASE NOTE CHANGE OF UNITS TO BECQUERELS

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Sellafield Ltd)				
Other authorised outlets	Alpha	BAT	1.91E+05	NA
	Beta	BAT	2.47E+05	NA
Incinerator	Alpha	2.00E+08	Nil	Nil
	Beta	2.50E+08	Nil	Nil
Capenhurst				
(Urenco UK)	Uranium	1.50E+07	3.36E+05	2.2
	Other alpha	4.80E+06	Nil	Nil
	Technetium-99	2.00E+08	Nil	Nil
	Others	4.50E+09	Nil	Nil
Sellafield[c]	Alpha	8.80E+08	8.97E+07	10
	Beta	4.20E+10	1.28E+09	3.0
	Tritium	1.10E+15	9.79E+13	8.9
	Carbon-14	3.30E+12	3.96E+11	12
	Krypton-85	4.40E+17	6.43E+16	15
	Strontium-90	7.10E+08	3.31E+07	4.6
	Ruthenium-106	2.80E+10	7.17E+08	2.6
	Antimony-125[1]	3.00E+10	5.73E+09	19
	Iodine-129	7.00E+10	1.22E+10	17
	Iodine-131	5.50E+10	4.47E+08	<1
	Caesium-137	5.80E+09	9.34E+07	1.6
	Plutonium alpha	1.90E+08	1.58E+07	8.3
	Plutonium-241	3.00E+09	1.36E+08	4.5
	Americium-241 and curium-242	1.20E+08	1.63E+07	14
Springfields	Krypton-85[2]	4.00E+11	3.99E+10	10
	Uranium[d]	5.30E+09	3.30E+08	6.2
Springfields	Tritium	1.00E+08	2.09E+06	2.1
(National Nuclear Laboratory)[e]	Carbon-14	1.00E+07	7.93E+04	<1
	Other alpha radionuclides	1.00E+06	Nil	Nil
	Other beta radionuclides	1.00E+07	4.46E+02	<1
Research establishments				
Dounreay[f]				
(Fuel Cycle Area)	Alpha[g,h]	9.80E+08	1.33E+07	1.4
	Beta[h,i,j]	4.50E+10	1.07E+08	<1
	Tritium	2.00E+12	1.35E+11	6.8
	Krypton-85[k]	3.00E+15	Nil	Nil
	Strontium-90	4.20E+09	1.55E+07	<1
	Ruthenium-106	3.90E+09	3.03E+06	<1
	Iodine-129	1.10E+09	5.41E+07	4.9
	Iodine-131	1.50E+08	8.42E+06	5.6
	Caesium-134	8.40E+08	3.91E+05	<1
	Caesium-137	7.00E+09	5.14E+05	<1
	Cerium-144	7.00E+09	2.54E+06	<1
	Plutonium-241	3.30E+09	7.45E+05	<1
	Curium-242	2.70E+08	4.30E+03	<1
	Curium-244[l]	5.40E+07	8.18E+02	<1
Dounreay[f]				
(Fast Reactor)	Alpha[h,m]	1.00E+07	9.35E+03	<1
	Beta[h,i,j]	1.50E+09	3.46E+04	<1
	Tritium	4.50E+12	2.15E+09	<1
	Krypton-85[k]	4.00E+08	2.14E+06	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq	% of annual limit[b]
Dounreay[f]				
(Prototype Fast Reactor)	Alpha[h,m]	6.00E+06	3.09E+04	<1
	Beta[h,i,j]	5.10E+07	2.58E+05	<1
	Tritium	1.05E+13	4.62E+10	<1
	Krypton-85[k]	4.00E+12	Nil	Nil
Dounreay[s]				
(PFR minor sources)	Alpha[h,m]	6.00E+04	4.57E+02	<1
	Beta[h,i,j]	5.00E+05	1.85E+03	<1
	Tritium	2.00E+11	8.99E+09	4.5
Dounreay[s]				
(East minor sources)	Alpha[h,m]	1.37E+07	7.45E+04	<1
	Beta[h,i,j]	3.71E+08	4.15E+05	<1
	Krypton-85[k]	1.00E+12	Nil	Nil
Dounreay[s]				
(West minor sources)	Alpha[h,m]	3.00E+05	2.46E+03	<1
	Beta[i,j]	7.50E+07	1.26E+04	<1
	Tritium	1.00E+10	2.49E+08	2.5
Harwell				
Research Sites Restoration Ltd	Alpha	8.00E+05	4.10E+04	5.1
(UKAEA)	Beta	2.00E+07	4.30E+05	2.2
	Tritium	1.50E+13	4.80E+11	3.2
	Krypton-85	2.00E+12	Nil	Nil
	Radon-220	1.00E+14	6.10E+12	6.1
	Radon-222	3.00E+12	2.70E+11	9.0
	Iodines	1.00E+10	Nil	Nil
	Other radionuclides	1.00E+11	Nil	Nil
Harwell				
(GE Healthcare B443.26)	Alpha	1.00E+05	2.49E+03	2.5
	Beta/gamma	3.00E+07	1.12E+04	<1
	Radon-222	1.00E+12	Nil	Nil
	Tritium	2.00E+12	Nil	Nil
	Krypton-85	6.00E+10	Nil	Nil
Winfrith				
Inutec	Alpha	1.00E+05	3.40E+03	3.4
	Tritium	1.95E+13	1.44E+12	7.4
	Carbon-14	3.00E+10	6.89E+06	<1
	Other	1.00E+05	1.30E+04	13
Winfrith				
Research Sites Restoration Ltd	Alpha	2.00E+06	2.02E+03	<1
	Tritium	5.00E+13	1.53E+10	<1
	Carbon-14	6.00E+09	1.19E+08	2.0
	Other	5.00E+06	3.29E+04	<1
Minor sites				
Imperial College Reactor Centre				
Ascot	Tritium	3.00E+08	1.07E+07	3.6
	Argon-41	1.70E+12	2.91E+10	1.7

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq	% of annual limit[b]
Nuclear power stations				
Berkeley[n]	Beta	2.00E+07	1.48E+05	<1
	Tritium	2.00E+10	9.07E+09	45
	Carbon-14	5.00E+09	4.72E+08	9.4
Bradwell	Beta	6.00E+08	4.71E+05	<1
	Tritium	1.50E+12	1.42E+10	<1
	Carbon-14	6.00E+11	3.84E+08	<1
Chapelcross	Tritium	5.00E+15	4.56E+13	<1
	Sulphur-35	5.00E+10	Nil	Nil
	Argon-41	4.50E+15	Nil	Nil
Dungeness A Station[3]	Beta[h]	5.50E+08	6.24E+06	1.1
	Tritium	2.60E+12	1.67E+10	<1
	Carbon-14	5.00E+12	2.82E+08	<1
Dungeness B Station	Tritium	1.20E+13	6.04E+11	5.0
	Carbon-14	3.70E+12	5.08E+11	14
	Sulphur-35	3.00E+11	1.46E+10	4.9
	Argon-41	7.50E+13	4.56E+12	6.1
	Cobalt-60[h]	1.00E+08	4.57E+06	4.6
	Iodine-131	1.50E+09	3.36E+07	2.2
Hartlepool	Tritium	1.00E+13	9.86E+11	9.9
	Carbon-14	4.50E+12	2.21E+12	49
	Sulphur-35	2.30E+11	1.91E+10	8.3
	Argon-41	1.50E+14	1.11E+13	7.4
	Cobalt-60[h]	1.00E+08	1.59E+07	16
	Iodine-131	1.50E+09	1.81E+08	12
Heysham Station 1	Tritium	1.00E+13	1.05E+12	11
	Carbon-14	4.50E+12	1.56E+12	35
	Sulphur-35	2.00E+11	3.14E+10	16
	Argon-41	1.50E+14	9.83E+12	6.6
	Cobalt-60[h]	1.00E+08	6.01E+06	6.0
	Iodine-131	1.50E+09	8.04E+07	5.4
Heysham Station 2	Tritium	1.00E+13	1.10E+12	11
	Carbon-14	3.70E+12	1.67E+12	45
	Sulphur-35	2.30E+11	1.10E+10	4.8
	Argon-41	7.50E+13	1.17E+13	16
	Cobalt-60[h]	1.00E+08	1.10E+07	11
	Iodine-131	1.50E+09	1.02E+08	6.8
Hinkley Point A Station[4]	Beta	5.00E+07	2.00E+05	<1
	Tritium	7.50E+11	4.40E+10	5.9
	Carbon-14	5.00E+10	6.70E+08	1.3
Hinkley Point B Station	Tritium	1.20E+13	1.17E+12	9.7
	Carbon-14	3.70E+12	1.17E+12	32
	Sulphur-35	3.50E+11	9.40E+10	27
	Argon-41	1.00E+14	1.06E+13	11
	Cobalt-60[h]	1.00E+08	7.73E+06	7.7
	Iodine-131	1.50E+09	7.07E+06	<1
Hunterston A Station	Beta[h]	6.00E+07	4.80E+05	<1
	Tritium	2.00E+10	9.50E+08	4.8
	Carbon-14	2.00E+09	8.00E+07	4.0

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq	% of annual limit[b]
Hunterston[f]				
B Station	Particulate beta	5.00E+08	1.06E+08	21
	Tritium	1.50E+13	3.25E+12	22
	Carbon-14	4.50E+12	1.30E+12	29
	Sulphur-35	5.00E+11	1.45E+11	29
	Argon-41	1.50E+14	1.11E+13	7.4
	Iodine-131	2.00E+09	3.75E+06	<1
Oldbury	Beta	1.00E+08	4.60E+07	46
	Tritium	9.00E+12	2.29E+12	26
	Carbon-14	4.00E+12	1.32E+12	33
	Sulphur-35	4.50E+11	8.09E+10	18
	Argon-41	5.00E+14	2.14E+13	4.3
Sizewell				
A Station[5]	Beta	8.50E+08	7.00E+05	<1
	Tritium	3.50E+12	7.93E+10	2.3
	Carbon-14	1.00E+11	4.20E+09	4.2
Sizewell				
B Station	Noble gases	3.00E+13	2.70E+12	9.0
	Particulate Beta	1.00E+08	6.00E+06	6.0
	Tritium	3.00E+12	7.16E+11	24
	Carbon-14	5.00E+11	3.02E+11	60
	Iodine-131	5.00E+08	2.60E+07	5.2
Torness	Particulate beta	4.00E+08	2.89E+06	<1
	Tritium	1.10E+13	2.69E+12	24
	Carbon-14	4.50E+12	9.93E+11	22
	Sulphur-35	3.00E+11	1.65E+10	5.5
	Argon-41	7.50E+13	5.05E+12	6.7
	Iodine-131	2.00E+09	3.29E+06	<1
Trawsfynydd	Beta	5.00E+07	1.47E+06	2.9
	Tritium	7.50E+11	3.28E+11	44
	Carbon-14	1.00E+10	1.82E+09	18
Wylfa	Beta	7.00E+08	2.92E+07	4.2
	Tritium	1.80E+13	3.04E+12	17
	Carbon-14	2.30E+12	1.26E+12	55
	Sulphur-35	4.50E+11	1.61E+11	24
	Argon-41	1.00E+14	1.81E+13	18
Defence establishments				
Aldermaston[o]	Alpha	1.65E+05	3.59E+04	22
	Particulate Beta	6.00E+05	1.82E+04	3.0
	Tritium	3.90E+13	7.00E+11	1.8
	Carbon-14	6.00E+06	Nil	Nil
	Argon-41	1.00E+09	Nil	Nil
	Krypton-85	7.50E+10	1.03E+10	14
	Volatile beta	4.40E+06	8.30E+05	19
Barrow[p]	Tritium	3.20E+06	Nil	Nil
	Argon-41	4.80E+10	Nil	Nil
Burghfield[d,o]	Tritium	1.00E+10	7.65E+03	<1
	Alpha	5.00E+03	1.05E+03	21
Coulport	Tritium	5.00E+10	6.05E+09	12
Derby[q,r]	Uranium	4.00E+06	4.94E+05	12
	Alpha[h]	2.40E+04	4.31E+01	<1
	Beta[h]	1.80E+06	4.46E+04	2.5
Devonport[s]	Beta/gamma[h]	3.00E+05	1.91E+04	6.4
	Tritium	4.00E+09	5.20E+08	13
	Carbon-14	4.30E+10	9.10E+08	2.1
	Argon-41	1.50E+10	6.73E+06	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq	% of annual limit[b]
Dounreay	Beta[h]	5.10E+06	1.20E+06	24
(Vulcan)	Noble gases	5.00E+09	1.90E+08	3.8
Rosyth[t]	Beta (particulate)	1.00E+05	Nil	Nil
	Tritium	2.00E+08	Nil	Nil
	Carbon-14	5.00E+08	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	2.25E+06	2.97E+05	13
	Radionuclides T1/2<2hr	7.50E+11	4.05E+10	5.4
	Tritium	2.00E+12	1.08E+06	<1
	Sulphur-35	3.50E+10	Nil	Nil
	Iodine-125	2.00E+10	7.55E+08	3.8
	Radon-222	1.00E+13	5.37E+12	54
	Other noble gases	5.00E+13	Nil	Nil
	Other including selenium-75 and iodine-131	1.60E+10	1.04E+08	<1
Cardiff (GE Healthcare)	Soluble tritium	1.56E+14	1.88E+12	1.2
	Insoluble tritium	6.00E+14	1.06E+12	<1
	Carbon-14	2.38E+12	3.67E+11	15
	Phosphorus-32/33	5.00E+06	Nil	Nil
	Iodine-125	1.80E+08	Nil	Nil
	Other radionuclides	1.00E+09	Nil	Nil
Industrial and landfill sites				
LLWR near Drigg	Alpha	BAT	1.83E+07	NA
	Beta	BAT	3.98E+07	NA
Lillyhall (Studsvik)				
	Alpha (particulate)	5.00E+05	Nil	Nil
	Beta (particulate)	5.00E+05	2.72E+02	<1

* *As reported to SEPA and the Environment Agency*

a *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*

b *Data quoted to 2 significant figures except where values are <1%*

c *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*

d *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location*

e *Formerly Nexia Solutions*

f *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection*

g *Excluding curium-242 and 244*

h *Particulate activity*

i *Excluding tritium*

j *Excluding krypton-85*

k *Krypton-85 discharges are calculated monthly*

l *Data excludes any curium-243 present*

m *Excluding radon and daughter products*

n *Combined data for Berkeley Power Station and Berkeley Centre*

o *Discharges were made by AWE plc*

p *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*

q *Discharges were made by Rolls Royce Marine Power Operations Ltd*

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

s *Discharges were made by Devonport Royal Dockyard Ltd*

t *Discharges were made by Rosyth Royal Dockyard Ltd*

1 *Discharge permit revised with effect from 1 April 2008, with a further variation with effect from 1 April 2010 (limit revised to 3.00E10 Bq), to reflect the trend of increasing discharges in 2009*

2 *Springfields Fuels Limited were granted a temporary variation to their permit, allowing them to discharge gaseous material, including Krypton-85 to the atmosphere*

3 *Discharge permit revised with effect from 1 September 2011, ^{35}S and ^{41}Ar are no longer within the permit*

4 *Discharge permit revised with effect from 11 January 2010*

5 *Discharge permit revised with effect from 22 March 2010*

NA Not applicable under permit

BAT Best available technology

Table A2.2. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2011

PLEASE NOTE CHANGE OF UNITS TO BECQUERELS

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq[b]	% of annual limit[c]
Nuclear fuel production and reprocessing				
Capenhurst				
(Rivacre Brook)	Uranium	7.50E+08	5.10E+06	<1
	Uranium daughters	1.36E+09	6.40E+06	<1
	Non-uranic alpha	2.20E+08	1.56E+07	7.1
	Technetium-99	1.00E+09	5.20E+06	<1
Sellafield[d] (sea pipelines)	Alpha	1.00E+12	1.17E+11	12
	Beta	2.20E+14	1.52E+13	6.9
	Tritium	2.00E+16	2.07E+15	10
	Carbon-14	2.10E+13	6.39E+12	30
	Cobalt-60	3.60E+12	6.46E+10	1.8
	Strontium-90	4.80E+13	1.93E+12	4.0
	Zirconium-95 + Niobium-95	3.80E+12	1.87E+11	4.9
	Technetium-99	1.00E+13	1.59E+12	16
	Ruthenium-106	6.30E+13	2.04E+12	3.2
	Iodine-129	2.00E+12	4.00E+11	20
	Caesium-134	1.60E+12	9.45E+10	5.9
	Caesium-137	3.40E+13	5.86E+12	17
	Cerium-144	4.00E+12	4.71E+11	12
	Neptunium-237	1.00E+12	4.31E+10	4.3
	Plutonium alpha	7.00E+11	1.06E+11	15
	Plutonium-241	2.50E+13	2.41E+12	9.6
	Americium-241	3.00E+11	3.18E+10	11
	Curium-243+244	6.90E+10	3.93E+09	5.7
	Uranium[e] (measured in kg)	2.00E+03	2.74E+02	14
Sellafield (factory sewer)	Alpha	3.00E+08	8.22E+07	27
	Beta	6.10E+09	1.40E+09	23
	Tritium	6.80E+10	1.28E+10	19
Springfields	Alpha	1.00E+11	2.20E+10	22
	Beta	2.00E+13	4.99E+12	25
	Technetium-99	6.00E+11	9.52E+10	16
	Thorium-230	2.00E+10	1.60E+09	8.0
	Thorium-232	1.50E+10	1.60E+08	1.1
	Neptunium-237	4.00E+10	5.80E+08	1.5
	Other transuranic radionuclides	2.00E+10	1.53E+09	7.7
	Uranium	4.00E+10	1.65E+10	41
Research establishments				
Dounreay	Alpha[f]	2.00E+10	Nil	Nil
PFR liquid metal disposal plant	Beta[g]	1.10E+11	Nil	Nil
	Tritium	1.40E+12	Nil	Nil
	Sodium-22	1.80E+12	Nil	Nil
	Caesium-137	6.60E+10	Nil	Nil
	Alpha[f]	9.00E+10	2.13E+08	<1
Other facilities	Beta[g]	6.20E+11	5.05E+08	<1
	Tritium	5.50E+12	7.68E+10	1.4
	Strontium-90	7.70E+11	3.20E+10	4.2
	Caesium-137	1.00E+12	5.24E+09	<1
Harwell (River Thames)[1]				
	Alpha	1.00E+07	9.21E+05	9.2
	Beta	6.00E+08	5.27E+07	8.8
	Tritium	1.00E+11	6.94E+08	<1
	Cobalt-60	5.00E+06	5.02E+05	10
	Caesium-137	2.00E+08	9.45E+06	4.7
Harwell (Lydebank Brook)[1]	Alpha	3.00E+07	4.38E+06	15
	Beta	3.00E+08	1.87E+07	6.2
	Tritium	2.00E+10	2.02E+09	10

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq[b]	% of annual limit[c]
Winfrith (inner pipeline)[s]	Alpha	2.00E+10	9.56E+07	<1
	Tritium	2.20E+14	5.59E+12	2.5
	Caesium-137	2.00E+12	2.50E+09	<1
	Other radionuclides	1.00E+12	1.24E+10	1.2
Winfrith (outer pipeline)	Alpha	2.00E+09	3.62E+06	<1
	Tritium	1.50E+11	8.57E+08	<1
	Other radionuclides	1.00E+09	1.51E+07	1.5
Winfrith (River Frome)	Tritium	7.50E+11	Nil	Nil
Minor sites				
Imperial College Reactor Centre	Tritium	4.00E+07	Nil	Nil
Ascot	Other radioactivity	1.00E+06	Nil	Nil
Nuclear power stations				
Berkeley	Tritium	1.00E+12	3.84E+09	<1
	Caesium-137	2.00E+11	9.73E+07	<1
	Other radionuclides	2.00E+11	2.14E+08	<1
Bradwell	Tritium	7.00E+12	7.60E+09	<1
	Caesium-137	7.00E+11	3.40E+09	<1
	Other radionuclides	7.00E+11	4.30E+09	<1
Chapelcross	Alpha	1.00E+11	4.09E+07	<1
	Beta[h]	2.50E+13	2.77E+10	<1
	Tritium	5.50E+12	8.66E+09	<1
Dungeness A Station	Tritium	8.00E+12	8.40E+10	1.1
	Caesium-137	1.10E+12	8.29E+09	<1
	Other radionuclides	8.00E+11	6.13E+09	<1
Dungeness B Station	Tritium	6.50E+14	1.40E+13	2.2
	Sulphur-35	2.00E+12	5.54E+10	2.8
	Cobalt-60	1.00E+10	5.63E+08	5.6
	Caesium-137	1.00E+11	6.76E+08	<1
	Other radionuclides	8.00E+10	1.21E+09	1.5
Hartlepool	Tritium	6.50E+14	3.37E+14	52
	Sulphur-35	3.00E+12	9.75E+11	33
	Cobalt-60	1.00E+10	2.83E+08	2.8
	Caesium-137	1.00E+11	4.56E+09	4.6
	Other radionuclides	8.00E+10	7.93E+09	9.9
Heysham Station 1	Tritium	6.50E+14	4.18E+14	64
	Sulphur-35	2.00E+12	5.07E+11	25
	Cobalt-60	1.00E+10	2.28E+08	2.3
	Caesium-137	1.00E+11	1.44E+09	1.4
	Other radionuclides	8.00E+10	4.79E+09	6.0
Heysham Station 2	Tritium	6.50E+14	3.13E+14	48
	Sulphur-35	2.00E+12	3.19E+10	1.6
	Cobalt-60	1.00E+10	6.55E+07	<1
	Caesium-137	1.00E+11	9.52E+08	<1
	Other radionuclides	8.00E+10	1.05E+10	13
Hinkley Point A Station[2]	Tritium	1.00E+12	2.79E+10	2.8
	Caesium-137	1.00E+12	2.40E+10	2.4
	Other radionuclides	7.00E+11	1.00E+11	14

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq[b]	% of annual limit[c]
Hinkley Point B Station	Tritium	6.50E+14	1.35E+14	21
	Sulphur-35	2.00E+12	2.48E+11	12
	Cobalt-60	1.00E+10	1.51E+08	1.5
	Caesium-137	1.00E+11	1.86E+09	1.9
	Other radionuclides	8.00E+10	3.57E+09	4.5
Hunterston A Station	Alpha	4.00E+10	1.73E+08	<1
	Beta	6.00E+11	9.31E+09	1.6
	Tritium	7.00E+11	3.48E+08	<1
	Plutonium-241	1.00E+12	1.68E+08	<1
Hunterston B Station	Alpha	1.00E+09	3.18E+07	3.2
	All other non-alpha	1.50E+11	1.19E+10	8.0
	Tritium	7.00E+14	1.86E+14	27
	Sulphur-35	6.00E+12	1.07E+12	18
	Cobalt-60	1.00E+10	4.00E+08	4.0
Oldbury	Tritium	1.00E+12	2.34E+11	23
	Caesium-137	7.00E+11	1.96E+11	28
	Other radionuclides	7.00E+11	9.78E+10	14
Sizewell A Station[3]	Tritium	5.00E+12	5.63E+10	1.1
	Caesium-137	1.00E+12	1.92E+11	19
	Other radionuclides	7.00E+11	8.06E+10	12
Sizewell B Station	Tritium	8.00E+13	4.29E+13	54
	Caesium-137	2.00E+10	7.80E+09	39
	Other radionuclides	1.30E+11	1.60E+10	12
Torness	Alpha	5.00E+08	5.36E+06	1.1
	All other non-alpha	1.50E+11	3.66E+09	2.4
	Tritium	7.00E+14	3.45E+14	49
	Sulphur-35	3.00E+12	2.00E+10	<1
	Cobalt-60	1.00E+10	1.63E+08	1.6
Trawsfynydd	Tritium	5.00E+11	1.37E+09	<1
	Strontium-90	5.00E+10	Nil	Nil
	Caesium-137	3.00E+10	3.90E+08	1.3
	Other radionuclides[i]	1.70E+11	8.20E+08	<1
Wylfa	Tritium	1.50E+13	6.90E+12	46
	Other radionuclides	1.10E+11	6.23E+09	5.7
Defence establishments				
Aldermaston (Silchester)	Alpha	1.00E+07	3.70E+06	37
	Other beta emitting radionuclides	2.00E+07	4.82E+06	24
	Tritium	2.50E+10	1.40E+08	<1
Aldermaston (to Stream)[j]	Tritium	Nil	5.37E+08	NA
Barrow[k,4]	Tritium	1.20E+10	1.30E+06	<1
	Carbon-14	2.70E+07	2.11E+04	<1
	Other gamma emitting radionuclides	3.50E+06	Nil	Nil
Derby[l]	Alpha[m]	2.00E+09	7.02E+07	3.5
	Alpha[n]	3.00E+05	8.00E+03	2.7
	Beta[n]	3.00E+08	3.23E+05	<1
Devonport[o] (sewer)	Tritium	2.00E+09	7.08E+07	3.5
	Cobalt-60	3.50E+08	5.07E+06	1.4
	Other radionuclides	6.50E+08	1.45E+08	22

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2011	
			Bq[b]	% of annual limit[c]
Devonport[o] (estuary)	Tritium	7.00E+11	6.76E+10	9.7
	Carbon-14	1.70E+09	3.05E+08	18
	Cobalt-60	8.00E+08	1.16E+08	15
	Other radionuclides	3.00E+08	3.79E+07	13
Faslane	Alpha	2.00E+08	6.00E+04	<1
	Beta[p,q]	5.00E+08	2.14E+06	<1
	Tritium	1.00E+12	6.18E+10	6.2
	Cobalt-60	5.00E+08	2.90E+05	<1
Rosyth[r]	Tritium	3.00E+09	2.33E+08	7.8
	Cobalt-60	3.00E+08	3.72E+06	1.2
	Other radionuclides	3.00E+08	3.22E+06	1.1
Radiochemical production				
Amersham (GE Healthcare)[p]	Alpha	3.00E+08	7.01E+06	2.3
	Tritium	1.41E+11	2.70E+06	<1
	Iodine-125	4.00E+09	4.03E+06	<1
	Caesium-137	5.00E+09	2.84E+06	<1
	Other radionuclides	6.50E+10	3.14E+08	<1
Cardiff (GE Healthcare)	Tritium	1.30E+14	1.65E+11	<1
	Carbon-14	9.10E+11	1.53E+09	<1
	Phosphorus-32/33	8.50E+07	Nil	Nil
	Iodine-125	3.00E+08	Nil	Nil
	Others	1.20E+08	Nil	Nil
Industrial and landfill sites				
LLWR near Drigg	Alpha	BAT	5.10E+07	NA
	Beta	BAT	3.10E+10	NA
	Tritium	BAT	6.15E+10	NA
Lillyhall (Studsvik)				
	Alpha	5.00E+05	Nil	Nil
	Beta	5.00E+05	Nil	Nil

[a] *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*
[b] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 2 decimal places*
[c] *Data quoted to 2 significant figures except when values are less than 1%*
[d] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[e] *The limit and discharge data are expressed in kg*
[f] *All alpha emitting radionuclides taken together*
[g] *All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together*
[h] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[i] *Including strontium*
[j] *The discharge permit has been replaced by a quarterly notification level of 30 Bq l^{-1}*
[k] *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*
[l] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[m] *Discharge limit is for Nuclear Fuel Production Plant*
[n] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Excluding cobalt-60*
[q] *Excluding tritium*
[r] *Discharges were made by Rosyth Royal Dockyard Ltd*
[s] *Discharges reported include those from INUTEC*
[1] *Discharge permit revised with effect from 07 November 2011*
[2] *Discharge permit revised with effect from 11 January 2010*
[3] *Discharge permit revised with effect from 22 March 2010*
[4] *BAE were granted a minor variation to their discharge permit, effective 26 July 2011, for the sampling and analysis of carbon-14, with an annual discharge limit of 2.70 E+07 Bq, to the sewer*

NA Not applicable under permit
BAT Best available technology

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2011

PLEASE NOTE CHANGE OF UNITS TO BECQUERELS

Establishment	Radioactivity	Disposal Limit Bq	Disposals during 2011	
			Bq	% of limit[a]
LLWR[b,1]	Tritium	1.00E+13	Nil	Nil
	Carbon-14	5.00E+10	Nil	Nil
	Cobalt-60	2.00E+12	Nil	Nil
	Iodine-129	5.00E+10	Nil	Nil
	Radium-226 plus			
	thorium-232	3.00E+10	Nil	Nil
	Uranium	3.00E+11	Nil	Nil
	Other alpha[c]	3.00E+11	Nil	Nil
	Others[c,d]	1.50E+13	Nil	Nil
Dounreay[e]	Alpha		Nil	NA
	Beta/gamma		Nil	NA

[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] *With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232*
[d] *Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table*
[e] *The current permit includes limits on concentrations of activity. At no time did the concentrations exceed the limits*
[1] *Discharge permit revised with effect 1 January 2011*
NA Not applicable

Table A2.4. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2011

Site	Month	Summary of occurrence	Consequences and action taken
Devonport (HM Naval Base)	June	Clean water from an accidentally activated tap caused an effluent tank and its secondary containment to overflow into a drain due to instrumentation failure. The drain also receives radioactive effluent and discharges were within limits.	The principal cause of the event was shortcomings in arrangements for equipment maintenance. The equivalent of a Warning Letter was issued. Formal enforcement powers do not apply to crown premises occupied by MoD.
Devonport (Royal Dockyard Limited)	June	Effluent tanks were accidentally overfilled with clean water and this led to an unpermitted discharge of radioactivity. This was well within limits and overall discharges to the environment were unaffected.	The principal cause of the event was inappropriate response to plant indicators and alarms by operators. A Caution was issued to DRDL, and formal commitment to certain environmental improvements was requested.
GE Healthcare Grove Centre, Amersham	June/July	Unexpected elevated discharges of radon-222 from building containing a redundant radium facility. However, these discharges remained with site permitted limits.	Site has conducted detailed investigations into the source/cause of the elevated discharges. This work is continuing to help inform short term and longer term BAT assessments, the latter of which will support the planned decommissioning of the radium facility which is programmed to occur within the next three years.
GE Healthcare Maynard Centre, Cardiff	February	In October 2010 two consignments of solid waste to Inutec at Winfrith were made with incorrect inventory information.	No environmental impact. The Environment Agency and the site conducted investigations and a number of actions were identified and progressed to help prevent future errors. Warning Letter issued in February 2011.
Oldbury	February	Around 300 litres of oil lightly contaminated with radioacvtivity leaked from a sealed oil cooler and was subsequently discharged to the River Severn.	The discharge was made to the River Severn where it would have been diluted and dispersed quickly and therefore it had a negligible environmental impact. The Environment Agency and the site conducted investigations and a number of actions were identified and progressed to help prevent future releases. Warning Letter issued in April 2011.
Sellafield	February	A leak of radioactive liquid occurred from a permitted ventilation discharge system within the Redundant Plutonium Purification Plant.	There was no off-site environmental or public human health impact as a result of the incident. This was a localised contamination event, contained within the facility. Following investigation a number of recommendations have been implemented to prevent a reoccurrence of the event. Warning Letter issued in August 2011.
Sellafield	July	A number of hazardous waste drums being consigned for disposal off site were found to contain low levels of radioactive contamination. The drums did not leave the site and were recovered back to the consignor.	There was no off-site environmental or public human health impact as a result of the incident. Following investigation a number of recommendations have been implemented to prevent a reoccurrence of the event. Our enforcement response is currently under review.

APPENDIX 3. Abbreviations and glossary

AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques or Best Available Technology
BNFL	British Nuclear Fuels plc
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
BSS	Basic Safety Standards
CCFE	Culham Centre for Fusion Energy
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
COBR	Cabinet Office Briefing Room
CoRWM	Committee on Radioactive Waste Management
DBPAG	Dalgety Bay Particles Advisory Group
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DH	Department of Health
DIO	Defence Infrastructure Organisation
DPAG	Dounreay Particles Advisory Group
DSRL	Dounreay Site Restoration Limited
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
Euratom	European Atomic Energy Community
EC	European Commission
EDF	Electricité de France
ESC	Environmental Safety Case
EPR 10	Environment Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
GAU	Geosciences Advisory Unit
GDA	Generic Design Assessment
GDL	Generalised Derived Limit
GE	General Electric
GOCO	Government Owned Contractor Operator
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency
HSE	Health & Safety Executive
IAEA	International Atomic Energy Agency
ICPMS	Inductively Coupled Plasma Mass Spectrometry
ICRP	International Commission on Radiological Protection
INES	International Nuclear and Radiological Event Scale
IRPA	International Radiation Protection Association
ISO	International Standards Organisation
JET	Joint European Torus
LGC	Laboratory of the Government Chemist
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries & Food
MoD	Ministry of Defence
MRF	Metals Recycling Facility
MRL	Minimum reporting level
MRWS	Managing Radioactive Waste Safely
NaK	Sodium / Potassium
ND	Not detected
NDA	Nuclear Decommissioning Authority
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NMP	Nuclear Management Partners Limited
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NPS	National Policy Statement
NRTE	Naval Reactor Test Establishment
OBT	Organically Bound Tritium
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
OSPAR	Oslo and Paris Convention
PBO	Parent Body Organisation
PRAG (D)	Particles Retrieval Advisory Group (Dounreay)
PWR	Pressurised Water Reactor
RAPs	Reference Animals and Plants
RDPP	Reactor Decommissioning Planning Project
REP	RSR Environmental Principle
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Limited
RRMPOL	Rolls Royce Marine Power Operations Limited
RNAS	Royal Naval Air Station
RSA 93	Radioactive Substances Act 1993
RSR	Radioactive Substances Regulation
RSRL	Research Sites Restoration Limited
RSS	Radioactive Substances Strategy
SAGE	Scientific Advisory Group in Emergencies
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Limited
SIXEP	Site Exchange Effluent Plant
SL	Scientifics Limited
SLC	Site Licence Company

SRP	Society for Radiological Protection
STW	Sewage Treatment Works
SWIMMER	Sustainable Water Integrated Management and Ecosystem Research
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally-Occurring Radioactive Material
TRAMP	Terrestrial Radioactive Monitoring Programme
UKAEA	United Kingdom Atomic Energy Authority
UKNWM	UK Nuclear Waste Management Limited
UOC	Uranium Ore Concentrate
UUK	Urenco UK Limited
AHVLA	Animal Health and Veterinary Laboratories Agency
VLLW	Very Low Level Waste
WELL	Winfrith Environmental Level Laboratory
WFD	Water Framework Directive
WHO	World Health Organisation
WWTW	Waste Water Treatment Works
YP	Ystradyfodwg and Pontypridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J kg^{-1}.
Authorised Premises	This is a premises that has been authorised by the environment agencies to discharge to the environment.
Becquerel	One radioactive transformation per second.
Bioaccumulation	Excretion may occur, however the rate of excretion is less than the rate of intake + accumulation.
Biota	Flora and fauna.
Committed effective dose	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.
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 used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative individual	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
TNORM	Naturally-occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally-occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally-occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue weighting factors	Factor used to weight the equivalent dose in a tissue or organ to takes account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01.
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation.

APPENDIX 4. 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).

Information on recently completed extramural research is presented in Table A4.1. 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 A4.1 also provides information on research that is currently underway. The results of this research will be made available in due course.

Table A4.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Soil and herbage survey	UKRSR01 and SCO00027	E, S	In press
Measurement of radioactivity in canteen meals for Euratom (2005-2013)	R03025	F	Mar-14

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

Environment Agency
Monitoring Assessment and New Reactor Permitting
Nuclear Regulation (North)
Lutra House, Off Seedlee Road, Walton Summit
Bamber Bridge
Preston PR5 8BX

Food Standards Agency
Chemical Safety Division
Aviation House
125 Kingsway
London WC2B 6NH

Northern Ireland Environment Agency
Industrial Pollution and Radiochemical Inspectorate
Klondyke Building
Cromac Avenue
Lower Ormeau Road
Belfast BT7 2JA

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

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