RIFE - 19

Radioactivity in Food and the Environment, 2013

Environment Agency

Food Standards Agency
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Radioactivity in Food and the Environment, 2013

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December 2014

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,
  the Industrial Pollution and Radiochemical Inspectorate of NIEA (IPRI@doeni.gov.uk)

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Preface

This report covers sampling and analysis carried out in 2013 for the UK-wide monitoring programmes of the environment agencies and the Food Standards Agency. The monitoring programmes conducted by these agencies are independent of, and also used as a check on, site operators' programmes.

Continuation of the monitoring programmes conducted by the agencies helps to demonstrate that radioactivity in food is well within safe levels and that exposure to members of the public from authorised discharges and direct radiation around the 39 nuclear sites in the UK has remained within legal limits.

The last significant deposition of radionuclides in the UK occurred following the accident at Chernobyl in 1986. Levels of radioactivity in the UK resulting from the incident have fallen significantly over time. The risks to consumers from radioactivity in food are very low and all restrictions on the movement of animals have been lifted.

The UK Government and the devolved administrations published a joint strategy in July 2014 concerning the management of waste containing Naturally Occurring Radioactive Material (NORM). Such wastes arise when NORM is concentrated through industrial activities such as oil and gas extraction, mining and mineral processing. Another such activity that generates NORM waste is the extraction of unconventional oil and gas, such as shale gas, through the process of hydraulic fracturing (commonly known as 'fracking'). At present there is only limited data available on the generation of NORM waste during fracking within the UK therefore it is not addressed in this document. However, it is anticipated that more data will be generated in future as exploration for unconventional oil and gas develops further and any such data will be included in future editions of the RIFE report.

Significant progress has been made to address the radioactive contamination at Dalgety Bay. Following the publication of the risk assessment together with the appropriate persons report, the Committee on Medical Aspects of Radiation in the Environment (COMARE) recommended that effective remediation of the affected area is undertaken as soon as is possible. The MoD has since published its broad management strategy and timescale which if successful should allow the current public protection measures to be removed. This will be discussed more in future RIFE reports.

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 licensed sites
- Radioactivity concentrations in samples collected around UK nuclear licensed 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 licensed sites

Radiation exposure around UK nuclear licensed sites

In this report we make an assessment of doses to the public near nuclear licensed sites using the results of monitoring of radioactivity in food and the environment, 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 external 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 of radioactivity from man-made processes. Source specific dose assessments are also performed in some cases to provide additional information and 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 combined 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 2013, radiation doses from authorised/permitted releases of radioactivity, to adults and children living around nuclear licensed 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 dose units).

For 2013, the site where the public received the highest dose was Amersham with a dose of 0.22 mSv. The dose received near Amersham was dominated by direct radiation from sources on the site. In comparison, the highest doses in 2012 were at Amersham and Sellafield. The decrease in the ranking of the Sellafield site was established following a detailed assessment of exposure pathways in 2013 including observations of reduced concentrations of radionuclides in food and the environment.

The next highest doses were at Barrow (0.076 mSv), Capenhurst (0.080 mSv), Sellafield (0.076 mSv) and Springfields (0.060 mSv). The dose at Capenhurst was mostly due to direct radiation from the site. The doses at Barrow, Sellafield and Springfields were all due to historic discharges of liquid waste from the Sellafield site.

In 2013, the person most exposed to Sellafield discharges was living on a houseboat near to Barrow. The dominant pathway of exposure was external radiation from radioactivity in marine sediments. In 2012, the person most exposed due to Sellafield discharges was a consumer of seafood collected near to Sellafield and received a dose of 0.30 mSv. This estimate includes a contribution from the past discharges from the former phosphate processing plant at Whitehaven and the Low-Level Waste Repository (LLWR) near Drigg. The equivalent local seafood consumer in 2013 received a dose of 0.061 mSv. This large drop in dose was due to (i) reductions in concentrations of polonium-210 from Whitehaven discharges in fish and crustaceans, and (ii) a smaller range of seafood species consumed by individuals at high rates. With these changes, the largest contribution to dose to seafood consumers at Sellafield is now from Sellafield discharges.

As a result of decreasing discharges of technetium-99 from Sellafield, doses from this radionuclide have been falling for several years. In 2013, technetium-99 contributed less than 0.001 mSv (less than 1 per cent) to the 0.061 mSv dose to the representative person (seafood consumer). The effects of iodine-129 discharges have also been determined and this radionuclide was estimated to have contributed 0.013 mSv in 2013, or about 20% of the dose due to Sellafield discharges. However, this estimate was based on results at the limit of detection of iodine-129 and is therefore a cautious overestimate of the dose actually received.

* *In this report doses to individuals are determined for those people most exposed to radiation. These results are for comparison with legal limits. The method of calculation involves an assessment for the 'representative person'. This term has the same meaning as 'average member of the critical group' which was used in earlier reports. In this report the term 'representative person' is sometimes shortened to 'person'. Such a person is a hypothetical construct for dose assessment purposes. Reports prior to the one for 2013 referred to an average dose to individuals in a group of people rather than to a single person. The doses are equivalent and comparable'*

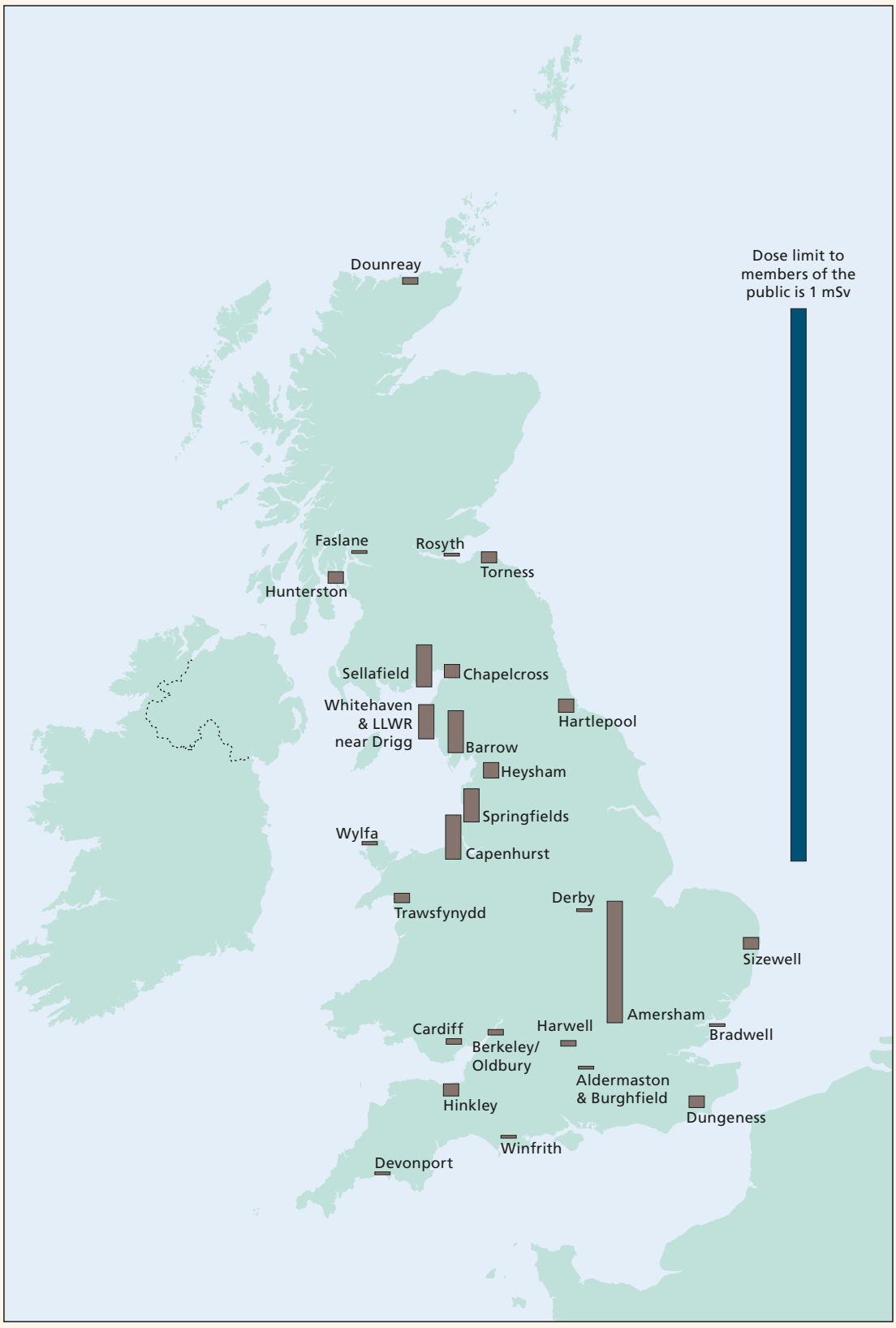


Figure S. *Total doses* in the UK due to radioactive waste discharges and direct radiation, 2013
(Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S. *Total doses* due to all sources at major UK sites, 2013[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.080	Direct radiation
Springfields	0.060	Gamma dose rate over sediment
Sellafield[e]	0.076	Gamma dose rate over sediment
Research establishments		
Dounreay	0.012	Domestic fruit, potatoes, root vegetables, $^{129}I^{d}$, $^{238}Pu^{d}$, $^{239/240}Pu^{d}$, $^{241}Am^{d}$
Harwell	0.010	Direct radiation
Winfrith	<0.005	Milk, ^{14}C
Nuclear power stations		
Berkeley and Oldbury	0.010	Gamma dose rate over sediment
Bradwell	<0.005	Green vegetables, potatoes, root vegetables, ^{14}C
Chapelcross	0.024	Milk, ^{90}Sr, $^{241}Am^{d}$
Dungeness	0.021	Direct radiation
Hartlepool	0.024	Direct radiation, gamma dose rate over sediment
Heysham	0.028	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	0.022	Gamma dose rate over sediment
Hunterston	0.021	Direct radiation
Sizewell	0.021	Direct radiation
Torness	0.020	Direct radiation
Trawsfynydd	0.017	Milk, ^{14}C, $^{241}Am^{d}$
Wylfa	<0.005	Gamma dose rate over sediment
Defence establishment		
Aldermaston and Burghfield	<0.005	Milk, $^{3}H^{d}$, $^{137}Cs^{d}$, ^{238}U
Barrow	0.076	Gamma dose rate over sediment
Derby	<0.005	Water from extraction point, $^{60}Co^{d}$
Devonport	<0.005	Fish, ^{14}C, $^{241}Am^{d}$
Faslane	<0.005	Gamma dose rate over sediment
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.010	Milk, ^{14}C, $^{32}P^{d}$
Industrial and landfill		
LLWR near Drigg[f]	0.061	Crustaceans, fish, Gamma dose rate over sediment, $^{129}I^{d}$, ^{210}Po
Whitehaven[f]	0.061	Crustaceans, fish, Gamma dose rate over sediment, $^{129}I^{d}$, ^{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 assessed contribution is based on data wholly at limits of detection*

[e] *The highest* total dose *due to Sellafield discharges was a person living on houseboat near Barrow in Cumbria*

[f] *The doses from man-made and naturally occurring radionuclides were 0.040 and 0.021 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*

Most liquid radioactive discharges from Sellafield have decreased in recent years. Consequently, concentrations of most radionuclides in fish and shellfish were also reduced, or generally unchanged.

The highest dose at Sellafield was mostly due to historical liquid discharges. The maximum dose at Sellafield for the person most affected by pathways related to gaseous discharge and direct radiation sources was 0.012 mSv in 2013, similar to the value for 2012. The person most exposed in 2013 was an adult who was a high-rate consumer of mushrooms and vegetables.

In Scotland, the representative person who received the highest dose from authorised releases of radioactivity consumed fish and shellfish on the Dumfries and Galloway coast. It is estimated that the representative person received a dose of 0.044 mSv in 2013. Most of this was due to the effects of past discharges from the Sellafield site.

Relatively high concentrations of tritium have previously been found in food and the environment near GE Healthcare Limited's Maynard Centre, at Cardiff, where radiochemicals for life science research were produced until 2010. In 2013, the person most exposed received an estimated dose of 0.010 mSv. His/her dose in 2012 was 0.005 mSv. The dose is now mostly due to external radiation that was not derived from operations at the Maynard Centre and the increase is likely to have been due to natural variations in dose rate. Eating fish from the Severn Estuary that contained tritium and carbon-14 also made a small contribution to the dose. In line with decreased discharges, doses from these radionuclides have followed a falling trend since 2000.

Habits surveys near UK nuclear licensed sites

In 2013, the regular programmes of habits surveys around nuclear licensed sites continued. These give site-specific information on diets and occupancy habits of people near nuclear licensed sites. Surveys were carried out at Sellafield in England, at Dounreay in Scotland and at Wylfa in Wales. 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 licensed sites.

Radioactivity concentrations in samples collected around UK nuclear licensed 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. The UK Strategy has resulted in substantial reductions in radioactive discharges and in nuclear licensed sites producing action plans to further reduce discharges. From a regulatory perspective, the Environment Agency and SEPA have continued to support the Strategy and in 2013, they issued new authorisations/permits, or varied existing ones, at two sites (for power stations: Hinkley Point and Chapelcross), 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 2013 compared to those in 2012. During the past decade, discharges from GE Healthcare Limited at Cardiff have continued to decline. This has led to a downward trend in concentrations of tritium in fish and molluscs near the site.

During 2013, discharges of technetium-99 from Sellafield continued to be 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 peak in 2003. Technetium-99 has been found in seaweed, but our 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. Small increases in plutonium isotopes and americium-241 have been observed in mud samples from the Ravenglass estuary near Sellafield. However, these have had little or no effect on radiation exposures.

On occasion, the effects of non-nuclear sites discharge are detected at low levels by the routine monitoring programme for nuclear licensed sites. In 2013, iodine-131 was detected in marine samples at several nuclear licensed sites. The source of the iodine-131 is not known with certainty but a likely cause was the therapeutic use of this radionuclide in local hospitals. The concentrations were of low radiological significance.

At Hartlepool, the reported polonium-210 concentration in winkles was enhanced above that value expected due to natural sources. Due to the scarcity of winkles at the

normal sampling location (inside the Tees Estuary entrance) in 2013, the sample consisted of a mixture including some winkles collected from an area known previously to be enhanced. The higher levels are not due to discharges from the power station but are believed to be due to the effects of waste slag from local iron and steel industries used in sea defences and the build-up of naturally occurring radionuclides in sediments at this location following degradation of these materials.

Dose rates from around UK nuclear licensed 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 2013 compared with 2012. 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 licensed site incidents and non-routine surveys

During 2013, as a result of an ongoing programme of monitoring by the operator, radioactive items were detected on beaches on the Cumbrian coastline, where particles* (including contaminated pebbles/stones) from Sellafield were removed (117 in financial year 2013/14). Public Health England† (PHE) has provided advice 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. 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 2013. At Dounreay, the comprehensive beach monitoring programme continued for fragments of irradiated nuclear fuel (particles) and further particles were recovered from local beaches. Fishing restrictions under the Food and Environment Protection Act (FEPA) 1985 are still in force.

'Special' (or *ad hoc*) sampling related to nuclear licensed site operation is undertaken at sites when the need arises, for example when increases in discharges are reported. No such need arose in 2013.

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, (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, with small quantities reaching Western Europe towards the end of March that year.

The UK response in 2011 included (but no further actions were required in 2013):

- 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

Controls on food imports from Japan took two forms, and these controls continued in 2013. 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 have to be certified by the Japanese authorities, with the exception of certain alcoholic beverages and (since March 2014) tea. In addition, a percentage of Japanese imports into the EU were monitored at ports of entry. 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.

After the initial detection of iodine-131 by the routine monitoring programmes, the environment agencies

* *"Particle" is a term used in this report which encompasses discrete radioactive items which can range in radioactivity concentration, size and origin. "Particles" include radioactive scale, fragments of irradiated nuclear fuel, incinerated waste materials, radioactive artefacts (e.g. dials) 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.*

† *Public Health England (PHE) was formed on 1 April 2013. It includes the functions previously undertaken by the Health Protection Agency (HPA). PHE is the national agency for dealing with the health effects of radiation in the UK.*

and the Food Standards Agency undertook additional monitoring but the concentrations of iodine-131 were very low and of minimal risk to public health. The additional monitoring ceased in July 2011 and monitoring returned to normal frequencies.

The environmental effects of the Chernobyl accident continued to be monitored in upland lakes in 2013. All restrictions on moving, selling and slaughtering sheep in upland areas of the UK have now been removed.

Food imported into the UK may contain radioactive contamination from unknown sources. A monitoring system is in place to detect radioactivity in consignments. Unlike previous years, in 2013, instruments were not triggered at any points of entry of consignments of food being brought into the UK. Where necessary, the Food Standards Agency will work with food businesses and local enforcement officers to ensure that unsuitable food is not placed on the market.

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 was a practice that generated what is sometimes known as 'Technologically enhanced Naturally Occurring Radioactive Material' (TNORM). Where discharges of TNORM occur, this can lead to an increase in the concentrations of naturally occurring radionuclides in the environment. This site stopped operating at the end of 2001, was decommissioned in 2002 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 2013 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. A person in the area who consumed large amounts of seafood was estimated to receive a dose of 0.061 mSv, with about 30% from polonium-210. The dose includes a contribution from the effects of discharges from the adjacent sites at Sellafield and the LLWR near Drigg.

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).

Work to address the radioactive contamination at Dalgety Bay is ongoing. Following the publication of the risk assessment together with the appropriate persons report in 2013, COMARE recommended that effective remediation of the affected area is undertaken as soon as is possible. The Ministry of Defence (MoD) has progressed with addressing the contamination by initially publishing its Outline Management Options Appraisal Report in January 2014 followed by the publication in July 2014 of its broad management strategy and timescale for implementation of its preferred management option. PHE, at the request of SEPA, has provided advice on target levels of radioactive contamination for Dalgety Bay following any remediation of the affected area.

Further details can be found in Section 7.6 of this report and on the Radioactive Substances pages of the SEPA website (www.sepa.org.uk). As work in this area is ongoing, an update will be provided in next year's Radioactivity in Food and the Environment (RIFE) report.

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 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.

The distribution of radionuclides in coastal seas away from nuclear licensed 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 licensed sites, contribute to the data collected by the OSPAR Commission. They also help to measure progress towards the UK Governments' objectives for improving the state of the marine environment.

Disposal of dredge material from harbours and other areas is licensed under the Marine and Coastal Access Act (MCAA), 2009. In 2013, the Marine Management Organisation (MMO) considered a proposal on behalf of the Department for Environment, Food and Rural Affairs (Defra) for the disposal of sediment from Bradwell in Essex, Heysham in Lancashire and Hinkley Point in

Somerset. Samples of the dredge material were analysed for radioactivity and an assessment of potential radiation doses was made. Doses to members of the public were all less than the International Atomic Energy Agency (IAEA) criterion of 0.010 mSv per year which is as a measure of risk for a situation to be regarded as being of no concern to the regulator, because of its triviality. There was no objection to the licence being issued from radiological considerations.

The monitoring programmes and further research

The monitoring programmes in this report involved four specialist laboratories working together, each with rigorous quality assurance procedures, 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 wastes. The programmes include monitoring on behalf of the Scottish Government, Channel Island States, the Department of Energy and Climate Change (DECC), Defra, the Isle of Man Government, Natural Resources Wales and the Welsh Government. Overall, around 12,000 analyses and dose rate measurements were completed in 2013.

The results of the analysis of food samples collected near nuclear licensed sites in England and Wales are published 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 inside front and back covers of 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 2013 and (iii) gives an overview of the main sources of radiation in a regulatory context.

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 (SEPA) 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 (NIEA). In 2013 the Food Standards Agency continued a small programme of monitoring of upland areas in England and Wales for caesium-137, arising from the 1986 Chernobyl accident. Surveillance of imports through points of entry continued but direct monitoring of the UK environment for effects of the Fukushima-Daiichi accident (March 2011) stopped in 2011 because of the low levels detected. The regular programme of monitoring of drinking water, air and rain continued on behalf of the Department of Energy and Climate Change (DECC), NIEA and the Scottish Government. The Food Standards Agency and SEPA also carry out nationwide monitoring of foodstuffs (including milk, animals, crops and canteen meals) that are remote from nuclear licensed sites. The marine environment of the whole of the British Isles away from nuclear licensed sites is monitored for the Department for Environment, Food and Rural Affairs (Defra).

The Food Standards Agency is responsible for food safety throughout the UK under the Food Standards Act 1999. The Environment Agency, NRW, 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 and NRW regulate radioactive waste disposal under the Environmental Permitting (England and Wales) Regulations 2010 (EPR 10), (United Kingdom - Parliament, 2010a), whilst in Scotland and Northern Ireland, SEPA and NIEA regulate radioactive waste disposal 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 nuclear site. Environmental and food results are used to assess dose to the public to confirm that the controls and conditions placed in the authorisations/permits provide the necessary protection and to ensure compliance with 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 the long-term trends of caesium-137 concentrations in affected areas. Monitoring of food imports from Japan acts to confirm that controls by the Japanese authorities are working adequately. 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 (EC). Guidance on planning and implementing routine environmental programmes has been

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 in conformity with the EU Basic Safety Standards Directive
- 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 2013

* *Created in April 2013, Natural Resources Wales (NRW) was created by and reports to the Welsh Government. This new body took over the functions previously carried out by the Environment Agency Wales, Countryside Council for Wales and Forestry Commission Wales and is the lead environmental regulator in Wales. The Environment Agency has an agreement with Natural Resources Wales to undertake some specific activities on its behalf in Wales including some environmental monitoring and aspects of radioactive substances regulation.*

published (Environment Agency, Food Standards Agency and Scottish Environment Protection Agency, 2010).

The RIFE report and the associated monitoring programmes conform to the requirements in Article 66 of the Euratom Directive laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Specifically it provides estimates of doses to members of the public from authorised practices and enables such results to be made available to stakeholders (European Commission, 2014a).

The Food Standards Agency completed a public consultation exercise to review the way it monitors radioactivity in food in June 2013 (Food Standards Agency, 2012a and 2013). This has resulted in a revised monitoring programme taking effect in 2014.

Appendix 1 is in a file accompanying the main report. It gives details of methods of sampling and analysis and explains how results are interpreted in terms of public radiation exposures. A report 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). A summary of the assessment approach and current trends in doses are given in section 1.2.

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 & Aquaculture Science (Cefas)
- Environmental Scientifics Group (ESG)
- Public Health England (PHE)
- LGC Limited (formerly Laboratory of the Government Chemist)

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 2013, 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 (see Figure 1.1). The first type of assessment is more complete in considering the effects of gaseous and liquid discharges of radioactive waste together and additionally includes exposure to direct radiation from nuclear licensed sites. It gives an estimate of *total dose* to people around the nuclear licensed sites and it is presented as the primary dose quantity. Direct radiation can be a significant contributor to dose close to operating power stations or to where radioactive materials are stored. The regulation of direct radiation is the responsibility of the Office for Nuclear Regulation (ONR)*. Operators of nuclear licensed sites provide estimates of direct radiation doses to ONR 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 offers additional information for key pathways. The sum of the doses from specific sources does not give the same result as the assessment of *total dose* from all sources. This is because the assessment methods use different ways of defining the most exposed people.

Both types of assessment consider the people in the population who are most exposed to radiation. These results are for comparison with legal limits. The method of calculation involves an assessment for the 'representative person'.

The calculated doses are 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 ICRP (International Commission on Radiological Protection, 1991) and are consistent with EU legislation (European Commission, 2014a).

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

Collective doses are beyond the scope of this report. They are derived using modelling techniques. The European Commission has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for the gaseous and liquid waste disposals in the years 2004 to 2008 (Jones *et al.*, 2013).

* *On 1 April 2014 ONR was established as a Public Corporation under the Energy Act 2013. Prior to this it was an agency of the Health and Safety Executive.*

Primary purpose	Assess dose from main sources of exposure at each site for comparison with 1 mSv limit			
Types of assessment	*Total dose*	Source specific dose		
Sources considered	Gaseous discharges Liquid discharges Direct radiation from site	Gaseous discharges	Liquid discharges	Direct radiation (dose estimates provided by ONR)
Habits data e.g. food consumption rates or occupancy of beaches	Define usage of pathways relating to all sources at site	Define usage of pathways relating to gaseous discharges at site	Define usage of pathways relating to liquid discharges at site	
Monitoring data	Collate monitoring data for relevant pathways e.g. radionuclide concentratons in food or dose rates on beaches	Collate monitoring data for relevant pathways e.g. radionuclide concentratons in food	Collate monitoring data for relevant pathways e.g. radionuclide concentrations in food or dose rates on beaches	
Dose calculations	Calculate dose from all sources to individuals who may represent those most exposed	Calculate dose from gaseous discharges to people representing those most exposed	Calculate dose from liquid discharges to people representing those most exposed	
	Select the highest dose for the person representing the most exposed			
Dose quantity	*Total dose*	Dose from gaseous discharges	Dose from liquid discharges	Dose from direct radiation

Figure 1.1. The dose assessment process for major nuclear sites

Radiation exposures to some specific groups of workers are included in the assessment of doses from nuclear licensed 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 2013

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). These data are presented in three parts. The representative person receiving the highest doses 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 doses from all pathways and sources are different from those in A and B. Therefore this case is presented in part C. The major contributions to dose are provided. 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 can be provided by contacting one of the agencies listed on the inside cover of the report.

In all cases, doses estimated for 2013 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 *total dose* was received by a person living near the Amersham site; this dose was almost entirely due to direct radiation emanating from the site. The highest *total dose* due to permitted waste discharges was due to operations at the Sellafield site. The person most exposed to radiation from Sellafield in 2013 was living on a houseboat on the Cumbrian coast near Barrow.

1.2.3 *Total dose* trends

A time-series of *total dose* from 2004 - 2013 is shown in Figure 1.2 (Table 1.3 gives numerical values). Many sites showed a downward 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 the LLWR near Drigg. In this case, the overall downward trend in *total dose* broadly followed the

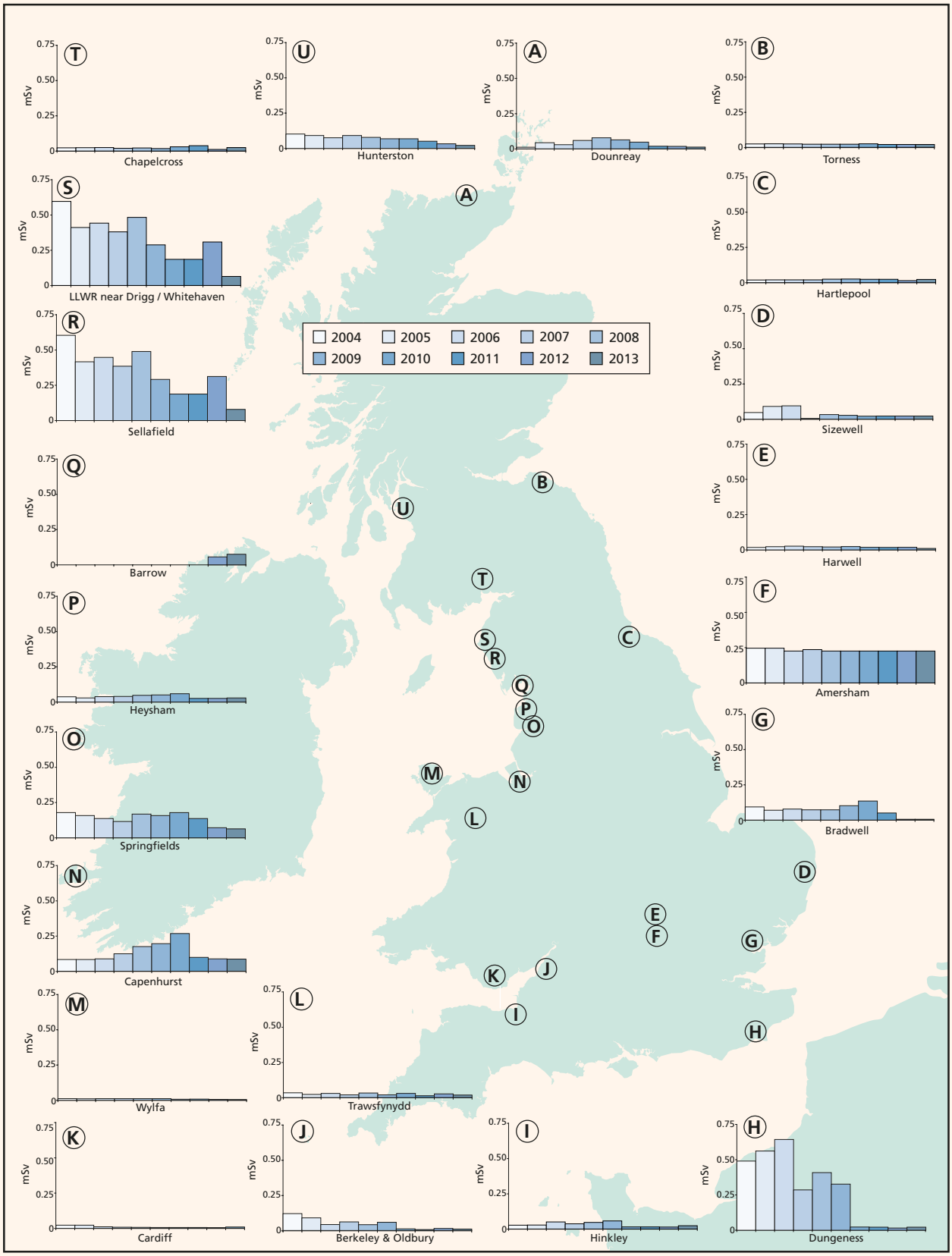


Figure 1.2. *Total doses* around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2013). (Exposures at Sellafield/Whitehaven/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

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. In 2013, the dose to these people reduced below others further afield such that the maximum *total dose* due to Sellafield operations was to a person living on a houseboat near Barrow.

At Cardiff, there has been an overall downward trend in *total dose* which is partly due to reductions in discharges of tritium and carbon-14 to sea. The recent increase in *total dose* at this site was due to higher carbon-14 concentrations in milk in 2013. 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, Hinkley Point and Springfields was largely due to findings from new habits surveys in 2011, 2010 and 2012 respectively.

1.2.4 Source specific dose results for 2013

The results of the source specific assessments for the main industrial sites in the UK are summarised in Table 1.4 and Figure 1.3. 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 the LLWR near Drigg, Sellafield and Whitehaven where seafood consumption dominated, and at Barrow and Springfields where external exposure on houseboats dominated. At the LLWR near Drigg, Sellafield and Whitehaven the majority of the dose was from the legacy of historical 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 Barrow and Springfields the dose was also largely due to historical discharges from Sellafield.

Although some source specific doses were estimated to be higher than *total doses,* the reasons for this are understood and relate to conservative assumptions in the source specific assessments about adding together the effects of consumption of different foods. The assumptions used for total dose assessments are more realistic and 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) and have published their aims in terms of environmental protection, that is (i) prevention or reduction of the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity, (ii) the conservation of species and the health and status of natural habitats, communities and ecosystems (International Commission on Radiological Protection, 2014).

In the UK, the current 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, 2005c). In relation to radioactivity, the environment agencies have characterised the aquatic environment using a screening tool, which forecasts the environmental impact of radioactive waste sources. The outcome of the assessment has been published and provided to the European Commission (Environment Agency, 2005). Subsequent stages within this framework involve designing and implementing monitoring programmes to reflect the results of the initial characterisation, reviewing environmental quality using the results from the monitoring programmes, developing standards and producing management plans to improve the environmental status of the UK aquatic environment.

Under the Habitats Regulations, the Environment Agency and SEPA review new and existing authorisations/permits to ensure that they do not have an adverse effect on the

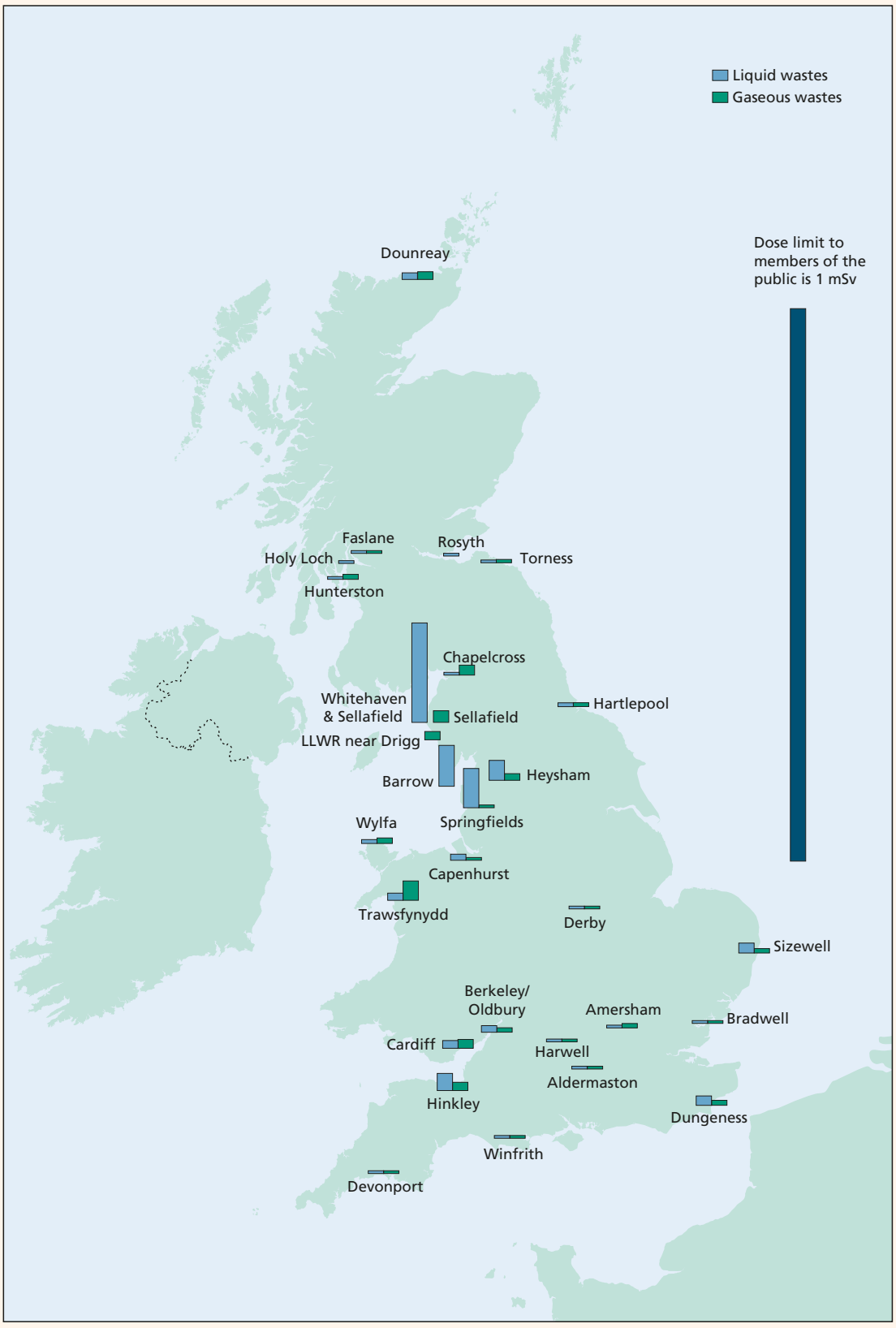


Figure 1.3. Source specific doses in the UK, 2013 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

integrity of Natura 2000 habitat sites. The Environment Agency has assessed the dose rates to reference organisms and feature species for authorised discharges under the Radioactive Substances Act 1993 and, since April 2010, the Environmental Permitting (England and Wales) Regulations 2010 (Environment Agency, 2009a). Environmental concentrations were predicted using appropriate dispersion models and the data were used to calculate the dose rates. The assessment concluded that, for all but two of the habitat sites, dose rates to the worst affected organisms were less than an agreed threshold of 40 μGy h^{-1}. Hence, there was no significant impact on the integrity of these habitat sites. The two habitat sites with the potential for dose rates to the worst affected organism to be greater than the agreed threshold were the Drigg coast and the Ribble and Alt Estuaries. A detailed assessment has been carried out for the Drigg coast using monitoring data and this confirmed there was no indication of significant impact from ionising radiation on the sand dune biota (Wood *et al.*, 2008). A detailed assessment was also carried out for the Ribble and Alt estuaries using monitoring data and taking into account new discharge limits for the Springfields site which came into force in 2008 (Environment Agency, 2009b). This assessment concluded that the dose rate to the worst affected organism was less than the agreed threshold and hence there was no significant impact on the integrity of this habitat site. 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.

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 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 Regulation in each country of the UK in 2009 as part of the Food Standards Agency programme of regulatory simplification to reduce administrative burden. In 2010, the Regulations were amended to update the lists of approved food irradiation facilities.

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 Food Standards Agency's website: http://www.food.gov.uk/foodindustry/imports/importers/irradiated

1.3 Sources of radiation exposure

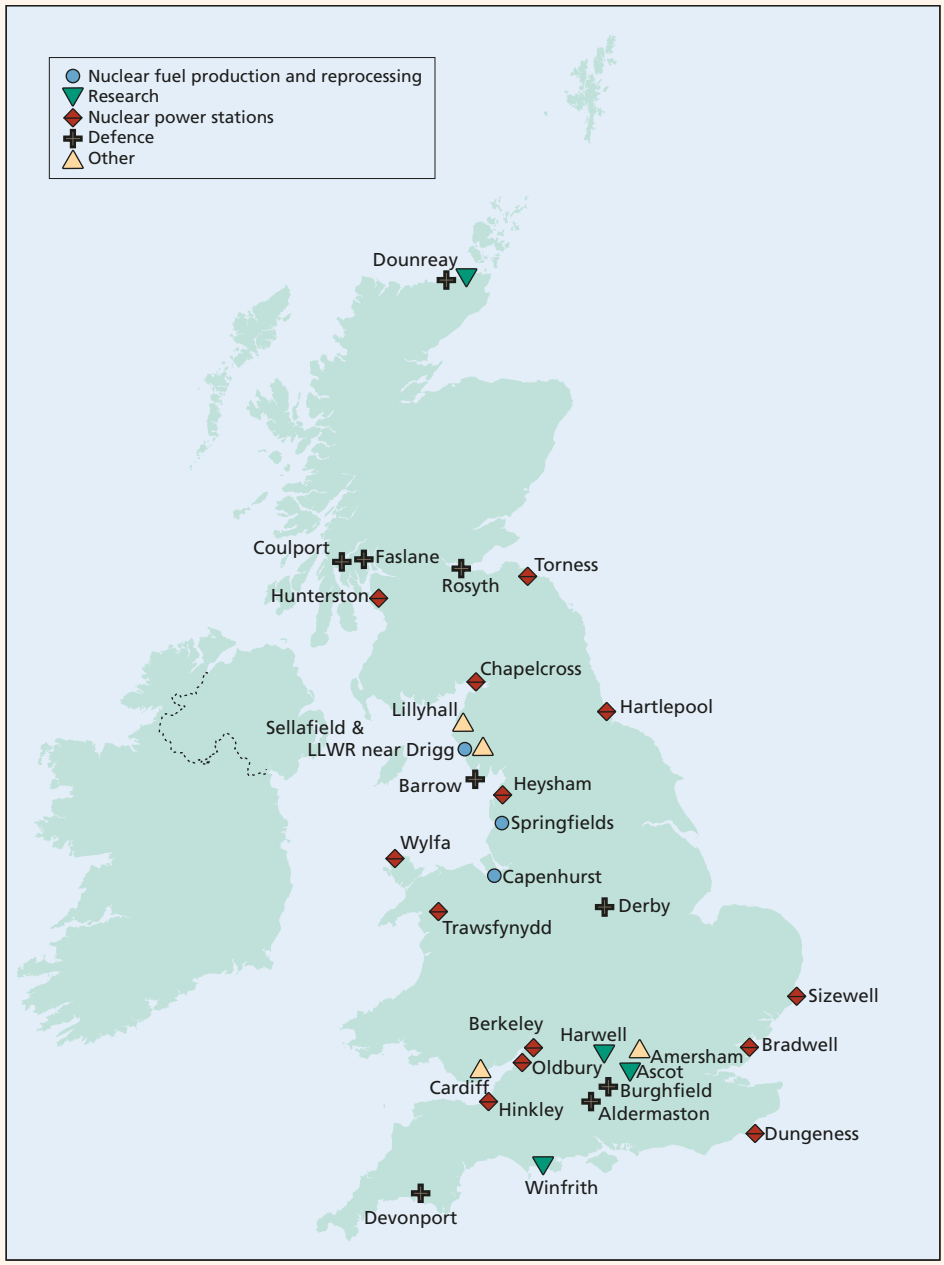
1.3.1 Radioactive waste disposal from nuclear licensed sites

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 licensed 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 which is due to start accepting waste for disposal in the next 12 months. These discharges and disposals are regulated by the environment agencies under RSA 93 or EPR 10*.

Figure 1.4 shows the nuclear licensed 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 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

* *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 1.4. Principal sources of radioactive waste disposal in the UK, 2013 (Showing main initial operation. Some operations are undergoing decommissioning)



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 and 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 licensed establishments in the UK during 2013. 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 2013, discharges and disposals were below the limits except at Dounreay where gaseous discharges of krypton-85 from the Dounreay Fast Reactor exceeded the limit for the facility. However, the impact from Dounreay discharges on members of the public and the environment was very low and estimated doses were well below the annual dose limit. Further details are provided in section 3.1. The tables show the percentage of the limit actually discharged in 2013. 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. Discharge limits 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 10, 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 2013.

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 Substances Strategy and signed the Sintra Statement which included the following commitment (OSPAR, 1998):

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

In July 2002, a UK Strategy for Radioactive Discharges was published (Department for Environment, Food and Rural Affairs, 2002). This described how the UK would implement the agreements reached at the 1998 and subsequent meetings of OSPAR. The aims of the Strategy related to liquid wastes from the major sources, primarily the nuclear industry, and not to gaseous or solid wastes.

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

The new Strategy builds on the 2002 publication, 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 operational 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 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 UK 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 OSPAR's 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, 2014). In particular, it describes the work of its Intersessional Correspondence Group which is evaluating approaches for assessing the objective of additional concentrations in the marine environment above historic levels being close to zero by 2020. 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, 2013). 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. The UK has submitted an initial assessment to the Commission (European Commission, 2012b).

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 *"Charting Progress 2"* in 2010 (Department for Environment, Food and Rural Affairs, 2010). The Department of the Environment, Northern Ireland and the Scottish Government have also published individual assessments of the state of the seas around their coasts (Baxter *et al.,* 2011; Department of the Environment, Northern Ireland 2011).

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, 2011a). 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 Statement (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 NPS's 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.

The ONR and the Environment Agency are continuing 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 Environment Agency's assessment of new nuclear power station designs is to make sure that, if they were built, their environmental impact, including the radioactive wastes they create and the discharges they make, would be acceptable.

In December 2011, ONR and the Environment Agency concluded their initial assessments of two designs: AP1000 (Westinghouse) and UK-EPR (EDF and AREVA), including taking into consideration the effects and review 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, ONR issued an interim Design Acceptance Confirmation to the designers of each of the reactors (Office for Nuclear Regulation, 2011). In December 2012, ONR finalised their GDA assessment following EDF and AREVA submissions of revised safety case documents and associated changes to generic design. A Design Acceptance Confirmation for the UK-EPR reactor has been issued and ONR have concluded that the reactor is suitable for construction on licensed sites in the UK, subject to site specific assessment and licensing (Office for Nuclear Regulation, 2012). The GDA process is continuing in 2014 with consideration of the Hitachi-GE UK Advanced Boiling Water Reactor design, as well as preparation for other potential GDAs (Environment Agency and Office for Nuclear Regulation, 2014).

In November 2012, ONR granted a nuclear site licence to NNB Generation Company Limited (NNB GenCo) for its proposed site at Hinkley Point C in Somerset. Now that it is licensed, the Company will be subject to statutory obligations and regulation by ONR. More details can be found at: http://www.onr.org.uk/new-reactors/index.htm.

The Environment Agency issued a permit for the proposed Hinkley Point C development to NNB GenCo to discharge (non-radioactive) waste water discharges for offsite construction (Environment Agency, 2012a). In addition, in 2013, the Environment Agency issued three further environmental permits for the site covering (i) disposal and discharge of radioactive wastes, (ii) operation of standby power supply systems using diesel generators and (iii) discharge cooling water and liquid effluents into the Bristol Channel. More information can be found at: http://www.environment-agency.gov.uk/hinkleypoint.

1.3.3 Managing radioactive liabilities in the UK

The UK Government has ratified the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (International Atomic Energy Agency, 1997). This agreement has an objective 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 is required, on a triennial basis, to submit National Reports for International peer review, to comply with their obligations with the Joint Convention (for example, Department of Energy and Climate Change, 2010; 2011b).

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 2012 (Nuclear Decommissioning Authority, 2012) and the plan for 2014/17 is available (Nuclear Decommissioning Authority, 2014). A report in 2012 has considered the financial implications of nuclear decommissioning and waste management (MacKerron, 2012). The NDA published an up-to-date inventory and forecast of radioactive wastes in the UK jointly with DECC in 2014 (Nuclear Decommissioning Authority and Department of Energy and Climate Change, 2014).

In 2007, the UK Government and Devolved Administrations issued a 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

UK Government policy is that geological disposal is the best available means of managing the UK's higher activity radioactive waste in the long term.

The 2008 White Paper '*Managing Radioactive Waste Safely (MRWS): A Framework for Implementing Geological Disposal*' set out a framework for implementing geological disposal, including a voluntarist process for identifying a Geological Disposal Facility (GDF) site that was based on local communities willingness to participate in the process (Department for Environment, Food and Rural Affairs, Department for Business, Enterprise and Regulatory Reform, Welsh Assembly Government and Northern Ireland Assembly, 2008).

The siting process set out in the 2008 White Paper operated for five years. A number of communities engaged with the process, and participated in its early stages. However, by February 2013, there were no longer any communities actively involved in the siting process.

The UK Government remains firmly committed to the policy of geological disposal and continues to favour an approach to siting a GDF that is based on the willingness of local communities to participate in the process. The UK Government conducted a review of the siting process that operated since 2008, including a call for evidence and formal public consultation, which took place in 2013.

In July 2014, UK Government published a White Paper 'Implementing Geological Disposal' that sets out the policy framework for managing higher activity radioactive waste in the long term through geological disposal (Department of Energy and Climate Change, 2014). It set out a number of initial actions to implement this policy framework; actions which will be led by the DECC and the developer for a GDF (Radioactive Waste Management Limited, a wholly owned subsidiary company of the Nuclear Decommissioning Authority). Formal discussions between interested communities and the developer will not begin until the initial actions set out in the White Paper have been completed, in around 2016.

Radioactive waste management is a devolved policy issue. Therefore the Scottish Government, Welsh Government and Northern Ireland Executive each have responsibility for this issue in respect of their areas.

The Scottish Government is not a sponsor of the programme for implementing geological disposal, but does remain committed to dealing responsibly with radioactive waste arising in Scotland. Scottish Government policy is that the long-term management of higher activity radioactive waste should be in near-surface facilities. Facilities should be located as near to the site as possible (Scottish Government, 2011).

The Welsh Government is committed to securing the long-term safety of radioactive wastes and to the implementation of a framework appropriate to the needs of Wales and continues to play an active part in the Managing Radioactive Waste Safely programme to promote the interests of the people of Wales. In 2008, the Welsh Government reserved its position on geological disposal in Wales.

The Northern Ireland Executive continues to support the implementation of geological disposal for the UK's higher activity radioactive waste, recognising that it is in the best interests of Northern Ireland that these wastes are managed in the safest and most secure manner.

Independent scrutiny of the Government's long-term management, storage and disposal of radioactive waste will continue by the Committee on Radioactive Waste Management (CoRWM) who have published their proposed work programme for 2014-2017 (Committee on Radioactive Waste Management, 2014).

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 (Section 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), Environment Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency (2009) and Environment Agency (2013a)). In addition, SEPA has issued a policy statement which specifies how it will regulate the disposal of Low Level Waste from nuclear licensed sites. The position identified has several practical implications including simplification of the process such that individual disposal sites need no longer be named in authorisations (SEPA, 2012).

Naturally occurring radioactive material (NORM) is contained in some wastes and is subject to existing regulatory systems which are designed to protect human health and the environment. However there are improvements that can be achieved and, following a broad ranging consultation, the UK, Scottish, UK and Welsh Governments and the Northern Ireland Department of the Environment published the UK NORM Waste Strategy in July 2014 (Department of Energy and Climate Change, the Scottish Government, The Welsh Government and the Northern Ireland Department of the Environment, 2014). The Strategy in respect of the NORM sector is based on stimulating investment in the waste management supply chain. It will achieve this principally through (i) reforming the regulatory framework to ensure it is clear, coherent and effective, (ii) removing policy barriers to the development of a robust and efficient market for NORM waste management and (iii) supporting efforts by waste producers and the waste management supply chain to

generate better data and information about current and future NORM waste arisings.

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 2012 are presented in Section 8 and confirm that the radiological impact of these disposals was insignificant.

In England, the Marine Management Organisation (MMO) administers a range of statutory controls that apply to marine works on behalf of the Secretary of State for Environment, Food and Rural Affairs; this includes issuing licences under the Marine and Coastal Access Act (MCAA), 2009 (United Kingdom - Parliament, 2009) for the disposal of dredged material at sea. Licences for disposals made in Scottish waters and around the coast of Northern Ireland are the responsibility of the Scottish Government (Marine Scotland) and the Department of Environment (NIEA), respectively. As of 1 April 2010, licences for Welsh waters are the responsibility of the Welsh Government.

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). An assessment of licence applications is provided in Appendix 5.

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. PHE has assessed incidents involving the transport of radioactive materials in the UK (Jones and Harvey, 2014). PHE 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, 2013). 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 2013. 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 exploration for, and extraction of, gas from shale rock is being actively investigated in the UK with support from the Department of Energy and Climate Change. This process, along with others for unconventional sources of gas such as coal bed methane, represents a potential source of exposure of the public and workers to naturally occurring radioactivity. The form of the radioactivity could be gaseous, liquid or solid. Examples of routes of exposure are inhalation of radon gas emissions, and ingestion of water and food where the process has enhanced levels of NORM.

Each of the environment agencies is working to ensure that appropriate regulatory regimes are in operation to control exposures of the public from unconventional gas exploration and extraction. Reports have been published to support engagement with industry, the public and other stakeholders (Environment Agency, 2013b; Northern Ireland Environment Agency, 2013; Scottish Environment Protection Agency, 2013). A review of potential public health impacts of exposures to radioactivity as a result of shale gas extraction has been issued by Public Health England (Kibble *et al*., 2014). Monitoring of exploration and extraction of shale gas in the environment and food is not undertaken by the environment agencies and the Food Standards Agency at present. However the agencies will continue to review the position as specific proposals for development are taken forward and any results of monitoring will be reported in future issues of the RIFE report.

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 was extended in 2006 to provide 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 further modification was made in 2007, which extends the regime to cover land contaminated with radioactivity originating from nuclear installations; though to date no sites meeting these criteria have been found. A profile of industries which may have caused land contamination has been published (Department for Environment, Food and Rural Affairs, 2006). 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, 2009c). DECC issued revised guidance for radioactive contaminated land to local authorities and the Environment Agency in 2012 (Department of Energy and Climate Change, 2012). The Environment Agency has issued a series of Briefing Notes that provide information on land contaminated with radioactivity in England and Wales (Environment Agency, 2012b). 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 heterogeneous contamination, and whether or not the probability of receiving the dose should be taken into account. To date, no site has been determined as 'contaminated land' due to radioactivity in Scotland.

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, 2004). 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 doses – direct radiation pathway, 2013

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.080
Sellafield	0.002
Springfields	0.024
Research establishments	
Dounreay	0.005
Harwell	0.010
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	Bgd[a]
Bradwell	Bgd[a]
Chapelcross	Bgd[a]
Dungeness	<0.020[b]
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	<0.010[c]
Hunterston	<0.020[d]
Oldbury	Bgd[a]
Sizewell	<0.020[e]
Torness	<0.020
Trawsfynydd	Bgd[a]
Wylfa	Bgd[a]
Defence establishments	
Aldermaston	Bgd[a]
Barrow	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	0.032

[a] *Doses not significantly different from natural background*
[b] *Datum for Dungeness B. Dungeness A (Bgd[a]) not used*
[c] *Datum for Hinkley B. Hinkley A (Bgd[a]) not used*
[d] *Datum for Hunterston B. Hunterston A (0.003) not used*
[e] *Datum for Sizewell B. Sizewell A (Bgd[a]) not used*

Table 1.2. *Total doses* integrated across pathways, 2013

Site	Representative person[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, $^{3}H^{c}$, $^{137}Cs^{c}$, ^{238}U
Amersham	Local adult inhabitant (0–0.25km)	0.22	Direct radiation
Barrow[d]	–	–	–
Berkeley and Oldbury	Infant milk consumer	0.008	Milk, ^{14}C
Bradwell	Prenatal child of green vegetable consumers	<0.005	Green vegetables, potatoes, root vegetables, ^{14}C
Capenhurst	Local inhabitants aged 10yr (0–0.25km)	0.080	Direct radiation
Cardiff	Infant milk consumer	0.010	Milk, ^{14}C, $^{32}P^{c}$
Chapelcross	Infant milk consumer	0.024	Milk, ^{90}Sr, $^{241}Am^{c}$
Derby	Adult cattle meat consumer	<0.005	Green vegetables, $^{241}Am^{c}$
Devonport	Prenatal child of domestic fruit consumers	<0.005	Domestic fruit, green vegetables, $^{3}H^{c}$
Dounreay	Adult green vegetable consumer	0.012	Domestic fruit, potatoes, root vegetables, $^{129}I^{c}$, $^{238}Pu^{c}$, $^{239/240}Pu^{c}$, $^{241}Am^{c}$
Dungeness	Local adult inhabitant (0–0.25km)	0.021	Direct radiation
Faslane	Adult consumer of cattle meat	<0.005	Cattle meat, $^{241}Am^{c}$
Hartlepool	Local adult inhabitant (0.5–1km)	0.020	Direct radiation
Harwell	Prenatal child of local inhabitants (0–0.25km)	0.010	Direct radiation
Heysham	Local adult inhabitant (0–0.25km)	0.021	Direct radiation
Hinkley Point	Infant milk consumer	0.014	Direct radiation, ^{14}C
Hunterston	Prenatal child of local inhabitant (0.25–0.5km)	0.021	Direct radiation
LLWR near Drigg	Local infant inhabitant (0.5–1km)	0.037	Direct radiation
Rosyth[d]	–	–	
Sellafield	Mushroom consumer	0.012	Domestic fruit, other vegetables, potatoes, root vegetables, ^{14}C, ^{90}Sr, $^{106}Ru^{c}$, ^{129}I, ^{241}Am
Sizewell	Prenatal child of local inhabitants (0.5–1km)	0.021	Direct radiation
Springfields	Local adult inhabitant (0–0.25km)	0.024	Direct radiation
Torness	Local adult inhabitant (0.5–1km)	0.020	Direct radiation
Trawsfynydd	Infant local inhabitant (0.25–0.5km)	0.017	Milk, ^{14}C, ^{241}Am
Winfrith	Infant milk consumer	<0.005	Milk, ^{14}C
Wylfa	Local inhabitant aged 1y (0.25–0.5km)	<0.005	Milk, ^{14}C, ^{35}S
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupant over riverbank	<0.005	Exposure over riverbank
Amersham	Adult occupant over riverbank	<0.005	Gamma dose rate over riverbank
Barrow	Adult occupant on a houseboat	0.076	Gamma dose rate over sediment
Berkeley and Oldbury	Adult occupant over sediment	0.010	Gamma dose rate over sediment
Bradwell	Adult fish consumer	<0.005	Fish, exposure over sediments, ^{241}Am
Capenhurst	Occupant over riverbank aged 10y	0.008	Gamma dose rate over sediment
Cardiff	Prenatal child of occupants over sediment	0.008	Gamma dose rate over sediment
Chapelcross	Adult occupant over sediment	0.014	Gamma dose rate over sediment
Derby	Adult consumer of locally sourced water	<0.005	Water, $^{60}Co^{c}$
Devonport	Adult fish consumer	<0.005	Fish, ^{14}C, $^{241}Am^{c}$
Dounreay	Adult occupant over sediment	0.011	Gamma dose rate over sediment
Dungeness	Prenatal child of occupants over sediment	0.006	Direct radiation, gamma dose rate over sediment
Faslane	Adult occupant over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Adult occupant over sea coal/sand	0.007	Gamma dose rate over sea coal/sand
Harwell	Adult occupant over sediment	<0.005	Gamma dose rate over riverbank
Heysham	Adult mollusc consumer	0.028	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupant over sediment	0.022	Gamma dose rate over sediment
Hunterston	Adult occupant over sediment	<0.005	Gamma dose rate over sediment
LLWR near Drigg[e]	Adult fish consumer	0.061[f]	Crustaceans, fish, gamma dose rate over sediment, $^{129}I^{d}$, ^{210}Po
Rosyth	Adult occupant over sediment	<0.005	Gamma dose rate over sediment
Sellafield[e,g]	Adult occupant on a houseboat	0.076	Gamma dose rate over sediment
Sizewell	Adult occupant over sediment	0.018	Gamma dose rate over sediment
Springfields	Adult occupant on a houseboat	0.060	Gamma dose rate over sediment
Torness	Adult fish consumer	0.006	Direct radiation, fish, ^{241}Am
Trawsfynydd	Adult fish consumer	0.012	Exposure over sediment, fish, ^{137}Cs, ^{241}Am
Whitehaven[e]	Adult fish consumer	0.061[f]	Crustaceans, fish, gamma dose rate over sediment, $^{129}I^{c}$, ^{210}Po
Winfrith	Adult fish consumer	<0.005	Fish, ^{241}Am
Wylfa	Adult occupant over sediment	<0.005	Gamma dose rate over sediment

Table 1.2. continued

Site	Representative person[a]	Exposure, mSv	
		Total	Dominant contributions[b]
C All sources			
Aldermaston and Burghfield	Infant milk consumer	<0.005	Milk, $^{3}H^{c}$, $^{137}Cs^{c}$, ^{238}U
Amersham	Local adult inhabitant (0–0.25km)	0.22	Direct radiation
Barrow	Adult occupant on a houseboat	0.076	Gamma dose rate over sediment
Bradwell	Prenatal child of green vegetable consumers	<0.005	Green vegetables, potatoes, root vegetables, ^{14}C
Capenhurst	Local inhabitant aged 10y (0–0.25km)	0.080	Direct radiation
Cardiff	Infant milk consumer	0.010	Milk, ^{14}C, $^{32}P^{c}$
Derby	Adult consumer of locally sourced water	<0.005	Water, $^{60}Co^{c}$
Devonport	Adult fish consumer	<0.005	Fish, ^{14}C, $^{241}Am^{c}$
Dounreay	Adult green vegetable consumer	0.012	Domestic fruit, potatoes, root vegetables, $^{129}I^{c}$, $^{238}Pu^{c}$, $^{239/240}Pu^{c}$, $^{241}Am^{c}$
Faslane	Adult occupant over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Local adult inhabitant (0–0.25km)	0.024	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal child of local inhabitants (0–0.25km)	0.010	Direct radiation
			molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupant over sediment	0.022	Gamma dose rate over sediment
Hunterston	Prenatal child of local inhabitants (0.25–0.5km)	0.021	Direct radiation
LLWR near Drigg[e]	Adult fish consumer	0.061[f]	Crustaceans, fish, gamma dose rate over
Rosyth	Adult occupant over sediment	<0.005	Gamma dose rate over sediment
Sellafield[e,g]	Adult occupant on a houseboat	0.076	Gamma dose rate over sediment
Sizewell	Local adult inhabitant (0–0.25km)	0.021	Direct radiation
Springfields	Adult occupant on a houseboat	0.060	Gamma dose rate over sediment
Trawsfynydd	Infant local inhabitant (0.25–0.5km)	0.017	Milk, ^{14}C, ^{241}Am
Whitehaven[e]	Adult fish consumer	0.061[f]	Crustaceans, fish, gamma dose rate over sediment, $^{129}I^{c}$, ^{210}Po
Winfrith	Infant milk consumer	<0.005	Milk, ^{14}C

[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 assessed contribution is based on data being wholly at limits of detection*

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

[e] *The effects of liquid discharges from Sellafield, Whitehaven and LLWR near Drigg are considered together when assessing exposures at these sites because their effects are manifested in a common area of the Cumbrian coast*

[f] *The doses from man-made and naturally occurring radionuclides were 0.040 and 0.021 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 into the same area*

[g] *The highest exposure due to operations at Sellafield was to a person living on a houseboat near Barrow*

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

Site	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Aldermaston and Burghfield	<0.005	<0.005	<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	0.22	0.22
Barrow										0.057	0.076
Berkeley and Oldbury		*0.12*	*0.090*	*0.042*	0.061	0.041	0.058	0.011	0.006	0.014	0.010
Bradwell		*0.09*	*0.067*	*0.075*	0.070	0.070	0.098	0.13	0.048	<0.005	<0.005
Capenhurst		*0.080*	*0.080*	*0.085*	*0.12*	0.17	0.19	0.26	0.095	0.085	0.080
Cardiff	0.038	0.023	0.023	0.011	0.008	0.007	0.006	0.006	0.006	0.005	0.010
Chapelcross		*0.022*	0.023	0.024	0.019	0.021	0.017	0.029	0.037	0.011	0.024
Derby							<0.005	<0.005	<0.005	<0.005	<0.005
Devonport		<0.005	<0.005	<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	0.017	0.012
Dungeness		*0.48*	0.55	0.63	0.28	0.40	0.32	0.022	0.021	0.015	0.021
Faslane		*<0.005*	*<0.005*	<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	0.015	0.024
Harwell		*0.017*	*0.022*	*0.026*	0.022	0.020	0.023	0.018	0.017	0.018	0.010
Heysham		*0.036*	*0.028*	0.037	0.038	0.046	0.049	0.057	0.025	0.025	0.028
Hinkley Point		*0.026*	*0.027*	0.048	0.035	0.045	0.055	0.014	0.014	0.013	0.022
Hunterston		0.10	0.090	0.074	0.090	0.077	0.067	0.067	0.050	0.032	0.021
LLWR near Drigg[b]	0.66	0.58	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.061
Rosyth		*<0.005*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sellafield[b]	0.66	0.58	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.076[c]
Sizewell		*0.045*	0.086	0.090	<0.005	0.031	0.026	0.020	0.021	0.021	0.021
Springfields		*0.17*	*0.15*	0.13	0.11	0.16	0.15	0.17	0.13	0.068	0.060
Torness		*0.024*	*0.025*	0.024	0.022	0.022	0.022	0.025	0.020	0.020	0.020
Trawsfynydd		*0.032*	0.021	0.028	0.018	0.031	0.018	0.028	0.012	0.025	0.017
Whitehaven[b]	0.66	0.58	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.061
Winfrith	<0.005	<0.005	<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	0.006	<0.005

[a] *Where no data is given, no assessment was undertaken due to a lack of suitable habits 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 habits data*

[b] *The effects of liquid discharges from Sellafield, Whitehaven and LLWR near Drigg are considered together when assessing exposures at these sites*

[c] *The highest exposure due to operations at Sellafield was to a person living on a houseboat near Barrow*

Table 1.4. Source specific doses due to discharges of radioactive waste in the United Kingdom, 2013*

Establishment	Radiation exposure pathways	Gaseous or liquid source[e]	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[h]	L	0.011	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005[i]	$^{3}H^{d}$, $^{99}Tc^{d}$, ^{234}U, ^{238}U
Springfields	Fish and shellfish consumption	L	0.023	Ext
	Terrestrial foods, external and inhalation near site[h]	G	<0.005[i]	^{90}Sr, $^{129}I^{d}$, $^{230/232}Th$, ^{234}U
	External in intertidal areas (children playing)[a,h]	L	<0.005	Ext
	Occupancy of houseboats	L	0.071	Ext
	External in intertidal areas (farmers)	L	0.041	Ext
	Wildfowl consumers	L	0.007	Ext
Sellafield[f]	Fish and shellfish consumption and external in intertidal areas (2009-2013 surveys) (excluding naturally occurring radionuclides)[l]	L	0.12	Ext, $^{239/240}Pu$, ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2009-2013 surveys) (including naturally occurring radionuclides)[m]	L	0.18	Ext, ^{210}Po, $^{239/240}Pu$, ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2013 surveys) (excluding naturally occurring radionuclides)[l]	L	0.10	Ext, $^{129}I^{d}$, $^{239/240}Pu$, ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[j]	G	0.021	^{14}C, ^{90}Sr, $^{106}Ru^{d}$, ^{129}I
	Terrestrial foods at Ravenglass[j]	G/L	0.032	^{14}C, $^{106}Ru^{d}$, $^{144}Ce^{d}$
	External in intertidal areas (Ravenglass)[a]	L	0.011	Ext
	Occupancy of houseboats (Ribble estuary)	L	0.071	Ext
	Occupancy of houseboats (Barrow)	L	0.074	Ext
	External (skin) to bait diggers	L	0.020[g]	Beta
	Handling of fishing gear	L	0.14[g]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	$^{106}Ru^{d}$, $^{241}Am^{d}$
	Seaweed/crops at Sellafield	L	0.009	$^{106}Ru^{d}$, $^{241}Am^{d}$
Research establishments				
Culham	Water consumption[o]	L	<0.005	$^{137}Cs^{d}$
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext
	Terrestrial foods, external and inhalation near site	G	0.014	^{90}Sr, $^{129}I^{d}$, $^{238}Pu^{d}$, $^{239/240}Pu^{d}$, $^{241}Am^{d}$
Harwell	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	$^{3}H^{d}$, ^{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[j]	G	<0.005	^{14}C
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.008	^{14}C
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	0.005	^{14}C
Chapelcross	Wildfowl and fish consumption and external in intertidal areas	L	<0.005	Ext, $^{241}Am^{d}$
	Crustacean consumption	L	<0.005	^{137}Cs
	Terrestrial foods, external and inhalation near site[j]	G	0.018	^{90}Sr, $^{241}Am^{d}$
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext, ^{241}Am
	Occupancy of houseboats	L	0.017	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.009	^{14}C
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext, ^{241}Am
	Exposure over sand and sea coal	L	0.007	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.007	^{14}C, ^{35}S, $^{60}Co^{d}$
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.036	Ext, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
	External in intertidal areas (turf cutters)	L	0.016	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.012	^{14}C
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.031	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.015	^{14}C
Hunterston	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{137}Cs, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	0.009	^{14}C, $^{35}S^{d}$, ^{90}Sr
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Occupancy of houseboats	L	0.018	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.008	^{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[j]	G	0.006	$^{35}S^{d}$, ^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.013	Ext, ^{137}Cs, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	0.035	^{241}Am
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.007	Ext, ^{137}Cs, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	0.010	^{14}C, ^{35}S

Table 1.4. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[e]	Exposure, mSv[b] per year	Contributors[c]
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005[i]	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005[i]	^{3}H, ^{137}Cs[d], ^{234}U, ^{238}U
Barrow	Occupancy of houseboats	L	0.074	Ext
	Fish and shellfish consumption and external in intertidal areas	L	0.035	Ext, ^{241}Am
Derby	Water consumption, fish consumption and external to anglers[o]	L	<0.005	^{60}Co[d]
	Terrestrial foods, external and inhalation near site	G	<0.005	^{241}Am[d]
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{14}C, ^{241}Am[d]
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[p]	G	<0.005	^{3}H[d]
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am[d]
	Terrestrial food consumption	G	<0.005	^{241}Am[d]
Holy Loch	External in intertidal areas	L	<0.005	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	<0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.008	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[p]	L	0.014	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.016	^{14}C, ^{32}P[d]
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	Ext, ^{14}C, ^{125}I[d], ^{137}Cs
Industrial and landfill				
LLWR near Drigg	Terrestrial foods[j]	G	0.015	^{14}C, ^{106}Ru[d]
	Fish and shellfish consumption and external in intertidal areas (2009-2013 surveys) (including naturally occurring radionuclides)[f,l,m]	L	0.18	Ext, ^{210}Po, $^{239/240}Pu$, ^{241}Am
	Water consumption[o]	L	<0.005	
Whitehaven	Fish and shellfish consumption and external in intertidal areas (2009-2013 surveys) (excluding artificial radionuclides)[f,l]	L	0.059	^{210}Po
	Fish and shellfish consumption and external in intertidal areas (2009-2013 surveys) (including artificial radionuclides)[f,m]	L	0.18	Ext, ^{210}Po, $^{239/240}Pu$, ^{241}Am

* *Source specific dose assessments are performed to provide additional information and as a check on the* total dose *assessment method*

[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 dose is received by an adult*

[c] *The contributors that give rise to more than 10% 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. 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] *The assessed contribution is based on data being wholly at limits of detection.*

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

[f] *The estimates for marine pathways include the effects of liquid discharges from LLWR. The contribution due to LLWR is negligible*

[g] *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)*

[h] *10 y old*

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

[j] *1 y old*

[k] *Excluding the effects of artificial radionuclides from Sellafield*

[l] *Excluding 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 enhanced concentrations due to the legacy of discharges of naturally occurring radionuclides from a phosphate processing works, Whitehaven*

[n] *Including the effects of artificial radionuclides from Sellafield*

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

[p] *Prenatal children*

2. Nuclear fuel production and reprocessing

Key points

- *Total doses* for the representative person were less than 8 per cent of the dose limit for all sites assessed and significantly decreased at Sellafield
- Doses, discharges, environmental concentrations and dose rates in 2013 were broadly similar to those in 2012

Capenhurst, Cheshire

- *Total dose* for the representative person decreased in 2013
- Gaseous discharges of alpha and beta radionuclides from Capenhurst Nuclear Services Limited increased in 2013

Springfields, Lancashire

- *Total dose* for the representative person was lower in 2013 and less than 6 per cent of the dose limit. The highest exposure was represented by occupancy on a houseboat; this was the lowest reported value in 2013 for a number of years
- Gaseous discharges of other beta radionuclides decreased, and carbon-14 increased, in 2013. Liquid discharges were generally lower, including a decrease in releases of uranium, technetium-99 and beta radionuclides
- Gamma dose rates were generally similar in the vicinity of the houseboats in 2013

Sellafield, Cumbria

- *Total doses* for the representative person were less than 8 per cent of the public dose limit in 2013, down from 30 per cent in 2012
- The highest *total dose* relating to the effects of Sellafield was represented by occupancy of a houseboat near Barrow
- External radiation from sediments due to historical discharges dominated the highest *total dose*
- The representative person changed from a high-rate seafood consumer near Sellafield in 2012 to a houseboat dweller near Barrow in 2013
- Radiation dose from natural radionuclides represented by a high-rate consumer of seafood was significantly lower in 2013, mostly due to a decrease in polonium-210 in crustaceans from past phosphate processing at Whitehaven. The *total dose* to this consumer from Sellafield discharges decreased due to changes in seafood consumption
- Gaseous discharges were generally similar to 2012, except antimony-125 which increased in 2013
- Liquid discharges of carbon-14 and iodine-129 were increased by small amounts in 2013
- Concentrations of Sellafield derived radionuclides and dose rates were generally similar to those in 2012. Plutonium radionuclides and americium-241 were generally similar in shellfish

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 three sites in the UK associated with civil nuclear fuel production and reprocessing. These sites are at:

Capenhurst, a site where uranium enrichment is carried out and management of uranic materials and decommissioning activities are undertaken; Springfields, a site where fuel for nuclear power stations is fabricated; Sellafield, a site where irradiated fuel from nuclear power stations is reprocessed.

The Capenhurst site is owned partly by Urenco UK Limited (UUK) and partly by NDA. UUK holds the Site Licence, and their main commercial business is production of enriched uranium for nuclear power stations. The NDA's legacy storage and decommissioning activities are now managed by an Urenco Group company, Capenhurst Nuclear Services Limited (CNS), and another Urenco Group company, Urenco Chemplants Limited (UCP) is currently building a new facility on a separate part of the site.

Both the Springfields and Sellafield sites are owned by the NDA. The Springfields site is leased long-term to Springfields Fuels Limited, who carry out nuclear fuel manufacture and other commercial activities and also have a contract with NDA to decommission legacy facilities on the site. In the case of Sellafield, Nuclear Management Partners Limited (NMP) has been the Parent Body Organisation (PBO) for the Sellafield Site Licence Company (SLC), Sellafield Limited, since 2008. In October 2013, the NDA announced its intention to extend the services of NMP as Parent Body Organisation for a further five years. The Windscale site, also owned by the NDA, is located on the Sellafield site and in 2008 the site licence for Windscale

was transferred to Sellafield Limited, integrating the Windscale and Sellafield sites. Windscale is discussed in Section 2.4. Note that the LLWR site near Drigg is separate from Sellafield and is discussed in Section 7.1.

Gaseous and liquid discharges from each of these sites are regulated by the Environment Agency. In 2013, 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 summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

2.1 Capenhurst, Cheshire

The site, near Ellesmere Port, was previously split into two adjacent nuclear licensed sites at Capenhurst. One nuclear licensed site was owned by the NDA, comprising uranic material storage facilities and activities associated with decommissioning redundant plan, and the other owned by Urenco UK Limited (UUK), operating three plants producing enriched uranium for nuclear power stations. In November 2012, the NDA completed the transfer of its Capenhurst site with the transition of Sellafield Limited activities to Capenhurst Nuclear Services (CNS), creating one nuclear licensed site owned and managed by UUK. The major operators at the site are now UUK, CNS and Urenco Chemical Plants (UCP). UCP are currently constructing a new facility, to allow safer long-term storage of depleted uranium, on a separate part of the site. This facility, the Tail Management Facility, will de-convert Uranium Hexafluoride (UF_6) to Uranium Oxide (U_3O_8) to allow the uranium to be stored in a more chemically stable oxide form for potential future reuse in the nuclear fuel cycle and will recover hydrofluoric acid for reuse in the chemical industry. It is anticipated that this facility will become operational around 2016. The plant is permitted and, when commissioned, will discharge gaseous waste to the environment, aqueous waste to UUK's effluent disposal system and will dispose of solid waste by off-site transfer.

The most recent habits survey was conducted in 2008 (Tipple *et al.*, 2009).

Doses to the public

In 2013, the *total dose* from all pathways and sources is assessed to have been 0.080 mSv (Table 2.1), or 8 per cent of the dose limit, and similar to the value for 2012 of 0.085 mSv. The dose was mostly due to direct radiation from the Capenhurst site. The dose assessment identifies a local child living near to the site as the most exposed person. The trend in *total dose* over the period 2004 – 2013 is given in Figures 1.1 and 2.1. Any changes in total doses with time are attributable to changes in the estimates of direct radiation from the site.

Source specific assessments indicated exposures for high-rate consumers of locally grown foods, and for children playing in and around Rivacre Brook, were less than the *total dose* in 2013 (Table 2.1). The dose for 10 year old children (who play near the brook and may inadvertently ingest water and sediment) was 0.011 mSv in 2013 and similar to that in previous years. The dose is estimated using cautious assumptions for occupancy of the bank of the brook, inadvertent ingestion rates of water and sediment and gamma dose rates.

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 CNS Limited (previously Sellafield Limited). Discharges of alpha and beta radionuclides increased from CNS Limited, in comparison to releases in 2012, due to an increased throughput from the Bottle Wash Facility in 2013. 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 2013 are given in Table 2.2(a). Concentrations of radionuclides in milk and food samples around the site were very low and similar to previous years. Concentrations of technetium-99 and uranium in soils were also low, with small increases in technetium-99 concentrations (in comparison to those in recent years). Figure 2.2 shows the trend of technetium-99 concentrations in grass from 2003. The trend reflects the reductions in discharges of technetium-99 from recycled uranium. In future, the enrichment of reprocessed uranium is anticipated to increase, which may lead to increases in discharges of technetium-99 and neptunium-237, if recycled uranium is processed. However, no increase is expected in the discharge limits.

Liquid waste discharges and aquatic monitoring

The UUK permit for the Capenhurst site allows liquid waste discharges to the Rivacre Brook for uranium and uranium daughters, technetium-99 and non-uranium alpha (mainly

Figure 2.1. *Total dose* due to operations, nuclear fuel production and reprocessing sites, 2004-2013
(Exposures at Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

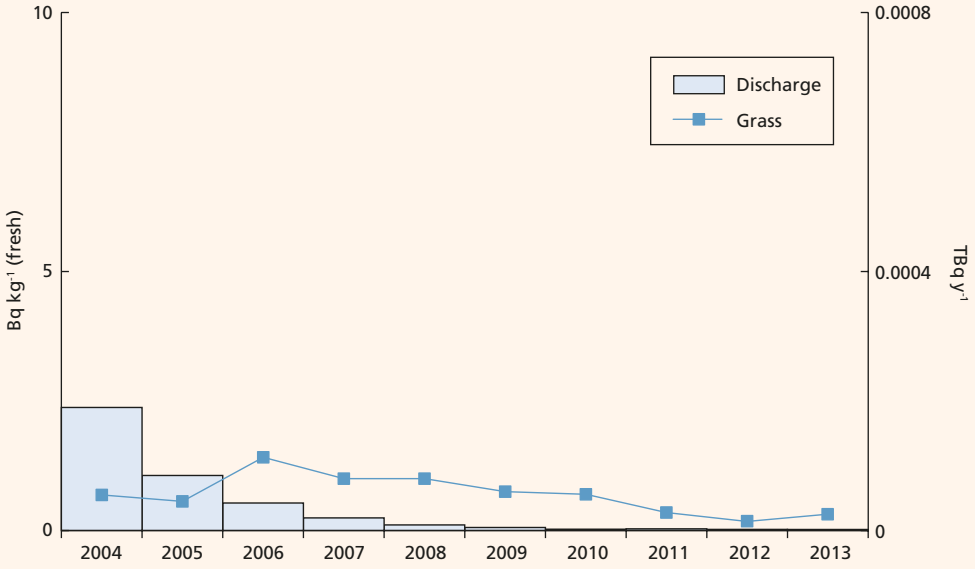


Figure 2.2. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2004-2013

neptunium-237). In 2013, discharges from Capenhurst were similar to those in 2012.

Monitoring included the collection of samples of fish and shellfish from the local marine environment (for analysis of a range of radionuclides) and of freshwater and sediments for the analysis of tritium, technetium-99, gamma emitting radionuclides, uranium, neptunium-237, and gross alpha and beta. Dose rate measurements were taken on the banks of the Rivacre Brook. Results for 2013 are given in Tables 2.2(a) and (b). Concentrations of radionuclides in foods from the local marine environment and dose rates were very low and generally similar to those in previous years. Thorium-234 in cockles was positively detected in 2013, just above the LoD. Downstream of the Rivacre Brook (at the location where children play), dose rates were generally similar to those in 2012 (these have been decreasing in previous years). The low concentrations in fish and shellfish reflect the distant effects of discharges from Sellafield. 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 recent years, measured dose rates were higher, relative to natural background, near to the discharge point.

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 monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.3.

The most recent habits survey was undertaken in 2012 (Ly *et al.*, 2013). In 2013 habits information, based on a five-year rolling average (2009 – 2013) was revised, resulting in a lower occupancy rate for high-rate houseboat dwellers. Revised figures for consumption rates, together with occupancy and handling rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

In 2013, the *total dose* from all pathways and sources is assessed to have been 0.060 mSv (Table 2.1), or 6 per cent of the dose limit. The person most affected was an adult houseboat dweller in a boatyard, who was exposed to external radiation from activity in muddy sediments. The dose to the houseboat dweller in 2013 was lower than in 2012 (0.068 mSv). The small reduction in *total dose* was mostly because gamma dose rates were measured on different types of substrate (at Freckleton). *Total doses* over the period 2004 – 2013 are given in Figure 2.4. Most recently, the estimated *total dose* has decreased, with the lowest reported value in 2013, due to direct measurements beneath houseboats being available.

Source specific assessments indicated that exposures were all less than or similar to the *total dose* (Table 2.1) for;

- Consumers of locally grown food and of seafood
- High-occupancy houseboat dwellers in the Ribble Estuary
- Children playing on the banks of the estuary
- Farmers spending time on the banks of the estuary
- Wildfowlers consuming game obtained from the estuary area

In 2013, the source specific assessment gave an estimated dose to a high-occupancy houseboat dweller of 0.071 mSv or approximately 7 per cent of the dose limit for members of the public of 1 mSv. This value is marginally higher than the *total dose* of 0.060 mSv assessed for the same representative person. The *total dose* assessment is based on more realistic assumptions. The dose to the representative person for high-rate consumers of seafood (including a contribution from external exposure) was 0.023 mSv in 2013. Of this dose, 0.021 mSv was from external exposure and the remainder was from the consumption of fish and shellfish. The dose in 2012 was 0.022 mSv. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site.

As in 2012, assessments were undertaken to determine the dose to wildfowlers from external exposure over salt marsh and the consumption of game, and to determine the dose to farmers from external exposure, at Springfields. The

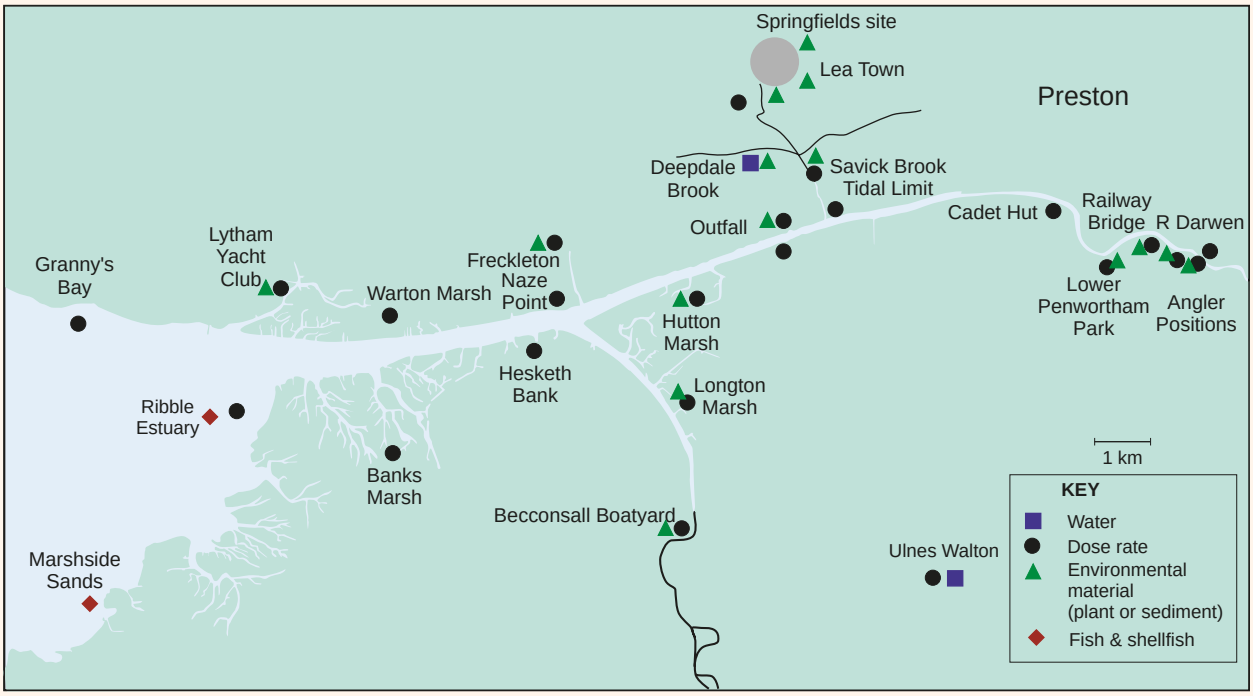


Figure 2.3. Monitoring locations at Springfields, 2013 (not including farms)

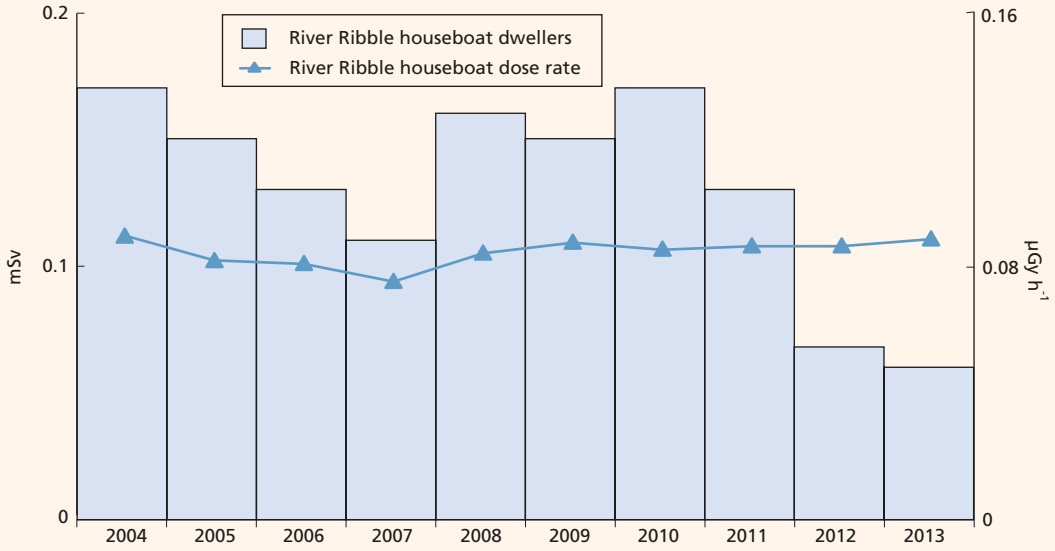


Figure 2.4. *Total dose* from all sources and dose rates at Springfields, 2004-2013

estimated doses in 2013 were 0.007 mSv and 0.041 mSv, respectively, for these pathways (Table 2.1).

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. Discharges of other beta radionuclides decreased, and carbon-14 increased, from the research and development facilities in 2013, in comparison to 2012.

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 2013 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. Carbon-14 concentrations were generally increased in foodstuffs (in comparison to those in 2012) and were all above the default values used to represent background levels. Most other concentrations of radionuclides were at limits of detection. Results were broadly similar to those of previous years.

Figure 2.5 shows the trends over time (2004 – 2013) of uranium discharges and total uranium radionuclide concentrations in food (cabbage). Over the period, concentrations of uranium were also found in soil around the site, but the isotopic ratio showed that they were naturally occurring. Total uranium was detected in cabbage samples during the period (no data in 2006), but the concentrations were very low. The apparent peak of uranium in cabbage in 2007 was also low and significantly less than that found in soil samples.

Liquid waste discharges and aquatic monitoring

Permitted 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 2013 were generally lower in comparison to those in 2012, 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. Process improvements in the uranium hexafluoride production plants on the Springfields site have reduced the amounts of other uranium compounds needing recycling; these improvements, alongside a reduction in legacy uranic residue processing, have led to a corresponding reduction in discharges of uranium in 2013. Discharges of technetium-99 depend almost entirely on which legacy uranic residues are being processed. Since completion of one particular residue processing campaign around the end of 2012, technetium-99 discharges have also decreased in 2013. 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 2013 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 were closely linked to recent discharges from the Springfields site. In 2013, thorium-234 concentrations in sediments (over the range of sampling sites) were generally similar compared to those in 2012. Over a much longer timescale (2004 – 2013), these concentrations have declined due to reductions in discharges as shown by the trend of sediment concentrations at the outfall, Lower Penwortham and Becconsall (Figure 2.5). The most significant change in the discharge trends was the step reduction of short half-life beta emitting radionuclides in liquid discharges, mostly thorium-234. The reduction was because the Uranium Ore Concentrate purification process ended in 2006.

Caesium-137, americium-241 and plutonium radionuclides were found in biota and sediments from the Ribble Estuary in 2012. The presence of these radionuclides was 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 generally similar to those in recent years.

Figure 2.5 also provides trend information over time (2004 – 2013) for a number of other permitted radionuclides and activity concentrations in food. Liquid discharges of uranium radionuclides steadily decreased (and other discharges to a lesser extent) over the whole period, whilst technetium-99 discharges increased (to a small extent) in recent years. Caesium-137 concentrations in flounder and salmon showed variations between years and this was mostly due to natural changes in the environment. Concentrations of technetium-99 in shrimps declined over the whole period, consistent with the reduction in technetium-99 discharges from Sellafield (Figure 2.14).

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 2013, gamma dose rates in the estuary, excluding rates taken for houseboat assessments, were generally similar to those in 2012, but with some small variations at some sites. Gamma dose rates measured in the vicinity of houseboat dwellers in 2013 (at Becconsall) were generally similar to those in 2012. Where comparisons can be made from similar ground types and locations, beta dose rates from sediments in 2013 were generally similar to those in recent years.

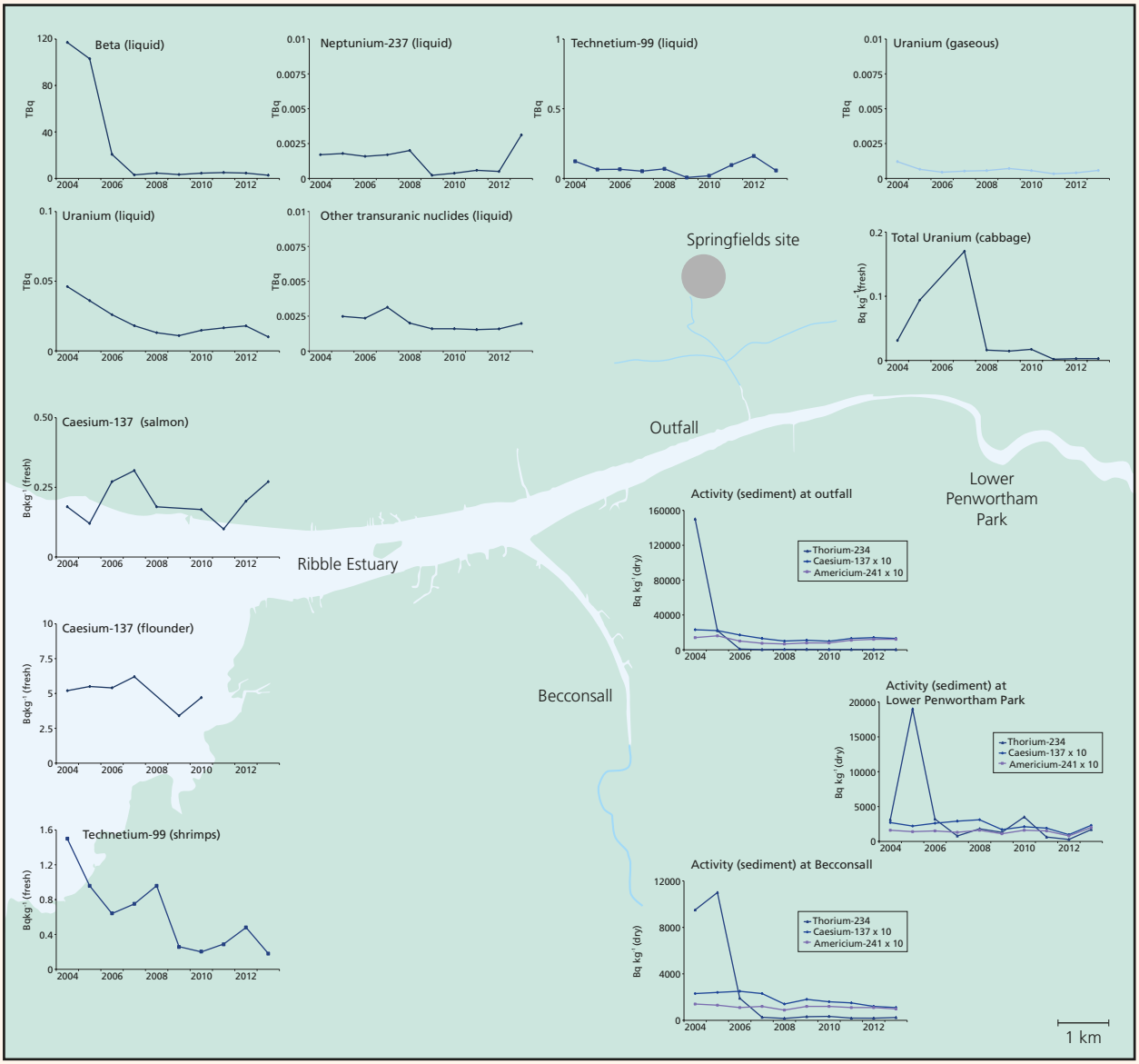


Figure 2.5. Discharges of gaseous and liquid radioactive wastes and monitoring of the environment, Springfields 2004–2013 (Note different scales used for discharges and activity concentrations)

2.3 Sellafield, Cumbria

This site is operated by Sellafield Limited (formerly 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 at Sellafield, and is discussed in Section 2.4.

In 2011, Sellafield Limited and the NDA published their plans for decommissioning of the Sellafield site (http://www.sellafieldsites.com/wp-content/uploads/2012/08/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. In 2013, a number of decommissioning projects continued including that of the Calder Hall reactors.

During the financial year 2013/14, 346 tonnes of spent oxide fuel (229 tonnes in 2012/13) was reprocessed in THORP, compared with an original performance target of 423 tonnes. The reprocessing of spent Magnox fuel for

2013/14 was a total of 470 tonnes of fuel (383 tonnes in 2012/13), compared with an original performance target of 644 tonnes. The reprocessing of the remaining fuel is scheduled for an end to reprocessing in 2018 and 2020 for THORP and Magnox reprocessing, respectively.

Every five years, a full 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. Annual review habits surveys are undertaken between these full habits surveys. These annual surveys investigate the pathways relating to liquid discharges, review high-rate fish and shellfish consumption by local people (known as the Sellafield Fishing Community) and review their intertidal occupancy rates. The most recent five-year habits survey was conducted in 2013 (Clyne *et al.*, 2014). Changes were found in the amounts and mixes of species consumed from the annual review habits survey conducted in 2012 (Papworth *et al.*, 2013). The most recent habits survey to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast was conducted in 2012 (Garrod *et al.*, 2013a). The results of this survey are used to determine the potential exposure pathways relating to permitted liquid discharges from the Sellafield nuclear licensed site in Cumbria. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1 (Table X2.2).

Habits surveys to obtain data on activities undertaken on beaches relating to potential public exposure to radioactive particles in the vicinity of the Sellafield nuclear licensed 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 historical 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 here 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 2013 (Clyne *et al.*, 2014) and the yearly review in 2012 (Papworth *et al.*, 2013). Calculations are performed for four age groups (adult, 10y, 1y and prenatal). The effects on high-rate consumers of fish and shellfish from historical discharges of naturally occurring radionuclides from non-nuclear industrial activity from the former phosphate works at Whitehaven are included to determine their contribution to the *total dose*. These works were demolished in 2004 and the authorisation to discharge radioactive wastes was revoked. The increase in concentrations of naturally occurring radionuclides due to the historical discharges is difficult to determine above a variable background (see Appendix 1).

In 2013, the highest *total dose* relating to the effects of Sellafield was assessed to have been 0.076 mSv, or less than 8 per cent of the dose limit to members of the public (Table 2.18). The most exposed person was an adult who was living on a houseboat on the Cumbrian coast near Barrow, and the *total dose* was entirely due to external radiation from sediments (due to the effects of historical Sellafield discharges). This represents a change in the most exposed person, from a high-rate seafood consumer near Sellafield (molluscan shellfish) in 2012, and a significant decrease from the total dose of 0.30 mSv in 2012. This was mostly attributable to (i) a decrease in concentrations of polonium-210 in locally caught crustaceans (crabs), and to lesser extents, from the decrease in concentrations of polonium-210 in locally caught fish (plaice) and (ii) a reduction in the breadth of seafood species consumed (from the revision of habits information), by the most exposed person for seafood consumption in 2013 (compared to those in 2012). Direct radiation from the Sellafield site (0.002 mSv, Table 1.1) was considered in the *total dose* assessments, but this made an insignificant contribution.

Contributions to the highest *total dose* each year, from all pathways and sources by specific radionuclides, are given in Figure 2.6 over the period 2003 – 2013. The trend of generally declining 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, from 2008 to 2009 and from 2012 to 2013) 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 most exposed person (from a consumer of molluscan shellfish to locally harvested marine plants). The largest proportion of the *total dose,* up till 2008 and again in 2011 and 2012, was mostly due to enhanced naturally occurring radionuclides from the historical discharges at Whitehaven and a smaller contribution from the historical discharges from Sellafield. From 2008 to 2010, the net result of progressive reductions of the naturally

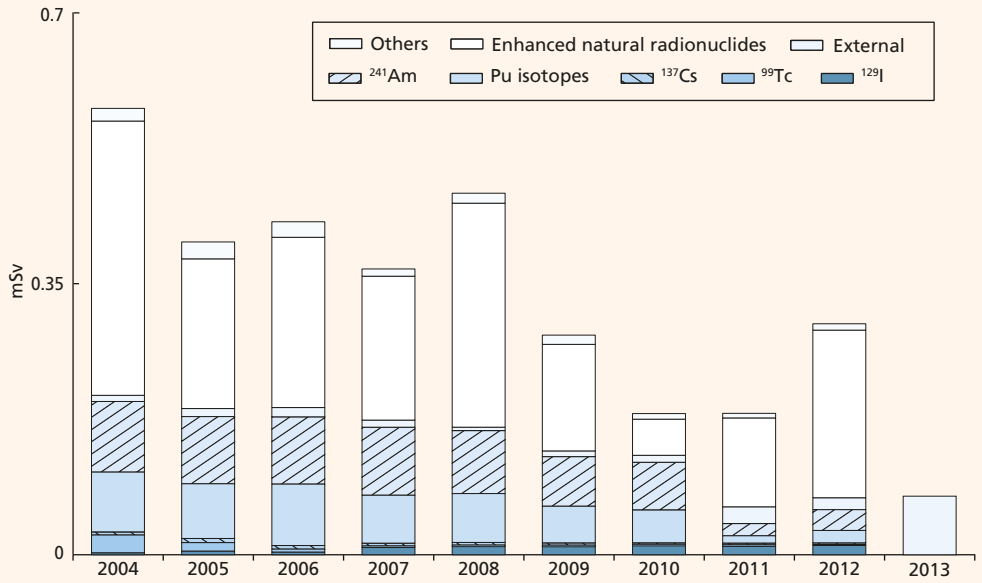


Figure 2.6. Contributions to *total dose* from all sources at Sellafield, 2004-2013

occurring radionuclides contribution to the *total dose* has been a relative increase in the proportion from artificial radionuclides. In 2013, whilst doses were still received in the vicinity of the Sellafield site through consumption of seafood by some people, a greater *total dose* was received by others further afield. In their case, the *total dose* was entirely due to external radiation from sediments (due to the effects of historical Sellafield discharges).

Total dose from all pathways and sources in the vicinity of the Sellafield site

The highest *total dose* for a local high-rate seafood consumer was assessed to have been 0.061 mSv in 2013, or approximately 6 per cent of the dose limit to members of the public (Table 2.18). The most exposed age was for an adult who consumed marine fish. This represents a change in the most exposed person from one who consumed molluscan shellfish at a high rate in 2012. Their *total dose* was 0.30 mSv in 2012.

In percentage terms, the most significant contributors to the *total dose* in the vicinity of the Sellafield site was from fish consumption, external exposure over sediments, crustacean consumption and mollusc consumption (59, 22, 14 and 4 per cent, respectively), the most important radionuclides were polonium-210, iodine-129, carbon-14, americium-241, caesium-137 and plutonium-239+240 (33, 21, 7, 5, 5 and 2 per cent, respectively).

Artificial radionuclides discharged by Sellafield (including external radiation) and historical discharges of naturally occurring radionuclides from Whitehaven contributed 0.040 mSv and 0.021 mSv, respectively (values are rounded to two significant figures). In 2012, the contributions were 0.082 mSv and 0.22 mSv, respectively. In 2013, the contribution from the external radiation was approximately 0.014 mSv (0.016 mSv in 2012). Data for naturally occurring radionuclides in fish and shellfish, and their variation in recent years, are discussed in Section 7.

The contribution to the *total dose* of 0.040 mSv in 2013 from artificial radionuclides (including external radiation) was lower than in 2012 (0.082 mSv). In 2013, the contributing radionuclides were mostly iodine-129, carbon-14 and caesium-137 (32, 10 and 7 per cent, respectively). Americium-241 and plutonium-239+240 contributed to a much lesser extent (7 and 3 per cent, respectively) in comparison to values in 2012 (33 and 15 per cent, respectively). The contribution to *total dose* from external exposure was 33 per cent (19 per cent in 2012). The decrease in the contribution to the *total dose* from 2012 was mostly due to the changes in seafood consumption (from the revision of habits information) of the representative person.

The contribution to the *total dose* of 0.021 mSv in 2013 from naturally occurring radionuclides was significantly lower than in 2012 (0.22 mSv). In 2013, the most contributing radionuclide was polonium-210 (96 per cent). A decrease in the polonium-210 concentrations in locally caught crustaceans (crabs), and to lesser extents, from the decrease in concentrations of polonium-210 in locally caught fish (plaice) and the reduction in the breadth of seafood species consumed (from the revision of habits information), by the most exposed person for seafood consumption in 2013 (compared to those in 2012). As in the previous 2 years, polonium-210 concentrations (above expected background) in mollusc samples did not contribute to the *total dose* in 2013 (~0.007 mSv in 2010).

Other age groups received less exposure (from seafood consumption) than the adult *total dose* of 0.061 mSv in 2013 (10y: 0.025; 1y: 0.011; prenatal: 0.037, 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.

Total dose from all pathways and sources (further afield from the Sellafield site)

With reductions in concentrations and in dose rates near to the Sellafield site in recent years, the relative importance of *total dose* further field has become more important. The monitoring data and assessments show that, in 2013, the highest *total dose* due to Sellafield operations is represented by an adult living on a houseboat near to the Barrow site (0.076 mSv). The small increase in dose from 0.057 mSv (in 2012) was due to an increase in dose rates underlying the houseboats in 2013.

Total dose from gaseous discharges and direct radiation

In 2013, the dose to a representative person receiving the highest *total dose* from the pathways predominantly relating to gaseous discharges and direct radiation was 0.012 mSv (Table 2.18), from 0.011 mSv in 2012 (values rounded to two significant figures). The most exposed age was an adult who was a high-rate consumer of mushrooms. In 2012, the most exposed age was an infant (1y) who was a high-rate consumer of root vegetables. The most significant contributors in 2013 to the *total dose* for an adult were from the consumption of potatoes, root vegetables, domestic fruit and other domestic vegetables (33, 23, 23 and 13 per cent, respectively), the most important radionuclides were americium-241, strontium-90, carbon-14, iodine-129 and ruthenium-106 (25, 23, 19, 16 and 11 per cent, respectively). Other ages received less exposure than the adult *total dose* of 0.012 mSv in 2013 (10y: 0.012; infant: 0.012; prenatal: 0.009, equivalent values rounded to two significant figures).

Contributions to the highest *total dose* each year, by specific radionuclides, are given in Figure 2.7 over the period 2004 – 2013. Up until 2007, there was a small decline in *total dose* due to a general reduction in concentrations of radioncuclides in food and the environment caused, in part, by reductions in discharges in this period and beforehand. The main feature in the changes in *total dose* over the whole period was the increase in 2009. This resulted from an increase of total radiocaesium in game collected near the site. There is no evidence to suggest that this was caused by a change in site operations.

Total dose from liquid discharges

The people receiving the highest *total dose* from the pathways predominantly relating to liquid discharges (both for living on houseboats near Barrow and for high-rate seafood consumers) are given in Table 2.18. Each *total dose* is the same as that giving their 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), to account for 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 2013, a 1 year-old child, who was a high-rate consumer of milk and was exposed to external and inhalation pathways from gaseous discharges, received the highest dose for all ages, at 0.021 mSv (adult: 0.015; 10y: 0.017; prenatal: 0.012) or approximately 2 per cent of the dose limit to members of the public (Table 2.18). The reason for the higher dose in 2013 (from 0.016 mSv in 2011) is mostly due to an increased maximum carbon-14 concentration in milk and, to a lesser extent, an increased strontium-90 concentration in domestic fruit.

Doses from seafood consumption

Two sets of habits data are used in these dose assessments. One is based on the habits seen in the area each year (2013 habits survey). The second is based on a five-year rolling average using habits data gathered from 2009 to 2013. Changes were found in the amounts and mixes of species consumed. For molluscs, the consumption rate increased in 2013, but decreased overall for the 2009 – 2013 data set. Conversely, crustacean consumption rates decreased in 2013, but with a small increase for the 2009 – 2013 data set. The occupancy rate over sediments decreased in both 2013 and 2009 to 2013 data sets. The revised habits data are given in Appendix 1 (Table X2.2). Aquatic pathway habits are normally the most important in terms of dose near 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

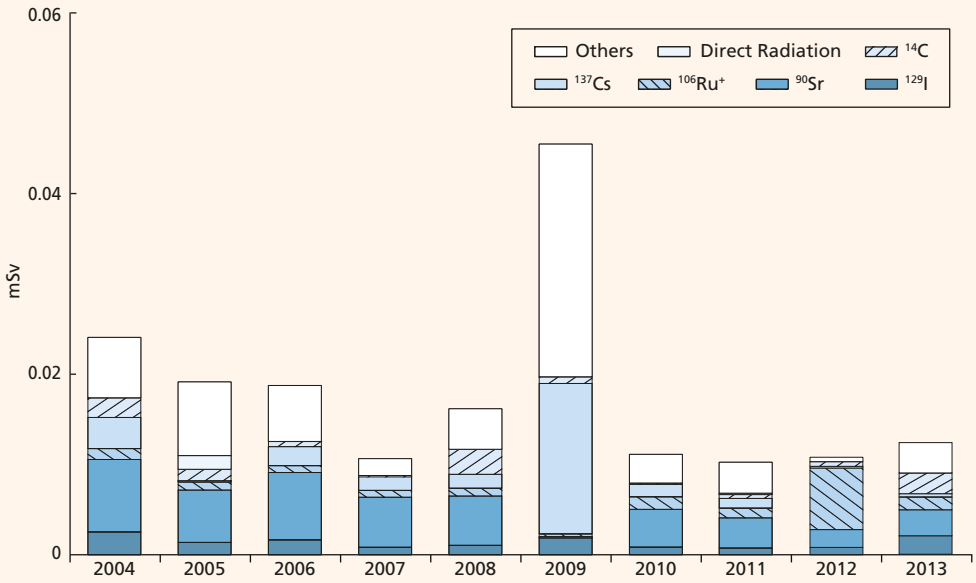


Figure 2.7. Contributions to *total dose* from gaseous discharge and direct radiation sources at Sellafield, 2004-2013 (+ based on limits of detection for concentrations in foods)

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 2013. The doses from artificial radionuclides to people, who consume a large amount of seafood, were 0.10 mSv and 0.12 mSv, using the annual and five-year rolling average habits data, respectively. These doses were generally similar and each includes a contribution due to external radiation exposure over sediments.

The dose to a local person (high-rate consumer of seafood) 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 0.059 mSv in 2013. Most of this was due to polonium-210 (96 per cent). The reason for the large decrease in dose in 2013 (from 0.19 mSv in 2012) is the same as that contributing to maximum *total dose*, that is to say (i) lower polonium-210 concentrations in seafood and (ii) a reduction in the breadth of seafood species consumed. For comparison (with the assessment using the five-year rolling average habits data), the dose from the single-year assessment for the Sellafield seafood consumer (based on consumption rates and habits survey data in 2013) was 0.029 mSv (Table 2.18).

Taking artificial and enhanced natural radionuclides together, the source specific doses were 0.13 mSv and 0.18 mSv for annual and five-year rolling average habits data, respectively. These estimates are larger than the estimate of *total dose* from all sources in the vicinity of Sellafield of 0.061 mSv. The main reason for this is a difference in the approach to selecting consumption rates for seafood for 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 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 in the wider communities were significantly less than for the local Sellafield population because of the lower concentrations and dose rates further afield. There were generally small changes in the doses (and contribution to doses) in each area when compared with those in 2012 (Table 2.17). All doses were well within the dose limit for members of the public of 1 mSv.

The dose to a person, who typically consumes 15 kg of fish per year from landings at Whitehaven and Fleetwood, is also given in Table 2.18. This consumption rate used represents an average for a typical consumer of seafood from the north-east Irish Sea. The dose was very low, less than 0.005 mSv in 2013.

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 of the north-east 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 re-suspended 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 2013 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, was received by a representative person living in houseboats near Barrow in Cumbria. In 2013, the dose was 0.074 mSv or less than 8 per cent of the dose limit for members of the public. Other people received lower external doses in 2013. The estimated dose to a person who spends a long time over the marsh in the Ravenglass Estuary was 0.011 mSv. The decrease in dose from 0.018 mSv (in 2012) was attributed to lower occupancy rates in 2013. Overall, gamma dose rates measurements in 2013 were generally similar to those in 2012 in the Ravenglass Estuary.

The doses to people in 2013 from a number of other activities were also estimated. Assessments were undertaken for a typical resident using local intertidal areas for recreational purposes at 300 hours per year, and for a typical tourist visiting the coast of Cumbria with 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), were assessed: residents that visit and use beaches and residents that visit local muddy areas or salt marsh. Typical occupancy rates (Clyne *et al*., 2008a; 2010a) are assumed and appropriate gamma dose rates have been used from Table 2.9. The activities for the typical tourist include consumption of local seafood and occupancy on beaches. Concentrations of radioactivity in fish and shellfish have been used from Tables 2.5 – 2.7, and appropriate gamma dose rates used from Table 2.9. The consumption and occupancy rates for activities of a typical resident and tourist are provided in Appendix 1 (Table X2.2).

In 2013, the doses to people from recreational use of beaches varied from 0.006 to 0.012 mSv with the higher doses being closer to the Sellafield source. The doses for recreational use of salt marsh and muddy areas had a greater variation from <0.005 to 0.015 mSv but were of a similar order of magnitude. The values for these activities were similar to those in recent years. The dose to a 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, both the rates for handling nets and pots and for handling sediments were lower in comparison to those in 2012. Revised handling figures are provided in Appendix 1 (Table X2.2). In 2013, the skin doses to a fisherman from handling his gear (including a component due to naturally occurring radiation), and a bait digger and a shellfish collector from handling sediment, were 0.14 mSv and 0.020 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, an infant represented those receiving the highest dose from consuming terrestrial foods that were potentially affected by radionuclides transported to land by sea spray. In 2013, their dose (including contributions from Chernobyl and weapon test fallout) was estimated to be 0.032 mSv, which was less than 4 per cent of the dose limit for members of the public. The largest contribution to the dose was from ruthenium-16 in milk. This represents an increase in the dose, in comparison to that in 2012 (0.018 mSv). The increase in dose was mostly attributed to a higher ruthenium-106 concentration in milk. The higher value was based on results at the limits of detection and the dose estimate is therefore an upper estimate. In 2012, other data were available to use models to improve, and reduce, the estimate of ruthenium-106 in foods. As in previous years, sea-to-land transfer was not of radiological importance in the Ravenglass area.

Doses from seaweed and seawashed pasture

In South Wales the food item laverbread, made from the brown seaweed *Porphyra,* is eaten. In 2013, a high-rate consumer received less than 0.005 mSv. Only small quantities of samphire, *Porphyra* and *Rhodymenia* (a red seaweed) are generally consumed, confirming this exposure pathway was of low radiological significance.

Seaweeds are sometimes used as fertilisers and soil conditioners. Assuming that a high-rate vegetable consumer obtains all of his/her supplies from the monitored plots near Sellafield, the dose in 2013 was estimated to be 0.009 mSv This dose was similar to that

in 2012 (0.008 mSv). 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. As in 2012, the adult age group received the highest dose and the small change in the dose was mostly due to an increase in the LoD for americium-241 in leafy green vegetables in 2013. 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 was 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 2013 (Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999). A further research study (relevant to the Scottish islands and coastal communities), conducted by PHE 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's 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, as well as from Calder Hall Power Station. Discharges from Calder Hall are now much reduced since the power station ceased generating electricity in 2003. Discharges to atmosphere during 2013 are summarised in Appendix 2 (Table A2.1). The permit limits gaseous discharges for gross alpha and beta activities, and 13 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 2013 were much less than the permit limits, and were generally similar to those in 2012. Discharges of antimony-125 increased in 2013 (together with small increases in tritium, carbon-14 and krypton-85), whilst plutonium radionuclides, alpha and beta radionuclides decreased by a small amount, in comparison to those in 2012.

Monitoring around the site related to gaseous discharges

Monitoring of terrestrial foods in the vicinity of Sellafield is conducted by the Food Standards Agency to reflect the scale of discharges from the site. This monitoring is the most extensive of that for the nuclear licensed sites in the UK. A wide range of foodstuffs was sampled in 2013 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 2013 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 recent years. 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 carbon-14 and strontium-90 (values for Organically Bound Tritium (OBT) and iodine radionuclides were below the limit of detection). Plutonium concentrations and americium-241 in game (wood pigeon), when detectable, were low and much lower than those found in seafood.

A wide range of fruit and vegetables was sampled in 2013 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 milk in 2013, just above the LoD. Small enhancements (above expected background) in concentrations of carbon-14 were found in some food samples (including meat and offal), as in recent years. Concentrations of transuranic radionuclides, when detectable in these foods, were very low. As in 2012, antimony-125 concentrations in 2012 were below limits of detection in foods and soil, and just above the detection limit in some grass samples, despite relatively enhanced discharges in recent years. Trends in maximum concentrations of radionuclides in milk, and corresponding discharge levels, near Sellafield over the last decade are shown in Figure 2.8. Over the whole period, concentrations of carbon-14 were relatively constant (with some variation between years, generally consistent with changes in discharges), and caesium-137 concentrations (and strontium-90 to a lesser extent) were declining overall.

2.3.3 Liquid discharges

Regulated liquid discharges derive from a variety of sources at the site including the fuel storage ponds, the

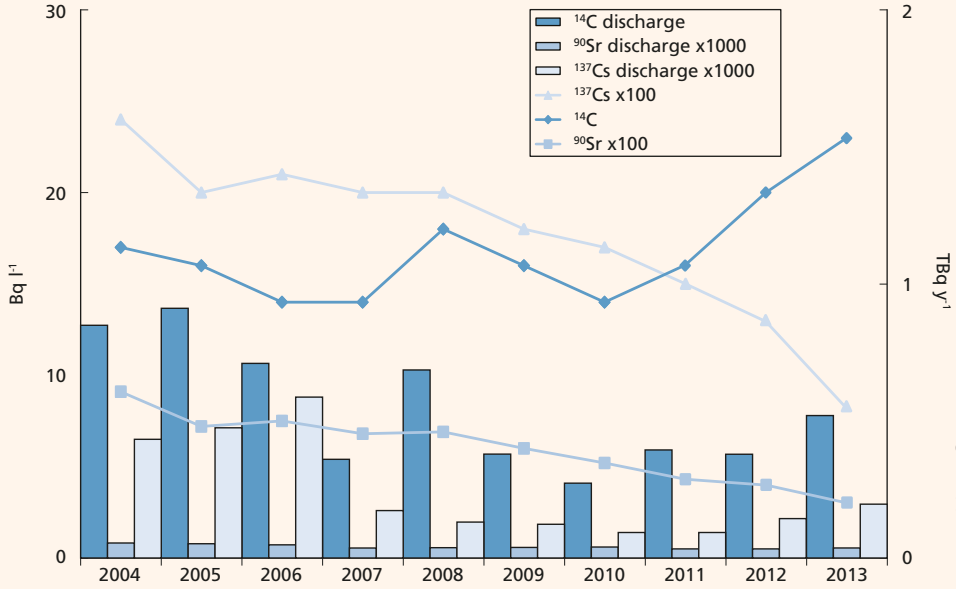


Figure 2.8. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2004-2013

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 River Ehen Estuary. Discharges from the Sellafield pipelines during 2013 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, Site Ion Exchange Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP). All of the discharges in 2013 were well below the limits in the permit. Most liquid discharges were generally similar in comparison to those in 2012, although carbon-14 and iodine-129 releases to the sea pipelines increased by small amounts, whilst releases to the factory sewer were lower, in 2013. 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 2013, to those in 2012. The long-term downward trend, from their peak of 192 TBq in 1995, has continued (Figure 2.9). 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.

Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2013, by the Environment Agency and Food Standards Agency (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland). The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figures 2.10 and 2.11. The medium-term trends in discharges, environmental concentrations and dose were considered in a 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 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.

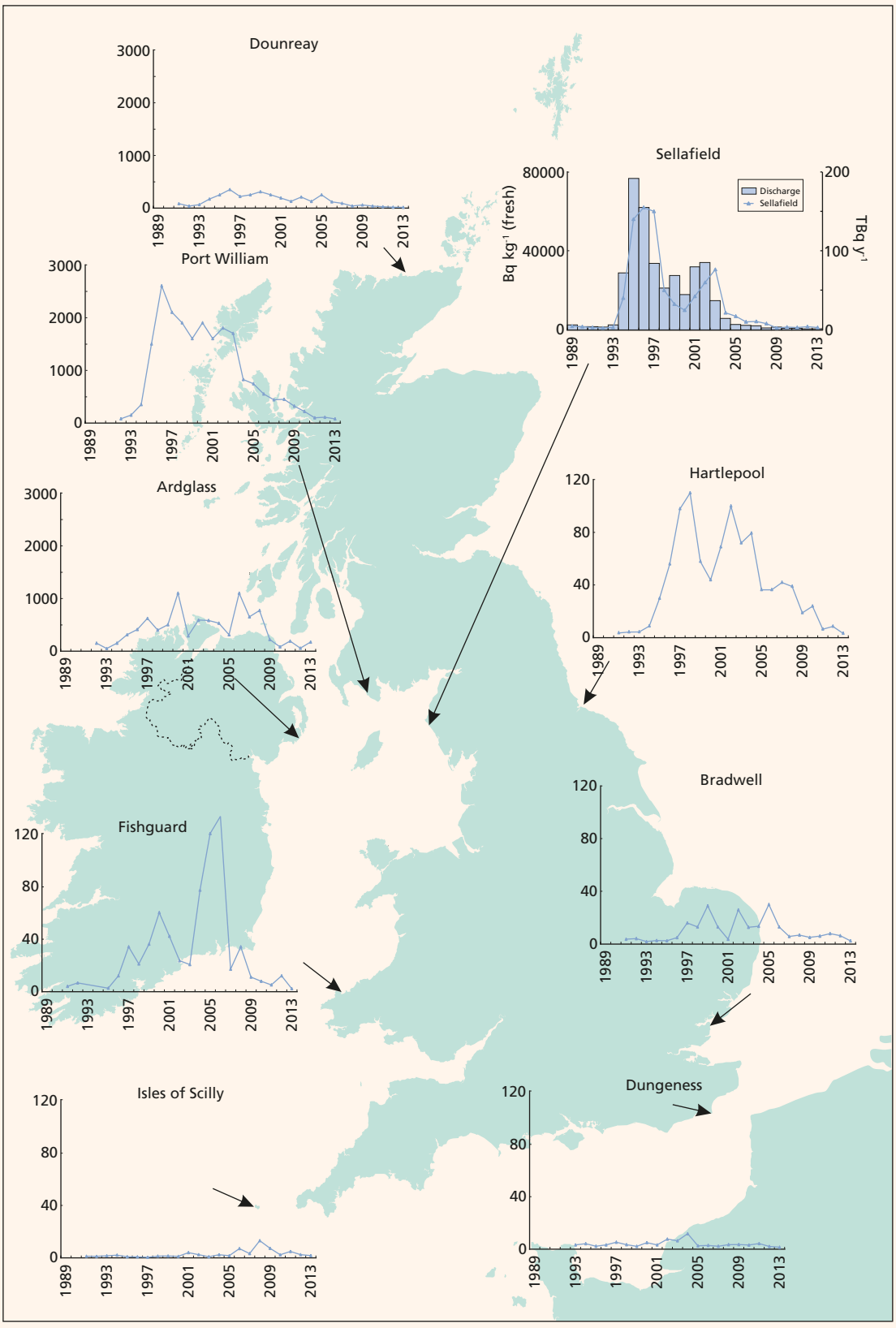


Figure 2.9. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2013 (Note different scales used for Ardglass, Dounreay, Port William and Sellafield)

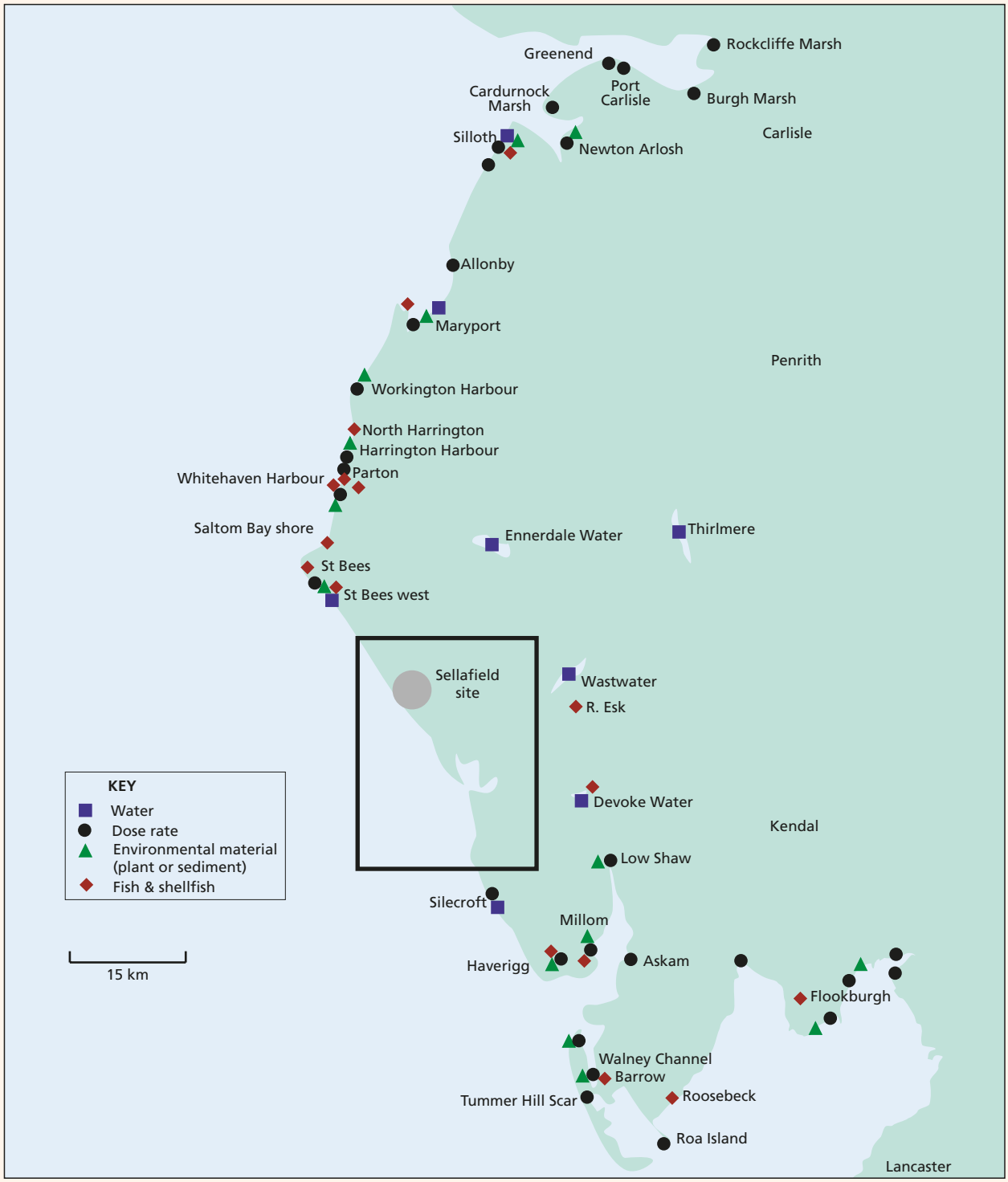


Figure 2.10. Monitoring locations in Cumbria, 2013 (not including farms)

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 2.12 – 2.17. There was variability from year to year, particularly for the more mobile radionuclides. Liquid discharges of technetium-99 in 2013 were similar to those in 2012. Overall, concentrations of technetium-99 in fish and shellfish have shown a continued reduction from the elevated levels in 2004, but were generally similar (with minor variations) over most recent years (Figure 2.14). For the transuranic elements (Figures 2.16 – 2.17), the long-term trends in reductions of concentrations from earlier decades appear to be slowing. Over the last decade, despite generally decreasing discharges, concentrations of americium-241 and plutonium-239+240 in fish and shellfish have shown some variations from year to year. Overall, concentrations

Figure 2.11. Monitoring locations at Sellafield, 2013 (not including farms)

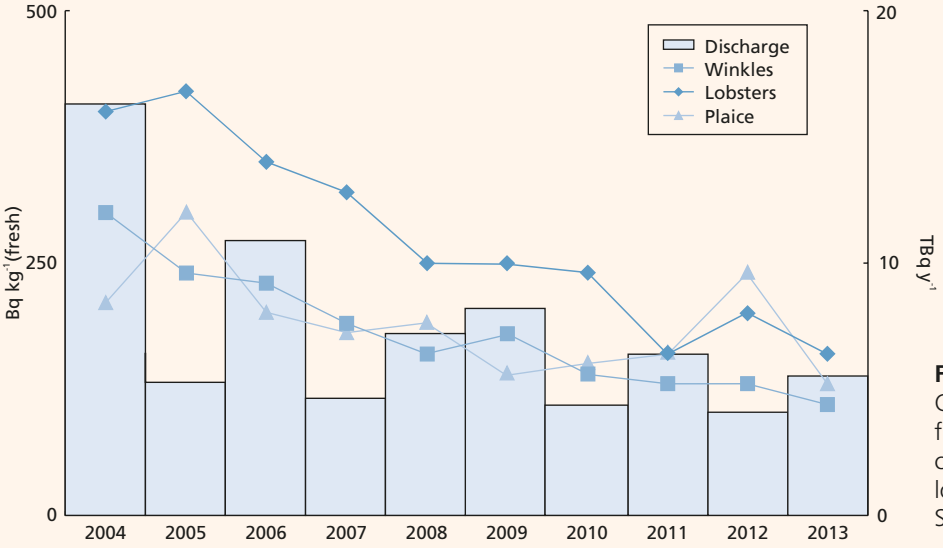


Figure 2.12.
Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

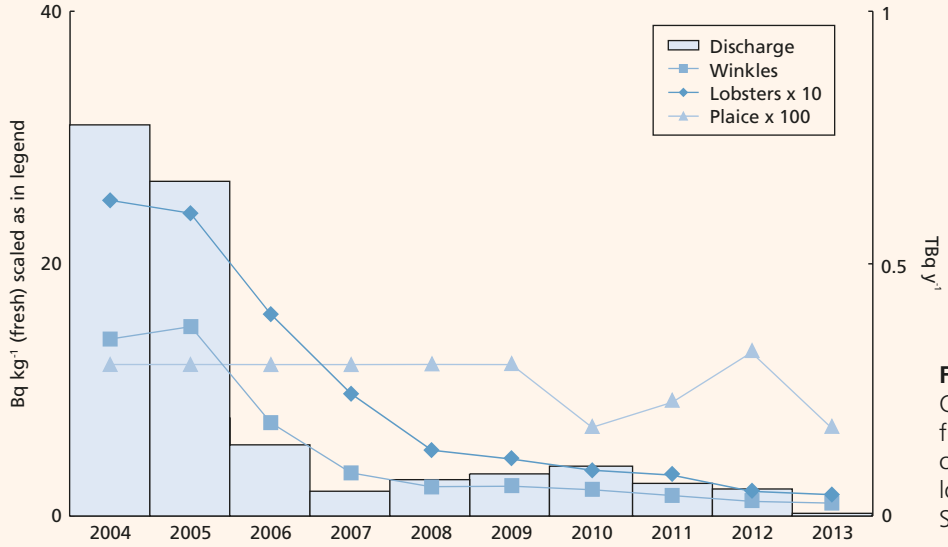


Figure 2.13.
Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

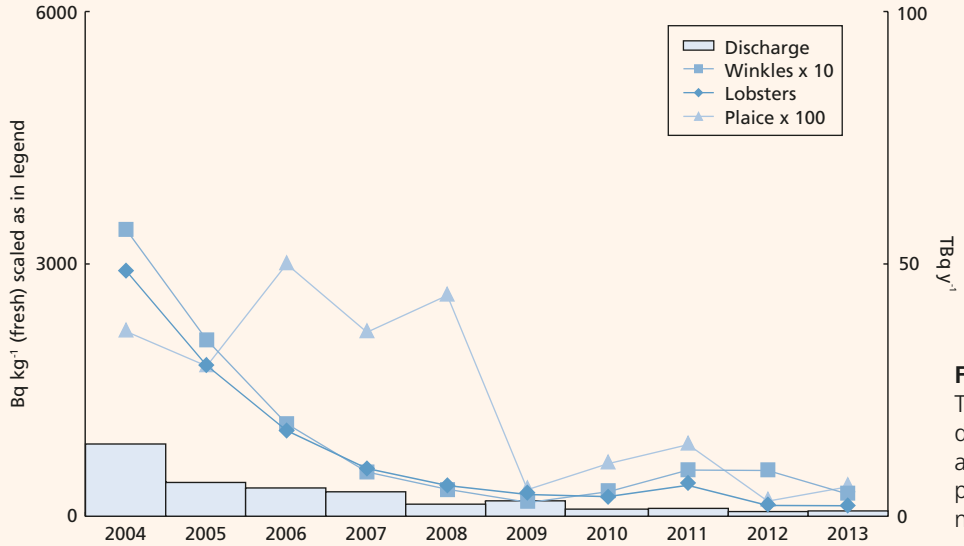


Figure 2.14.
Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

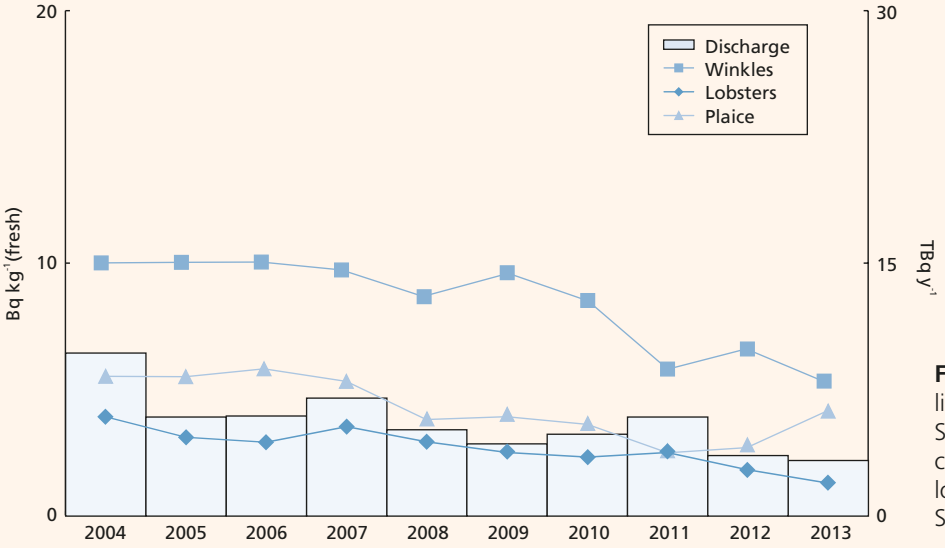


Figure 2.15. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

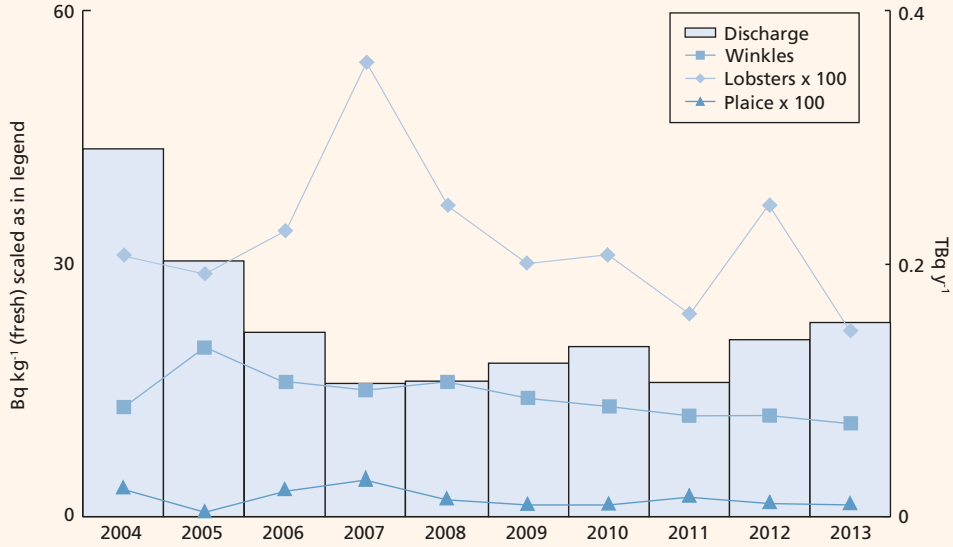


Figure 2.16. Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

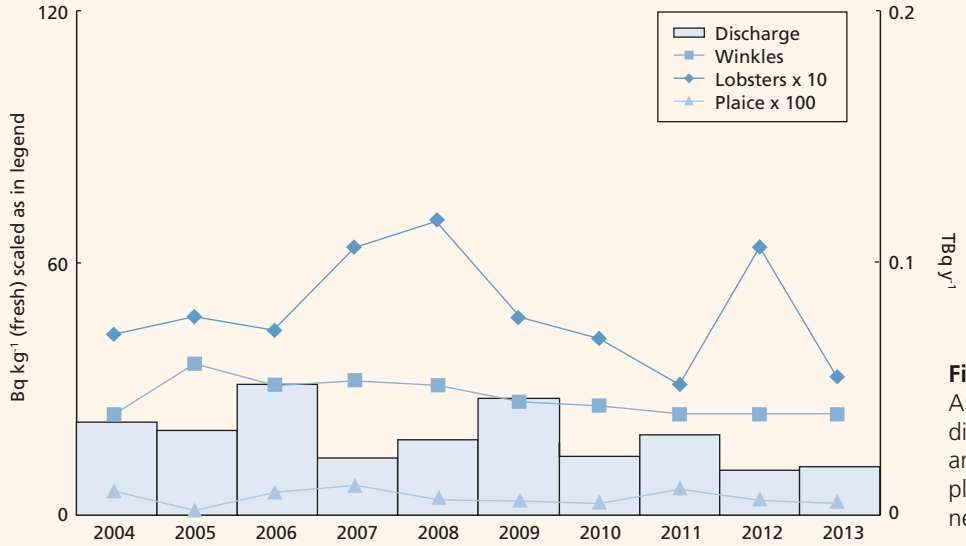


Figure 2.17. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

of plutonium radionuclides and americium-241 in lobsters were lower in 2013 compared to those in 2012.

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 in comparison to those in 2012. 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.

As in previous years, brown trout was sampled for analysis from the River Calder, which flows through the Sellafield site. The long-term trend for concentrations of caesium-137 over time (1977 – 2013) is shown in Figure 2.18. The caesium-137 concentration in brown trout was 2.8 Bq kg^{-1} in 2013 (lower than that in 2012 (37 Bq kg^{-1})) and significantly lower than those in 2011 and 2009 (360 Bq kg^{-1} and 300 Bq kg^{-1}, respectively). Additional enhanced activity concentrations in fish were also detected periodically in earlier decades. The changes in concentrations were likely to be due the combined effects of Sellafield discharges and fallout from Chernobyl, accentuated by the movement of such fish in the Calder river system.

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 continued local enhancement of carbon-14 due to discharges from Sellafield. In 2013, tritium (total) provided the highest activity concentration in marine fish (plaice, 210 Bq kg^{-1}), with similar concentrations of OBT. The limited tritium 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.

For shellfish, a wide range of radionuclides is 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 2013 and 2012 data across a wide range of sampling locations and shellfish species, technetium-99 concentrations were generally similar, but reduced in comparison to those years prior to 2012 due to the progressive reductions in discharges of this radionuclide. Concentrations of other radionuclides in 2013 were also broadly similar to those in 2012.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2013 are given in Table 2.7. Transuranic elements are less mobile than other radionuclides in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranic elements in shellfish compared with fish. Comparing 2013 and 2012 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish were generally similar. Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In comparison to 2012 data, the concentrations in shellfish were generally similar for plutonium radionuclides and americium-241 at most of the north-eastern Irish Sea locations in 2013, with a small decrease in activity concentrations in lobsters (Sellafield Coastal Area). Variations of these observations in previous years were likely to have resulted from a combination of mechanisms including natural environmental variability and redistribution of sediments due to natural processes.

Monitoring of sediments

Radionuclides in Sellafield liquid discharges are taken up into sediments along the Cumbrian Coast in particular in more muddy (fine grained) areas such as estuaries. Some of these areas are used by the public. Levels of radionuclides are regularly monitored, both because of their relevance to exposure and in order to keep distributions of radioactivity under review. The results for 2013 are shown in Table 2.8. Radionuclides detected include cobalt-60, strontium-90, caesium-137 and transuranic elements. 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 transuranic elements, 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 2013 were generally similar to those in recent years.

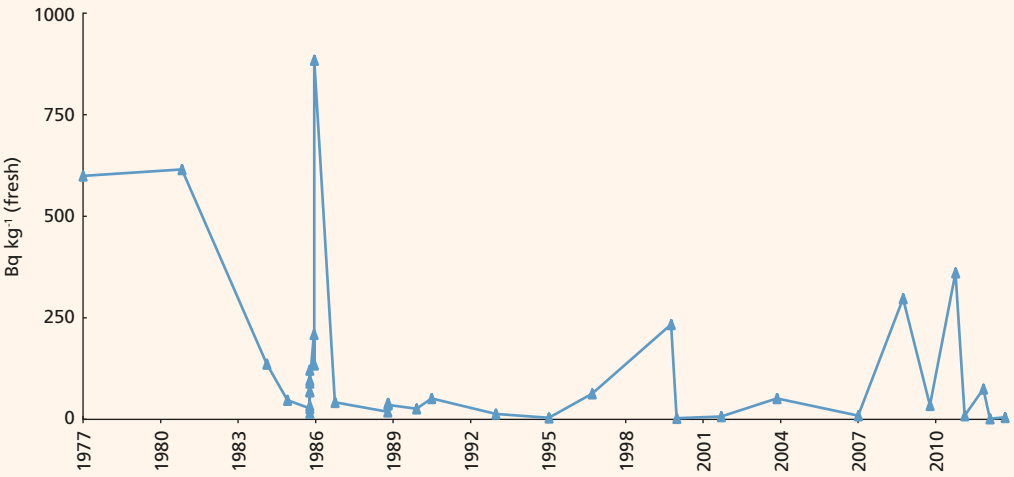


Figure 2.18. Concentration of caesium-137 in River Calder brown trout, 1977-2013

The trends over time (1988 – 2013) for activity concentrations in mud from Ravenglass with discharges from Sellafield are shown in Figures 2.19 – 2.22. 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 in earlier years but reduced over the last decade, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 2.21). Over the last decade, caesium-137 and transuranic concentrations in sediments have remained relatively constant (Figures 2.19, 2.20 and 2.22). 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 caesium-137 and transuranic elements activities in sediments (peaking over the period, ~2003 – 2006), and americium-241 peaking in 2006 and possibly again in 2012. 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 2.15 – 2.17) and will continue to be monitored.

Concentrations of caesium-137 and americium-241 in sediments from coastal locations of the north-east Irish Sea are also shown in Figure 2.23. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations in 2013 at a given location were generally similar to those in 2012, and any fluctuations were most likely due to normal variability in the environment. Limited evidence suggests that small peaks in activity concentrations have occurred in sediments at some locations at distance from Sellafield in recent years, but these are still below peak values reported over the whole period of time (except at Carsluith). The effect appears to be more pronounced for americium-241 and is likely to be due to the spreading of activity away from Sellafield combined with the effect of grow-in from plutonium-241 (Hunt *et al.*, 2013).

A research study, commissioned by the Food Standards Agency, determined the depth distributions of technetium-99 concentrations in sea-bed cores to produce an estimate of the total inventory residing in the sub-tidal sediments of the Irish Sea (Jenkinson *et al.*, 2014). The study concluded that the inventory of technetium-99 was estimated to have been of the order of 30 TBq (or approximately 2 per cent of the total cumulative Sellafield discharge), with approximately 8 TBq present in surface material and thereby potentially most susceptible to re-dissolution or re-suspension.

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 2013 were generally similar to those in recent years. Any variations between years are likely to have been due to normal variability in the environment. As in previous years, 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 were 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.

Gamma dose rates above mud and salt marshes, from a range of coastal locations in the vicinity of Sellafield,

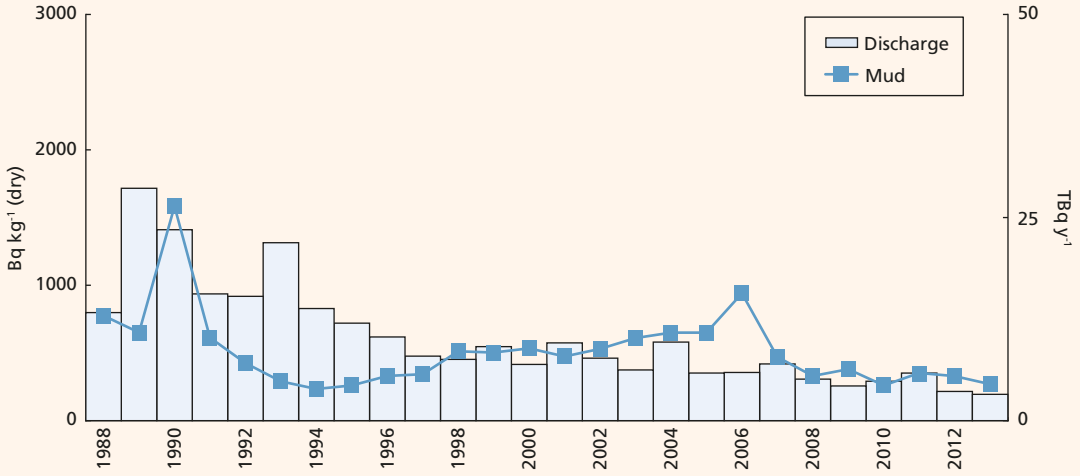


Figure 2.19. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

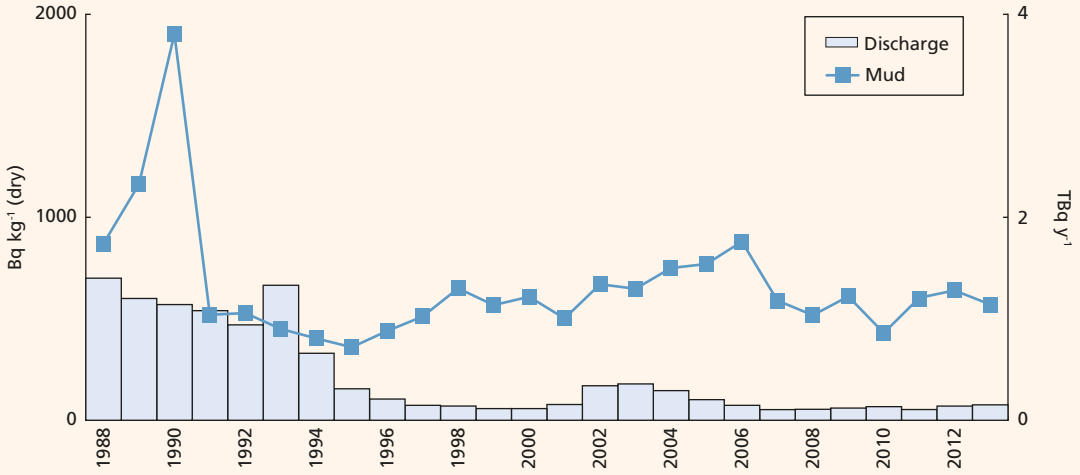


Figure 2.20. Plutonium-alpha liquid discharge from Sellafield and plutonium-239+240 concentration in mud at Ravenglass, 1988-2013

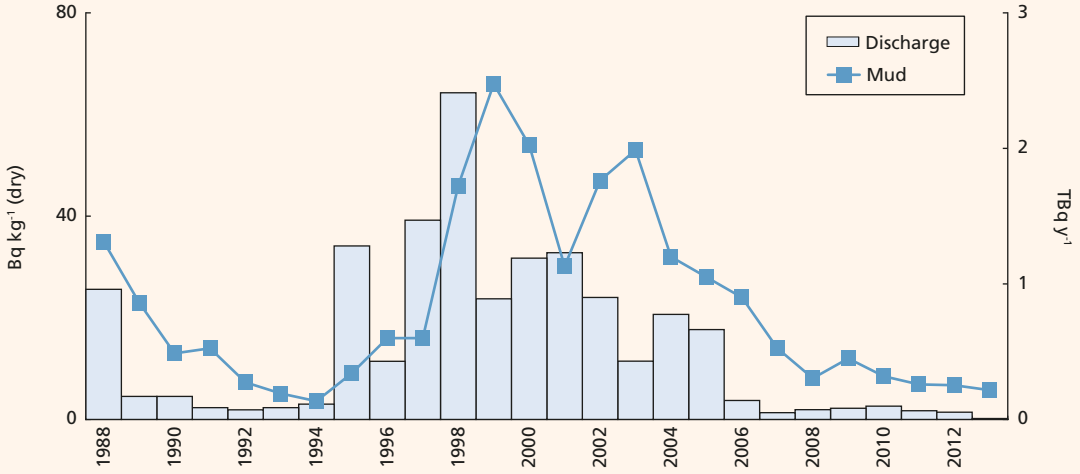


Figure 2.21. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

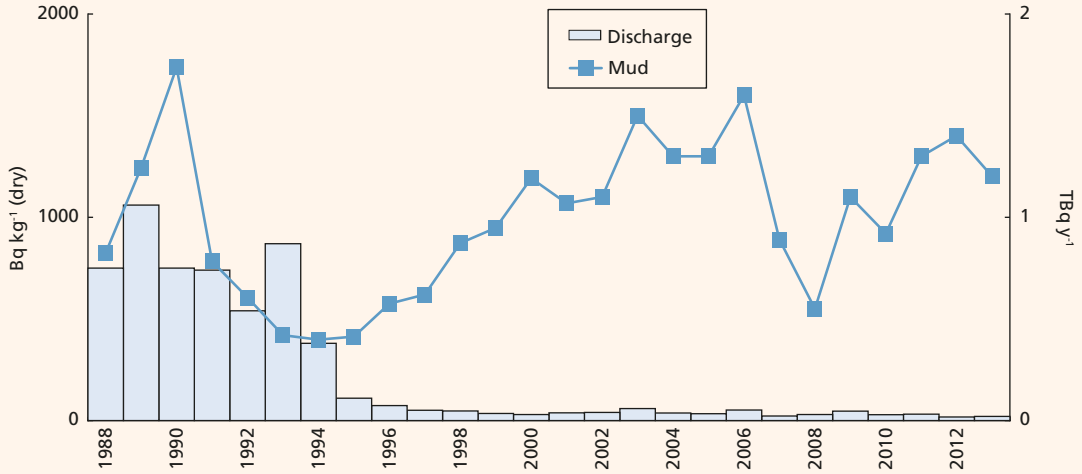


Figure 2.22. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

are shown in Figure 2.24. 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 were slowly declining over the whole period, with the lowest reported values in 2012. 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 estuary have shown a less clear trend, with concentrations of some radionuclides fluctuating from year to year (for example, see Figure 2.20). 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 historical 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 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, fishing gear may entrain particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination monitors. Results for 2013 are given in Table 2.10. Overall, measured dose rates were similar to those in recent years.

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments (using contamination monitors), to allow estimation of exposure of people who handle sediments regularly, are given in Table 2.11. Overall, positively detected dose rates in 2013 were generally lower in comparison to those in 2012 (where comparisons can be made from similar ground types and locations), with some measurements close to the LoD. Beta dose rates were much lower in sand at Whitehaven (outer harbour) in 2013 (compared to 2012) and more typical of those in previous years.

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 2013, no material was found using

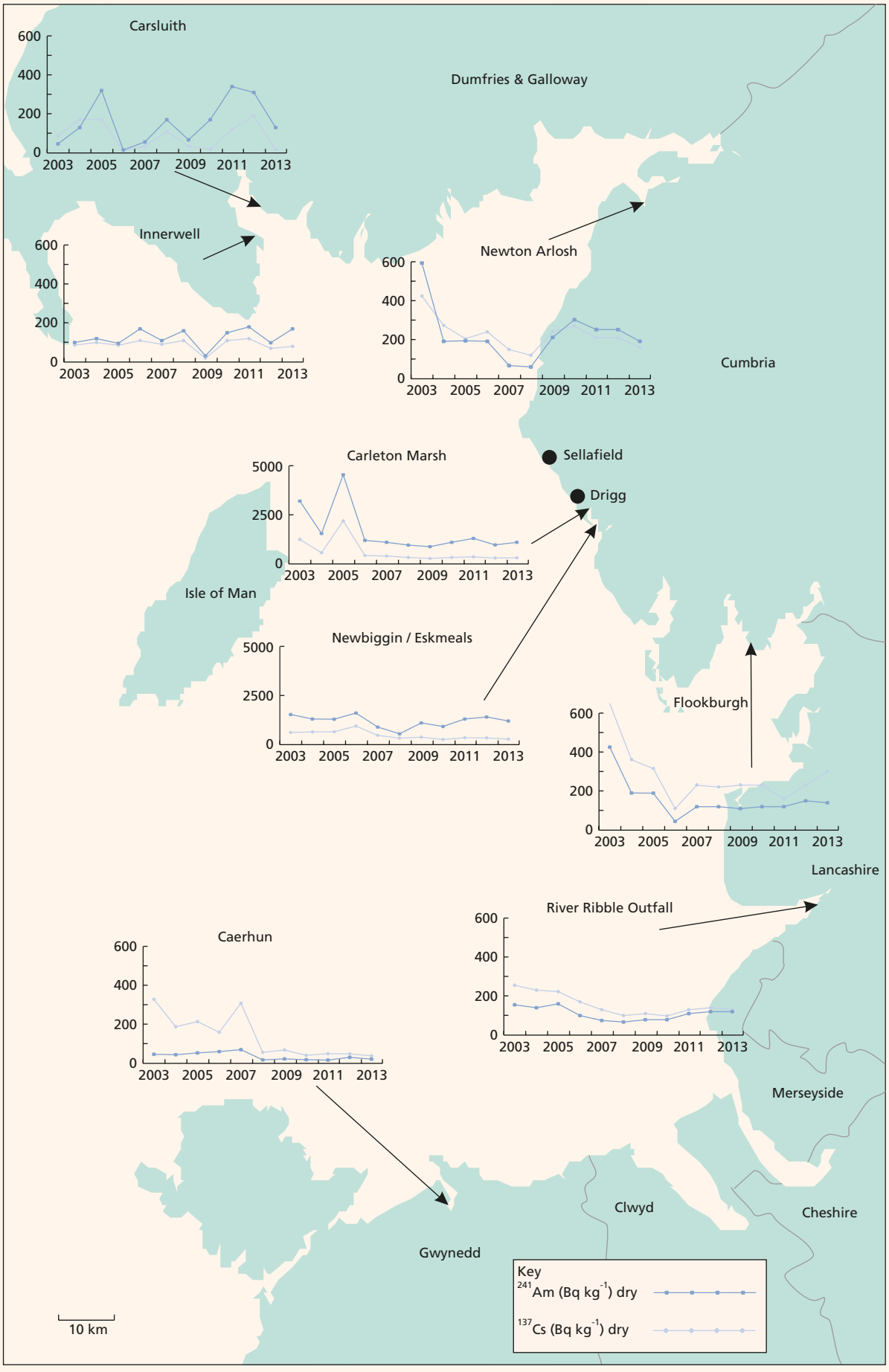


Figure 2.23. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2003-2013 (Note different scales used for Newbiggin and Carleton Marsh)

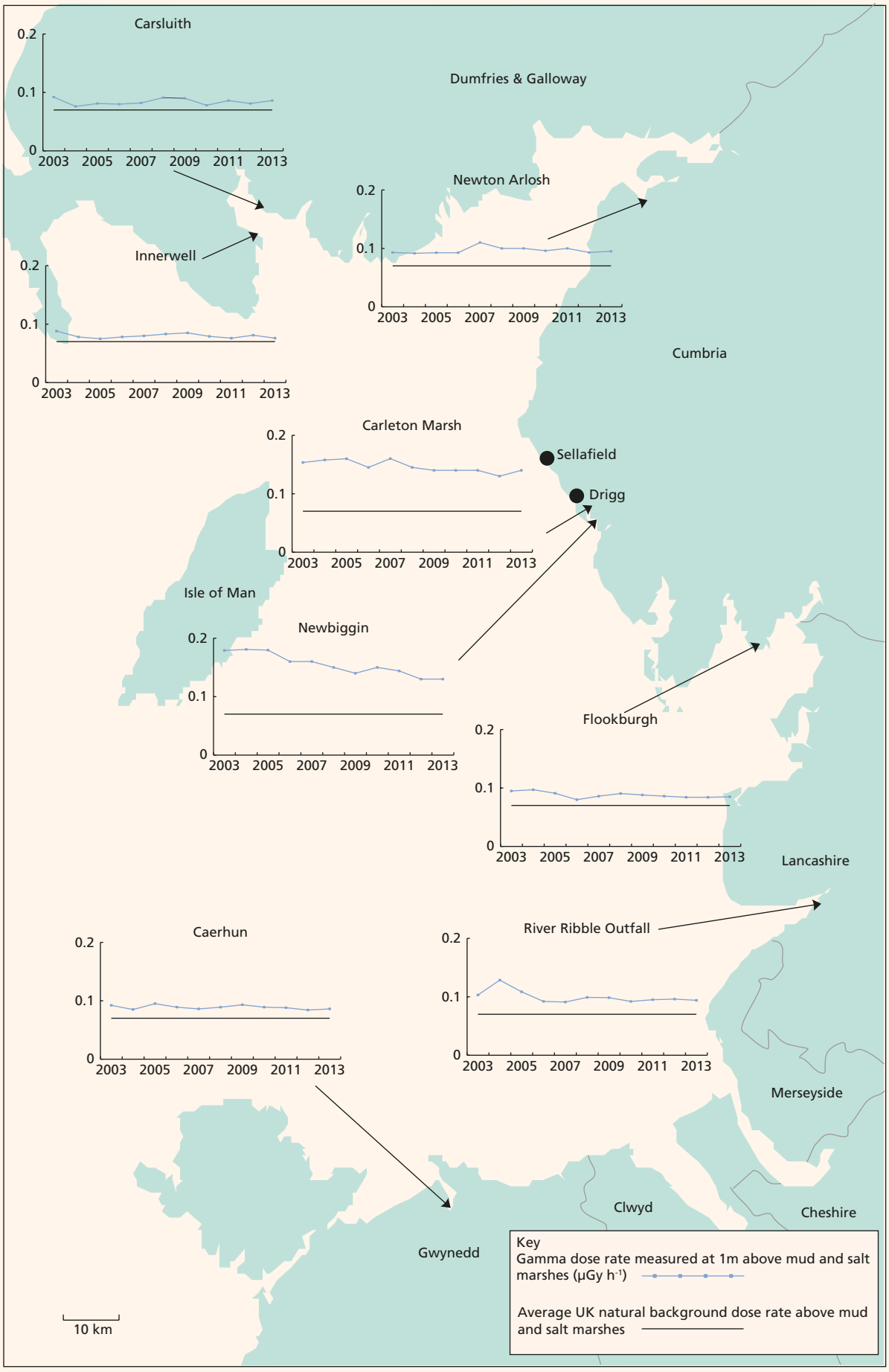


Figure 2.24. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2003-2013

these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

In 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 the Sellafield site (Environment Agency, 2008c). The work so far has included investigating the distribution and behaviour of Sellafield-related particles, particle analysis and identification, risks from particles, and a review of particle dispersion and transport models focused on the Eastern Irish Sea and Solway Firth.

Since vehicle-mounted beach survey work began in November 2006, and up to the end of March 2013, approximately 1694 hectares 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 currently (since August 2009) is the Groundhog™ Synergy system, which is an improvement on the use of the original Groundhog™ Evolution system. The Groundhog™ Synergy system has a specific capability in relation to the detection of medium/high energy gamma emitting radionuclides and also provides improved detection capability for low energy gamma emissions, increasing the detection of particles containing americium-241.

During 2013/14, further beach monitoring was completed in line with the Environment Agency's specification of 150 hectares (Sellafield Limited, 2014). The 150 hectares was divided into three programmes; core and near-field investigative programmes (totally 15 hectares and 95 hectares, respectively), and a far-field investigative programme (totally 40 hectares). The former programmes focused on the beaches at Sellafield, Braystones and St. Bees and the latter programme on beaches from Whitehaven to Allonby (in the north) to Seascale (in the south). The number of radioactive finds identified in the period from April 2013 to March 2014 was 117 (compared with 249 in the previous year), of which 109 were classified as particles (less than 2 mm in size) and 8 as stones (larger than 2 mm in size). The majority of the finds were concentrated on a 5 km stretch of beach running NW from the Sellafield site. All have been removed from the beaches.

Monitoring along the Cumbrian coast will continue, with the current proposal being a further 150 hectares to be surveyed between April 2014 and March 2015, 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. The outputs from the exercise were used to inform an offshore sampling and monitoring exercise undertaken by Sellafield Limited in 2012 and two seabed grab sampling campaigns in 2013. So far, only a single radioactive particle has been identified (in 2012) by these offshore surveys and two further campaigns have been programmed to take place in 2014/15.

In 2012, Public Health England (PHE) reported their review of the results and position on risk following the introduction of the improved Synergy™ monitoring system. The report concluded that the increase in particle finds following the introduction of this system was a result of its improved capability and also that advice previously given by PHE to the Environment Agency following a detailed assessment of risks in 2010 remained valid (Brown and Etherington, 2011; Etherington *et al.*, 2012). The report restated the conclusion that based on the currently available information, the overall health risks to beach users are very low and significantly lower than other risks people accept when using the beaches. As such the PHE advice remained 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 PHE's advice. The Environment Agency will also continue to work with relevant authorities to keep the situation under review.

In 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) and the beach monitoring programme was temporarily extended to include two locations on the north Solway coastline (Kirkcudbright Bay and Southerness). This was 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.

Between 2010 and 2013, the Environment Agency provided updates on further progress of the enhanced beach monitoring (Environment Agency, 2010; 2011b; 2013c) with work prior to 2010 described elsewhere (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a). Further detail on the

monitoring data compiled so far can be obtained from Sellafield Limited and the Environment Agency:

http://sustainability.sellafieldsites.com/environment/environment-page/particles-in-the-environment/

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298570/Enhanced_monitoring_for_radioactive_particles_May_2013.pdf

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials (as radionuclides are concentrated by seaweeds), facilitating assessments and assisting the tracing of these radionuclides in the environment. Table 2.12 gives the results of measurements in 2013 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 2013, are shown in Figure 2.9. In the north-east Irish Sea, technetium-99 concentrations have been reasonably constant over the present decade, consistent with the relatively low discharges; the highest concentrations which were found near Sellafield were much less than those in the mid 1990's and the decade thereafter (in response to the progressive reduction in discharges). In general, there was also 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* collected from sites in Cumbria were generally lower than to those in 2012. At specific locations (Auchencairn, Scotland; Cemaes Bay, Wales; Carlingford Lough, Northern Ireland), known to have had fluctuating levels in previous years, activity concentrations in seaweed (*Fucus*) were also lower in 2013 compared with those in 2012. 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 2013 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 caesium-137, 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 in to those in 2012. These activity concentrations in vegetables provide no evidence for significant uptake. Concentrations of gamma-emitting radionuclides in vegetables were below the LoD.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2013; 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 2013 are given in Table 2.12. In 2013, ruthenium-106 concentrations in *Porphyra* from the Cumbrian coast (Seascale and St Bees) were below the LoD, and reduced in comparison to those in earlier years (due to the decreased discharges of this radionuclide in 2005 and 2006). Results for analyses of samples of the major manufacturers' laverbread that are regularly collected from markets in South Wales are also given in Table 2.12. In 2013, activity concentrations in laverbread were below the LoD, with the exception of small concentrations of caesium-137 and americium-241 in one sample.

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 2013 are given in Table 2.14. In general, the data are similar to those for 2012 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. As in previous years, the evidence for sea to land transfer was very limited in 2013. However, elevated concentrations of plutonium-239+240, plutonium-238+240 and americium-241, were detected in one beef sample (kidney). Positively detected technetium-99 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). Previous reported results (published in recent RIFE reports, Tables 2.5 and 2.7) for activity concentrations in farmed salmon from the west of Scotland confirm 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 8.

Sampling of fresh water from rivers and lakes in west Cumbria is conducted as part of the regular environmental monitoring programme around Sellafield; however, other environmental materials are likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2013 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 River Ehen Estuary, immediately prior to the confluence with the River Calder. Unlike some previous years, there was no evidence of tritium 100m downstream of the outfall in 2013 (Table 2.15). These 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 2.11) 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 2013 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 a wood pigeon sample collected in 2013 are included in Table 2.4. The total radiocaesium activity concentration in the muscle of wood pigeon (<0.067 Bq kg^{-1}) in 2013 was similar to the maximum value reported in 2012 (0.067 Bq kg^{-1}). These total radiocaesium concentrations have had fluctuating levels in recent years prior to 2011. 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 2013 are shown in Table 2.16, and were generally similar to those in 2012. In 2010, elevated concentrations (of strontium-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 appropriate action. The results indicate that the elevated levels in 2010 were not sustained during the period 2011 to 2013, and that these results were mostly consistent with other road drains sampled. 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 were taken to reduce contamination.

2.4 Windscale, Cumbria

Windscale was historically a separate licensed site located at Sellafield. 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. At Windscale there are three nuclear 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 and these activities are continuing. The reactor decommissioning of the Windscale Advanced Gas Cooled Reactor was completed in 2011. Gaseous wastes are regulated from specific stacks on the Windscale site; liquid radioactive wastes are disposed of, after appropriate treatment, to the Irish Sea via the Sellafield site pipelines. Both gaseous and liquid discharges are included as part of the regulated Sellafield discharges (Appendix 2). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from the Sellafield nuclear licensed site.

Regular monitoring of the environment by the Environment Agency and the Food Standards Agency in relation to any releases from the Windscale site 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 doses – Capenhurst and Springfields, 2013

Site	Representative person[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 inhabitant aged 10 yr (0–0.25km)**	**0.080**	**–**	**<0.005**	**–**	**–**	**<0.005**	**0.080**
Source	Infant consumer of locally grown food[d]	<0.005	–	<0.005	–	–	<0.005	–
specific doses	Child playing at Rivacre Brook[c,d]	0.011	–	–	0.010	<0.005	–	–
Springfields								
***Total dose* – all sources**	**Adult occupant on a houseboat**	**0.060**	**–**	**–**	**0.060**	**–**	**–**	**–**
Source	Seafood consumer	0.023	<0.005	–	0.021	–	–	–
specific doses	Houseboat occupant	0.071	–	–	0.071	–	–	–
	Child playing at Lower Penwortham[c,d]	<0.005	–	–	<0.005	<0.005	–	–
	Farmer	0.041	–	–	0.041	–	–	–
	Wildfowl consumption	0.007	–	<0.005	0.006	–	–	–
	Consumer of locally grown food[c]	<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 people unless otherwise stated

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

[c] *Child 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, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{99}Tc	^{137}Cs	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np
Marine samples										
Dab	Liverpool Bay	1	<25							
Plaice	Liverpool Bay	1	<25							
Flounder	Mersey Estuary	1	<25							
Plaice	Mersey Estuary	1	<25							
Shrimps	Wirral	2	<25	0.27	0.88	*				
Mussels	Liverpool Bay	2	<25							
Mussels	Mersey Estuary	2	<25							
Cockles	Dee Estuary	4		1.4	1.2	7.4				
Sediment	Rivacre Brook	2[E]		130	2.3	75	87	4.6	47	<3.0
Sediment	Rivacre Brook (1.5km downstream)	2[E]		35	1.4	19	22	<1.3	15	<3.0
Sediment	Rossmore (3.1km downstream)	2[E]		50	1.1	<14	24	<2.6	16	<3.0
Sediment	Rivacre Brook (4.3km downstream)	2[E]		11	<0.45	12	8.7	<1.4	7.4	<3.0
Freshwater	Rivacre Brook	2[E]	<3.0	<0.12			0.038	<0.0030	0.024	<0.085
Freshwater	Rivacre Brook (1.5km downstream)	2[E]	<3.6	<0.13			0.024	<0.0040	0.013	<0.085
Freshwater	Rossmore (3.1km downstream)	2[E]	<2.9	<0.13			0.024	<0.0035	0.016	<0.085
Freshwater	Rivacre Brook (4.3km downstream)	2[E]	<3.5	<0.10			0.022	<0.0025	0.012	<0.085

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									
Shrimps	Wirral	2			<0.10				
Cockles	Dee Estuary	4	0.099	0.68	1.6	*	*		
Sediment	Rivacre Brook	2[E]						240	900
Sediment	Rivacre Brook (1.5km downstream)	2[E]						<120	400
Sediment	Rossmore (3.1km downstream)	2[E]						<120	370
Sediment	Rivacre Brook (4.3km downstream)	2[E]						<110	350
Freshwater	Rivacre Brook	2[E]						<0.13	0.58
Freshwater	Rivacre Brook (1.5km downstream)	2[E]						<0.060	0.29
Freshwater	Rossmore (3.1km downstream)	2[E]						<0.065	0.30
Freshwater	Rivacre Brook (4.3km downstream)	2[E]						<0.055	0.28

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	<1.8	<0.0015	<0.00097	<0.00034	<0.00048
Milk	max		<2.5	<0.023	0.0012	<0.00057	<0.00057
Gooseberries		1		<0.11	0.0014	0.00024	0.0017
Kale		1			0.0031	<0.00025	0.0030
Potatoes		1		<0.11	0.0052	<0.00027	<0.0051
Grass		4		<0.11	0.032	0.0013	0.032
Grass	max			<0.12	0.082	0.0028	0.079
Grass/herbage	North of Ledsham	1[E]		<1.1	<0.72	<0.40	<0.62
Grass/herbage	South of Capenhurst	1[E]		<0.29	<0.17	<0.14	<0.18
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<0.79	0.23	<0.088	0.22
Grass/herbage	East of station	1[E]		<0.28	<0.27	<0.057	<0.23
Silage		2		<0.36	0.022	<0.0015	0.022
Silage	max			<0.60	0.026	<0.0018	0.026
Soil		1[#]			3.8	0.14	4.0
Soil	North of Ledsham	1[E]		3.8	17	<0.82	18
Soil	South of Capenhurst	1[E]		7.2	15	<1.2	16
Soil	Off lane from Capenhurst to Dunkirk	1[E]		13	16	<1.0	14
Soil	East of station	1[E]		<5.6	24	<1.6	23

* *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, 2013

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Grass	2	0.096
Rivacre Brook 1.5 km downstream	Grass	2	0.084
Rossmore Road West 3.1 km downstream	Mud and sand	1	0.085
Rossmore Road West 3.1 km downstream	Grass	1	0.076
Rivacre Brook 4.3 km downstream	Grass	1	0.083
Rivacre Brook 4.3 km downstream	Vegetation	1	0.082

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2013

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	^{129}I	^{137}Cs	^{228}Th
Marine samples										
Grey mullet	Ribble Estuary	2			<0.25				2.0	
Sole	Ribble Estuary	1			<0.15				1.6	
Bass	Ribble Estuary	1			<0.12				3.8	
Salmon	Ribble Estuary	1			<0.09				0.27	
Shrimps	Ribble Estuary	2		45	<0.06		0.18		1.5	0.013
Cockles[d]	Ribble Estuary	2			<0.12				1.7	0.71
Mussels	Ribble Estuary	2			<0.06				0.86	0.18
Wildfowl	Ribble Estuary	1	<25	28	<0.06	0.062		<1.5	0.86	0.0075
Samphire	Marshside Sands	1			<0.07				0.15	
Sediment	River Ribble outfall	4[E]			<0.48				130	33
Sediment	Savick Brook	2[E]			<0.52				180	47
Sediment	Lea Gate	2[E]			<0.51				180	43
Sediment	Lower Penwortham Park	4[E]			<1.2				230	46
Sediment	Penwortham rail bridge	3[E]			<1.1				210	44
Sediment	Penwortham rail bridge – West bank	1[E]			<0.49				170	40
Sediment	Penwortham position 1	4[E]			<1.5				110	28
Sediment	Penwortham position 2	1[E]			<0.43				77	25
Sediment	Lytham Yacht Club	1[E]			<0.48				190	40
Sediment	Becconsall	4[E]			<0.51				110	27
Sediment	Freckleton	1[E]			<0.54				230	42
Sediment	Hutton Marsh	1[E]			<1.3				420	43
Sediment	Longton Marsh	1[E]			<0.53				350	52
Grass (unwashed)	Hutton Marsh	1[E]					1.3			
Soil	Hutton Marsh	1[E]					51			

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np	^{238}Pu
Marine samples										
Grey mullet	Ribble Estuary	2			*					
Sole	Ribble Estuary	1			*					
Bass	Ribble Estuary	1			*					
Salmon	Ribble Estuary	1			*					
Shrimps	Ribble Estuary	2	0.0055	0.0036	*				0.000091	0.0019
Cockles[d]	Ribble Estuary	2	0.55	0.31	2.3					0.24
Mussels	Ribble Estuary	2	0.18	0.10	1.9					
Wildfowl	Ribble Estuary	1	0.0091	0.0032	*					0.0022
Sediment	River Ribble outfall	4[E]	54	29	190	20	<1.4	21		
Sediment	Savick Brook	2[E]	100	34	3500	30	1.9	27		
Sediment	Lea Gate	2[E]	110	38	3400	36	2.2	32		
Sediment	Lower Penwortham Park	4[E]	98	37	1700	29	<2.5	27		
Sediment	Penwortham rail bridge	3[E]	96	40	1900	31	<2.1	31		
Sediment	Penwortham rail bridge – West bank	1[E]	71	35	1200	23	<1.5	24		
Sediment	Penwortham position 1	4[E]	51	29	140	19	<1.2	18		
Sediment	Penwortham position 2	1[E]	41	23	55	21	<1.6	21		
Sediment	Lytham Yacht Club	1[E]	85	35	160	21	<1.2	23		
Sediment	Becconsall	4[E]	56	27	240	18	<1.2	18		
Sediment	Freckleton	1[E]	78	38	580	26	1.5	29		
Sediment	Hutton Marsh	1[E]	210	44	<21	34	<2.9	31		
Sediment	Longton Marsh	1[E]	290	46	46	30	<1.9	28		

Table 2.3(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Grey mullet	Ribble Estuary	2		<0.26				
Sole	Ribble Estuary	1		<0.11				
Bass	Ribble Estuary	1		<0.11				
Salmon	Ribble Estuary	1		<0.23				
Shrimps	Ribble Estuary	2	0.013	0.023	*	*		
Cockles[d]	Ribble Estuary	2	1.5	4.0	*	*		
Mussels	Ribble Estuary	2		0.77				
Wildfowl	Ribble Estuary	1	0.023	<0.026	*	0.000050		
Samphire	Marshside Sands	1		<0.13				
Sediment	River Ribble outfall	4[E]		120			450	1100
Sediment	Savick Brook	2[E]		160			580	4600
Sediment	Lea Gate	2[E]		150			600	4700
Sediment	Lower Penwortham Park	4[E]		200			640	3100
Sediment	Penwortham rail bridge	3[E]		180			540	3200
Sediment	Penwortham rail bridge – West bank	1[E]		150			520	2000
Sediment	Penwortham position 1	4[E]		<90			<430	1000
Sediment	Penwortham position 2	1[E]		64			330	730
Sediment	Lytham Yacht Club	1[E]		180			370	1400
Sediment	Becconsall	4[E]		98			330	1100
Sediment	Freckleton	1[E]		200			550	1500
Sediment	Hutton Marsh	1[E]		270			640	1700
Sediment	Longton Marsh	1[E]		200			730	1300

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
Terrestrial samples							
Apples		1	<2.3	13	<0.039	<0.067	<0.05
Beetroot		1	<2.4	19	<0.049	<0.017	<0.07
Blackberries		1	<2.2	16	0.027	<0.041	<0.05
Cabbage		1	<2.2	18	0.04	<0.027	<0.06
Potatoes		1	<2.4	20	<0.044	<0.048	<0.06
Rabbit		1	<3.4	35	<0.041	<0.067	<0.04
Runner beans		1	<2.5	19	0.049	<0.022	<0.06
Sediment	Deepdale Brook	2[E]					2.0
Grass		1					0.31
Freshwater[e]	Ulnes Walton	1[E]	<3.2				<0.20

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		5				<0.0012	<0.0011	<0.0011
Milk	max					<0.0019	<0.0019	<0.0019
Apples		1	<0.00041	<0.00041		<0.0010	<0.0010	0.0023
Beetroot		1	0.013	0.013		0.012	<0.00035	0.013
Blackberries		1	<0.0021	<0.00078		0.0022	<0.00045	0.0019
Cabbage		1	0.0032	0.0011		<0.00031	<0.00025	0.00065
Potatoes		1	0.014	0.012		0.026	0.0011	0.027
Rabbit		1	0.0075	0.0042	2.5	0.0040	<0.00019	0.0037
Runner beans		1	<0.00037	<0.00037		<0.0040	<0.0028	0.0040
Sediment	Deepdale Brook	2[E]			140	100	4.9	94
Grass		1				0.073	0.0034	0.064
Grass	Site fence	1[E]				1.2	<0.15	1.4
Grass	Opposite site entrance	1[E]				2.3	<0.20	2.3
Grass	Opposite windmill	1[E]				0.32	<0.12	<0.35
Grass	Deepdale Brook	1[E]				<0.53	<0.19	<0.18
Grass	Lea Town	1[E]				<0.24	<0.18	<0.15
Grass	N of Lea Town	1[E]				0.48	<0.066	0.57
Silage		1				0.18	0.0061	0.17
Soil		1[#]				23	1.1	23
Soil	Site fence	1[E]				300	14	280
Soil	Opposite site entrance	1[E]				98	5.4	89
Soil	Opposite windmill	1[E]				91	5.1	88
Soil	Deepdale Brook	1[E]				110	3.5	110
Soil	Lea Town	1[E]				50	<1.7	45
Soil	N of Lea Town	1[E]				44	1.9	44
Freshwater	Deepdale Brook	4[E]				0.37	0.018	0.36
Freshwater[e]	Ulnes Walton	1[E]	<0.0029	<0.0011		0.32	0.015	0.31

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	<0.00025	<0.00036	<0.22	0.00020		
Beetroot		1	<0.00017	<0.00077	<0.23	0.00010		
Blackberries		1	<0.00015	0.00013	<0.22	0.00029		
Cabbage		1	<0.000062	<0.000080	<0.25	0.00010		
Potatoes		1	<0.000068	0.00021	<0.27	0.00038		
Rabbit		1	<0.000074	0.00010	<0.29	0.00045		
Runner beans		1	<0.000084	0.00010	<0.20	0.00013		
Sediment	Deepdale Brook	2[E]					370	980
Grass		1				<0.29		
Freshwater	Deepdale Brook	4[E]					0.54	0.72
Freshwater[e]	Ulnes Walton	1[E]					0.49	0.52

* *Not detected by the method used*

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

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

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

[d] *The concentrations of ^{233}Pa was 0.40 Bq kg^{-1}*

[e] *The concentration of ^{228}Th was <0.0017 Bq kg^{-1}*

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

[#] *Fresh concentrations*

Table 2.3(b). Monitoring of radiation dose rates near Springfields, 2013

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	Salt marsh	1	0.12
Warton Mud Marsh	Grass	1	0.12
Warton Mud Marsh	Salt marsh[a]	1	0.13
Warton Mud Marsh	Grass[a]	1	0.12
Warton Salt Marsh	Salt marsh	1	0.095
Warton Salt Marsh	Grass	1	0.098
Freckleton	Salt marsh	1	0.10
Naze Point	Salt marsh	1	0.11
Naze Point	Grass	1	0.12
Banks Marsh	Salt marsh	1	0.12
Banks Marsh	Grass	1	0.12
Banks Marsh	Salt marsh[a]	1	0.12
Banks Marsh	Grass[a]	1	0.13
Hesketh Bank	Grass	2	0.10
Becconsall Boatyard	Grass and mud	1	0.094
Becconsall Boatyard	Grass	3	0.085
Becconsall Boatyard (beneath houseboat)	Mud	2	0.087
Becconsall (vicinity of houseboats)	Asphalt	2	0.066
Longton Marsh	Grass	1	0.13
Hutton Marsh	Grass and salt marsh	1	0.12
River Ribble outfall	Mud	3	0.093
River Ribble outfall	Grass and mud	1	0.095
Savick Brook, confluence with Ribble	Grass	2	0.098
Savick Brook, tidal limit	Grass	2	0.10
Savick Brook, Lea Gate	Grass	2	0.10
South bank opposite outfall	Grass	1	0.12
Penwortham Bridge cadet hut	Mud	1	0.086
Penwortham Bridge cadet hut	Mud and sand	1	0.085
Lower Penwortham Park	Grass	4	0.080
Lower Penwortham Railway Bridge	Mud	1	0.084
Lower Penwortham Railway Bridge	Mud and sand	2	0.086
Lower Penwortham Railway Bridge	Grass and mud	1	0.091
River Darwen	Grass	4	0.086
Riverbank Angler location 1	Grass and sand	1	0.080
Riverbank Angler location 1	Grass	3	0.080
Riverbank Angler location 2	Mud	1	0.079
Ulnes Walton, BNFL area survey	Grass	3	0.080
Mean beta dose rates			μSv h^{-1}
Lytham – Granny's Bay	Mud and sand	1	0.14
Banks Marsh	Salt marsh	1	*
Banks Marsh	Grass	1	0.040
Warton Mud Marsh	Salt marsh	1	0.080
Warton Mud Marsh	Grass	1	0.060
Warton Salt Marsh	Salt marsh	1	0.020
Warton Salt Marsh	Grass	1	0.020

[a] *15cm above substrate*

* *Not detected by the method used*

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2013

Material	Selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{131}I
Milk		16	<2.6	<2.0	23	<0.07	<0.030	<0.019	<0.61	<0.16	<0.010	<0.0055
Milk	max		<2.8		28	<0.08	0.047		<0.73	<0.19	0.018	<0.0068
Apples		2	<2.7	<2.7	18	<0.06	<0.039	<0.13	<0.47	<0.13	<0.049	
Apples	max		<3.3	<3.3	23	<0.07	<0.052		<0.53	<0.14	<0.078	
Barley		1	<4.5	<4.5	36	<0.07	0.15		<0.63	<0.17	<0.11	
Beef kidney		1				<0.23	<0.046		<2.3	<0.65		
Beef liver		1	<3.1	<3.1	42	<0.07	<0.060	<0.25	<0.72	<0.22	<0.052	
Beef muscle		1	<6.2	<6.2	64	<0.10	<0.045	<0.15	<0.61	<0.19	<0.025	
Blackberries		2	<3.0	<3.0	25	<0.04	0.87		<0.38	<0.09	<0.018	
Blackberries	max				30				<0.40		<0.019	
Broad beans		1	<3.7	<3.7	26	<0.08	0.036		<0.53	<0.18	<0.033	
Broccoli		1	<2.6	<2.6	17	<0.07	<0.056		<0.55	<0.09	<0.024	
Cabbage		1	<2.1	<2.1	12	<0.06	0.092		<0.63	<0.12	<0.034	
Carrots		1	<2.0	<2.0	16	<0.09	0.11	<0.16	<0.79	<0.16	<0.086	
Cauliflower		1	<2.1	<2.1	9.2	<0.10	0.054		<0.68	<0.16	<0.035	
Deer		1	<2.9	<2.9	24	<0.08	<0.054	<0.18	<0.61	<0.19	<0.045	
Duck		1	<2.9	<2.9	29	<0.05	0.13	<0.18	<0.47	<0.11	<0.011	
Eggs		1	<2.7	<2.7	46	<0.07	0.093		<0.69	<0.19	<0.044	
Elderberries		1	<2.0	<2.0	26	<0.11	0.044		<0.52	<0.18	<0.078	
Honey		1	<4.6	<4.6	100	<0.06	0.14		<0.53	<0.22	<0.034	
Mushrooms		1	<2.1	<2.1	30	<0.04	<0.045		<0.36	<0.10	<0.15	
Onions		1	<2.0	<2.0	11	<0.06	0.086		<0.47	<0.12	<0.065	
Pheasants		1	<3.5	<3.5	66	<0.09	<0.066	<0.20	<0.51	<0.18	<0.032	
Potatoes		1	<3.2	<3.2	38	<0.09	0.057		<0.82	<0.15	<0.065	
Runner beans		1	<2.0	<2.0	17	<0.06	0.33		<0.52	<0.11	<0.055	
Sheep muscle		2	<3.8	<3.8	50	<0.07	<0.040	<0.14	<0.55	<0.11	<0.022	
Sheep muscle	max		<4.1	<4.1	68	<0.08	<0.051	<0.15		<0.14	<0.024	
Sheep offal		2	<3.6	<3.6	42	<0.06	0.14	<0.15	<0.62	<0.11	<0.026	
Sheep offal	max		<3.7	<3.7	54		0.16		<0.76	<0.12	<0.027	
Strawberries		1	<2.0	<2.0	15	<0.06	0.14		<0.64	<0.16	<0.053	
Swede		1	<3.4	<3.4	13	<0.06	0.15		<0.45	<0.10	<0.018	
Turnips		1	<5.1	<5.1	18	<0.07	0.46		<0.42	<0.12	<0.031	
Wheat		1	<4.4	<4.4	100	<0.04	1.5		<0.54	<0.20	0.12	
Wood pigeon muscle		2	<3.3	<3.3	51	<0.05	<0.045		<0.52	<0.10	<0.059	
Wood pigeon muscle	max		<3.8	<3.8			<0.046		<0.68		0.075	
Grass		5	<0.13					<0.16	<1.3	<0.63		
Grass	max		<0.22						<1.7	1.5		
Soil		3				<3.4			<3.1	<1.6		
Soil	max					<9.8			<6.9	<3.8		

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	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk		16	<0.08	<0.08				<0.000037	<0.000036	<0.10	<0.000096
Milk	max		<0.09	<0.15				<0.000070	<0.000051	<0.13	<0.00015
Apples		2	<0.06	<0.08				<0.000068	0.00047	<0.21	0.00097
Apples	max		<0.07	0.12				0.000073	0.00063	<0.22	0.0012
Barley		1	<0.09	<0.07				0.00020	0.0018	<0.51	0.0021
Beef kidney		1	<0.23	<0.15	0.0041	<0.00023	0.0059	<0.00029	0.00029	<0.34	0.00073
Beef liver		1	<0.10	<0.07				0.00041	0.0023	<0.35	0.00018
Beef muscle		1	<0.10	0.39				<0.00054	0.00041	<0.22	0.0024
Blackberries		2	<0.04	0.12				<0.00011	0.00083	<0.24	0.0014
Blackberries	max		<0.05	0.16				0.00013	0.0010	<0.27	0.0018
Broad beans		1	<0.10	<0.07				<0.00011	0.00019	<0.28	0.00019
Broccoli		1	<0.07	<0.06				<0.000097	<0.00018	<0.25	0.00013
Cabbage		1	<0.09	<0.06				<0.000071	<0.00015	<0.23	<0.000041
Carrots		1	<0.10	0.13							<0.12
Cauliflower		1	<0.07	<0.06	<0.00019	<0.00019	0.0013	<0.00011	<0.000065	<0.25	0.000051
Deer		1	<0.07	0.77				<0.00013	<0.00011	<0.22	0.00013
Duck		1	<0.07	0.12				<0.000046	<0.000071	<0.28	0.000071
Eggs		1	<0.07	<0.05				<0.000055	0.000053	<0.21	<0.00039
Elderberries		1	<0.08	0.14				0.0011	0.0040	<0.27	0.0078
Honey		1	<0.05	<0.09				<0.000097	<0.000097	<0.31	0.000035
Mushrooms		1	<0.05	0.30				0.0021	0.010	<0.21	0.026
Onions		1	<0.06	<0.05							<0.10
Pheasants		1	<0.09	0.17				<0.00015	<0.00013	<0.34	0.0023
Potatoes		1	<0.11	<0.07							<0.12
Runner beans		1	<0.06	<0.06				<0.00010	0.00034	<0.19	0.00070
Sheep muscle		2	<0.06	0.33				<0.000088	0.00023	<0.29	0.000068
Sheep muscle	max			0.46				<0.000091	0.00030	<0.33	0.000085
Sheep offal		2	<0.06	0.15	0.0070	<0.00058	0.0060	0.00077	0.0065	<0.23	0.0047
Sheep offal	max		<0.08	0.16	0.0077	<0.00091		0.0010	0.0083	<0.26	0.0060
Strawberries		1	<0.07	<0.04				<0.00013	<0.00028	<0.29	<0.00020
Swede		1	<0.05	<0.05							<0.10
Turnips		1	<0.05	<0.06	<0.00049	<0.00025	0.00049				<0.10
Wheat		1	<0.08	0.49				0.00015	0.0028	<0.23	0.0019
Wood pigeon muscle		2	<0.06	<0.06				<0.000050	0.00010	<0.26	<0.00019
Wood pigeon muscle	max		<0.07	<0.07				<0.000055	0.00014		
Grass		5	<0.16	1.1							<0.23
Grass	max		<0.22	2.1							<0.32
Soil		3	<0.79	63	19	0.69	18				5.8
Soil	max		<2.0	87							8.1

[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, 2013

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}Nb	^{95}Zr	^{99}Tc
Cumbria										
Maryport	Plaice	4				<0.09		<0.16	<0.19	
Parton	Cod	4				<0.11		<0.33	<0.31	
Whitehaven	Cod	4			60	<0.10	<0.043	<0.17	<0.22	
Whitehaven	Plaice	4				<0.09	0.15	<0.22	<0.22	
Whitehaven	Skates / rays	4				<0.13		<0.57	<0.41	
Whitehaven	Sole	4				<0.15		<0.33	<0.36	
Sellafield coastal area	Cod	8				<0.08		<0.29	<0.25	
Sellafield coastal area	Plaice	4	110	120		<0.09		<0.23	<0.22	
Sellafield coastal area	Bass	1				<0.09		<0.52	<0.39	
Sellafield coastal area	Grey mullet	1				<0.08		<0.12	<0.17	
Sellafield offshore area	Cod	2			42	<0.22	0.044	<0.49	<0.53	0.21
Sellafield offshore area	Dab	2				<0.08		<0.16	<0.19	
Sellafield offshore area	Plaice[a]	2			130	<0.10	0.13	<0.64	<0.40	3.6
Sellafield offshore area	Lesser spotted dogfish	2				<0.11		<0.58	<0.40	
Sellafield offshore area	Skates / rays	2				<0.11		<0.37	<0.35	
River Esk	Brown trout	1				<0.13		<0.27	<0.28	
River Calder	Brown trout	1				<0.10		<0.18	<0.24	
Ravenglass	Cod	6				<0.09		<0.22	<0.23	
Ravenglass	Plaice	4	130	140		<0.12		<0.22	<0.24	
Morecambe Bay (Flookburgh)	Flounder	3			58	<0.06		<0.27	<0.22	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.07		<0.31	<0.26	
Morecambe Bay (Morecambe)	Bass	2				<0.09		<0.79	<0.44	
Morecambe Bay (Morecambe)	Flounder	4	<25	<27		<0.07	<0.024	<0.19	<0.20	0.25
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.06	<0.046	<0.18	<0.18	
Fleetwood	Cod	2				<0.09		<0.38	<0.30	
Fleetwood	Plaice	4				<0.08		<0.23	<0.21	
Fleetwood	Whiting	2			31	<0.09	0.046	<0.19	<0.20	<0.18
Ribble Estuary	Grey mullet	2				<0.25		<0.71	<0.71	
Ribble Estuary	Sole	1				<0.15		<0.64	<0.50	
Ribble Estuary	Bass	1				<0.12		<1.0	<0.65	
Ribble Estuary	Salmon	1				<0.09		<0.25	<0.27	
Liverpool Bay	Plaice	1		<25						
Mersey Estuary	Plaice	1		<25						
Mersey Estuary	Flounder	1		<25						
Scotland										
Shetland	Fish meal (herring)	1[S]				<0.13			<1.9	
Shetland	Fish oil (herring)	1[S]				<0.11		<0.13	<0.21	
Shetland	Fish oil (salmon)	1[S]				<0.10		<0.10	<0.17	
Minch	Herring	1[S]				<0.10		<0.24	<0.22	
West of Scotland	Mackerel	1[S]				<0.10			<1.6	
Minch	Mackerel	1[S]				<0.10		<0.21	<0.19	
Kirkcudbright	Plaice	4[S]			17	<0.10		<0.16	<0.18	0.47
Inner Solway	Flounder	2[S]			46	<0.10	<0.10	<0.95	<0.50	0.23
Inner Solway	Salmon	1[S]		<5.0		<0.10		<0.10	<0.19	
Inner Solway	Sea trout	1[S]		<5.0		<0.10		<0.58	<0.43	
Isle of Man										
Isle of Man	Cod	4				<0.07		<0.15	<0.17	
Isle of Man	Herring	3				<0.11		<0.57	<0.40	
Isle of Man	Mackerel	1				<0.11		<0.18	<0.24	
Wales										
North Anglesey	Thornback ray	2				<0.08		<1.1	<0.48	
North Anglesey	Lesser spotted dogfish	2				<0.11		<0.49	<0.39	
North Anglesey	Plaice	2	<25	<26	32	<0.08		<0.19	<0.19	
North Anglesey	Bass	1				<0.06		<0.17	<0.16	

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	<0.80	<0.21	<0.09	2.4	<0.43	<0.20	
Parton	Cod	4	<0.91	<0.26	<0.10	4.7	<0.48	<0.23	
Whitehaven	Cod	4	<0.84	<0.23	<0.10	3.9	<0.42	<0.21	
Whitehaven	Plaice	4	<0.78	<0.21	<0.09	2.5	<0.42	<0.20	
Whitehaven	Skates / rays	4	<1.2	<0.28	<0.13	2.9	<0.51	<0.21	
Whitehaven	Sole	4	<1.5	<0.30	<0.15	1.6	<0.49	<0.21	
Sellafield coastal area	Cod	8	<0.78	<0.20	<0.08	3.7	<0.39	<0.17	180
Sellafield coastal area	Plaice	4	<0.77	<0.20	<0.09	2.9	<0.34	<0.16	150
Sellafield coastal area	Bass	1	<1.0	<0.26	<0.10	7.5	<0.58	<0.24	
Sellafield coastal area	Grey mullet	1	<0.77	<0.21	<0.09	2.6	<0.47	<0.23	
Sellafield offshore area	Cod	2	<2.1	<0.59	<0.21	5.4	<1.1	<0.57	
Sellafield offshore area	Dab	2	<0.77	<0.21	<0.08	2.1	<0.46	<0.22	
Sellafield offshore area	Plaice[a]	2	<0.92	<0.22	<0.10	3.2	<0.45	<0.19	
Sellafield offshore area	Lesser spotted dogfish	2	<1.2	<0.27	<0.12	4.3	<0.48	<0.19	
Sellafield offshore area	Skates / rays	2	<1.0	<0.27	<0.11	4.1	<0.48	<0.23	
River Esk	Brown trout	1	<1.3	<0.30	<0.15	1.8	<0.49	<0.23	
River Calder	Brown trout	1	<0.94	<0.27	<0.10	2.8	<0.61	<0.29	
Ravenglass	Cod	6	<0.82	<0.23	<0.09	4.3	<0.42	<0.20	
Ravenglass	Plaice	4	<0.97	<0.25	<0.11	3.5	<0.43	<0.20	
Morecambe Bay (Flookburgh)	Flounder	3	<0.65	<0.19	<0.07	10	<0.35	<0.15	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<0.69	<0.19	<0.08	4.9	<0.36	<0.16	
Morecambe Bay (Morecambe)	Bass	2	<1.0	<0.26	<0.10	10	<0.52	<0.22	
Morecambe Bay (Morecambe)	Flounder	4	<0.70	<0.19	<0.07	5.7	<0.38	<0.17	
Morecambe Bay (Sunderland Point)	Whitebait	1	<0.64	<0.17	<0.06	3.5	<0.39	<0.19	
Fleetwood	Cod	2	<0.83	<0.19	<0.09	2.0	<0.39	<0.16	
Fleetwood	Plaice	4	<0.72	<0.17	<0.08	0.72	<0.35	<0.16	
Fleetwood	Whiting	2	<0.74	<0.17	<0.08	2.0	<0.31	<0.15	
Ribble Estuary	Grey mullet	2	<2.4	<0.51	<0.25	2.0	<0.86	<0.40	
Ribble Estuary	Sole	1	<1.5	<0.30	<0.15	1.6	<0.48	<0.20	
Ribble Estuary	Bass	1	<1.2	<0.26	<0.11	3.8	<0.50	<0.20	
Ribble Estuary	Salmon	1	<0.86	<0.23	<0.10	0.27	<0.53	<0.24	
Scotland									
Shetland	Fish meal (herring)	1[S]	<1.4	<0.33	<0.10	0.46	<1.1	<0.33	
Shetland	Fish oil (herring)	1[S]	<1.1	<0.30	<0.12	<0.12	<0.59	<0.26	
Shetland	Fish oil (salmon)	1[S]	<0.81	<0.25	<0.10	<0.10	<0.50	<0.22	
Minch	Herring	1[S]	<0.58	<0.15	<0.10	0.20	<0.31	<0.12	
West of Scotland	Mackerel	1[S]	<1.2	<0.28	<0.11	0.26	<0.75	<0.23	
Minch	Mackerel	1[S]	<0.47	<0.13	<0.10	0.23	<0.30	<0.12	
Kirkcudbright	Plaice	4[S]	<0.60	<0.17	<0.10	<0.10	<0.34	<0.15	
Inner Solway	Flounder	2[S]	<0.86	<0.24	<0.10	9.1	<0.53	<0.19	
Inner Solway	Salmon	1[S]	<0.60	<0.17	<0.10	0.26	<0.36	<0.15	
Inner Solway	Sea trout	1[S]	<0.94	<0.26	<0.10	2.5	<0.64	<0.25	
Isle of Man									
Isle of Man	Cod	4	<0.61	<0.16	<0.07	1.2	<0.30	<0.15	
Isle of Man	Herring	3	<1.0	<0.23	<0.11	0.48	<0.43	<0.19	
Isle of Man	Mackerel	1	<1.1	<0.29	<0.12	1.1	<0.56	<0.29	
Wales									
North Anglesey	Thornback ray	2	<0.88	<0.21	<0.09	0.95	<0.51	<0.22	
North Anglesey	Lesser spotted dogfish	2	<1.2	<0.26	<0.12	1.1	<0.57	<0.25	
North Anglesey	Plaice	2	<0.69	<0.16	<0.08	0.70	<0.27	<0.13	
North Anglesey	Bass	1	<0.57	<0.16	<0.06	3.6	<0.30	<0.15	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc
Northern Ireland								
North coast	Lesser spotted dogfish	2^{N}		<0.17		<1.3	<0.79	
North coast	Spurdog	2^{N}		<0.14		<0.36	<1.0	
Ardglass	Herring	2^{N}		<0.15		<0.41	<0.39	
Kilkeel	Cod	4^{N}	28	<0.08		<0.37	<0.27	
Kilkeel	Plaice	4^{N}		<0.06		<0.53	<0.29	
Kilkeel	Skates / rays	3^{N}		<0.12		<1.4	<0.63	
Kilkeel	Thornback ray	1^{N}		<0.14		<0.97	<0.64	
Kilkeel	Haddock	4^{N}		<0.06		<0.30	<0.22	
Glenarm	Brown trout	1		<0.06		<0.11	<0.13	<0.26
Further afield								
Baltic Sea	Cod	2		<0.06		<0.14	<0.15	
Baltic Sea	Herring	2		<0.11		<0.35	<0.32	
Barents Sea	Haddock	2		<0.05		*	*	
Norwegian Sea	Herring	1		<0.08		*	<1.8	
Norwegian Sea	Mackerel	1		<0.09		*	<1.9	
Norwegian Sea	Haddock	2		<0.06		<0.22	<0.19	
Norwegian processed	Cod	1	19	<0.05		<0.48	<0.29	
Iceland area	Cod	1		<0.07		<0.45	<0.30	
Skagerrak	Cod	2		<0.06		<0.24	<0.20	
Skagerrak	Herring	2		<0.09		<0.32	<0.28	
Mid North Sea	Cod	2	24	<0.04	<0.026	<0.06	<0.08	
Mid North Sea	Plaice	2	22	<0.09	<0.032	<0.16	<0.19	
Gt Yarmouth (retail shop)	Cod	2		<0.05		<0.10	<0.11	
Gt Yarmouth (retail shop)	Plaice	2		<0.10		<0.21	<0.25	
Southern North Sea	Cod	1		<0.05	<0.024	<0.09	<0.11	
Southern North Sea	Herring	1		<0.07		<0.99	<0.47	
Southern North Sea	Skates / rays	1		<0.07		<0.08	<0.12	
Southern North Sea	Sole	2		<0.05	<0.025	<0.11	<0.13	
English Channel-East	Plaice	2		<0.07		<0.34	<0.24	
English Channel-East	Whiting	1		<0.07		<0.22	<0.20	
English Channel-East	Flounder	1		<0.07		<0.39	<0.29	
English Channel-West	Mackerel	2		<0.09		<0.25	<0.24	
English Channel-West	Plaice	2	28	<0.11		<0.34	<0.33	
English Channel-West	Whiting	2		<0.06		<0.11	<0.13	
Celtic Sea	Whiting	1	21	<0.07	<0.029	<0.14	<0.16	
Celtic Sea	Common ling	1		<0.06		<0.09	<0.12	
Celtic Sea	Haddock	1		<0.05		<0.13	<0.14	
Celtic Sea	Pollack	1		<0.07		<0.17	<0.18	
Northern Irish Sea	Dab	1		<0.08		<0.23	<0.22	
Northern Irish Sea	Lesser spotted dogfish	1		<0.19		<0.52	<0.51	
Northern Irish Sea	Skates / rays	1		<0.14		<0.95	<0.64	

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
Northern Ireland								
North coast	Lesser spotted dogfish	2^{N}	<1.8	<0.36	<0.18	1.0	<0.60	<0.24
North coast	Spurdog	2^{N}	<1.6	<0.34	<0.15	1.3	<0.73	<0.26
Ardglass	Herring	2^{N}	<1.2	<0.29	<0.14	0.57	<0.54	<0.25
Kilkeel	Cod	4^{N}	<0.76	<0.17	<0.08	1.3	<0.34	<0.14
Kilkeel	Plaice	4^{N}	<0.60	<0.14	<0.06	1.1	<0.33	<0.14
Kilkeel	Skates / rays	3^{N}	<1.2	<0.27	<0.12	2.2	<0.55	<0.21
Kilkeel	Thornback ray	1^{N}	<1.4	<0.31	<0.14	2.8	<0.53	<0.19
Kilkeel	Haddock	4^{N}	<0.57	<0.14	<0.06	0.40	<0.28	<0.13
Glenarm	Brown trout	1	<0.50	<0.12	<0.06	0.17	<0.22	<0.09
Further afield								
Baltic Sea	Cod	2	<0.50	<0.14	<0.06	5.4	<0.23	<0.10
Baltic Sea	Herring	2	<1.0	<0.24	<0.11	3.6	<0.45	<0.19
Barents Sea	Haddock	2	<0.60	<0.09	<0.06	0.14	<0.24	<0.06
Norwegian Sea	Herring	1	<0.96	<0.17	<0.09	<0.07	<0.42	<0.13
Norwegian Sea	Mackerel	1	<1.1	<0.21	<0.10	<0.08	<0.60	<0.20
Norwegian Sea	Haddock	2	<0.51	<0.12	<0.06	0.11	<0.25	<0.11
Norwegian processed	Cod	1	<0.54	<0.12	<0.06	0.14	<0.28	<0.12
Iceland area	Cod	1	<0.68	<0.16	<0.07	0.08	<0.35	<0.16
Skagerrak	Cod	2	<0.52	<0.12	<0.06	0.20	<0.27	<0.12
Skagerrak	Herring	2	<0.80	<0.19	<0.09	0.37	<0.41	<0.20
Mid North Sea	Cod	2	<0.33	<0.08	<0.04	0.22	<0.15	<0.07
Mid North Sea	Plaice	2	<0.84	<0.19	<0.09	0.12	<0.30	<0.13
Gt Yarmouth (retail shop)	Cod	2	<0.46	<0.11	<0.05	0.12	<0.22	<0.11
Gt Yarmouth (retail shop)	Plaice	2	<0.94	<0.23	<0.11	<0.10	<0.38	<0.18
Southern North Sea	Cod	1	<0.42	<0.10	<0.05	0.28	<0.17	<0.08
Southern North Sea	Herring	1	<0.64	<0.14	<0.07	0.13	<0.33	<0.11
Southern North Sea	Skates / rays	1	<0.59	<0.16	<0.07	0.25	<0.30	<0.16
Southern North Sea	Sole	2	<0.46	<0.12	<0.05	0.10	<0.23	<0.12
English Channel-East	Plaice	2	<0.66	<0.16	<0.07	<0.07	<0.30	<0.12
English Channel-East	Whiting	1	<0.60	<0.15	<0.07	0.21	<0.31	<0.15
English Channel-East	Flounder	1	<0.64	<0.15	<0.07	0.15	<0.32	<0.13
English Channel-West	Mackerel	2	<0.77	<0.19	<0.08	<0.14	<0.36	<0.17
English Channel-West	Plaice	2	<1.0	<0.23	<0.11	0.11	<0.40	<0.17
English Channel-West	Whiting	2	<0.53	<0.14	<0.06	0.22	<0.27	<0.14
Celtic Sea	Whiting	1	<0.53	<0.14	<0.06	0.30	<0.29	<0.15
Celtic Sea	Common ling	1	<0.51	<0.12	<0.06	0.38	<0.20	<0.09
Celtic Sea	Haddock	1	<0.48	<0.12	<0.05	0.12	<0.24	<0.13
Celtic Sea	Pollack	1	<0.62	<0.15	<0.07	0.38	<0.31	<0.16
Northern Irish Sea	Dab	1	<0.68	<0.15	<0.07	0.41	<0.27	<0.12
Northern Irish Sea	Lesser spotted dogfish	1	<1.9	<0.40	<0.19	0.63	<0.70	<0.27
Northern Irish Sea	Skates / rays	1	<1.6	<0.35	<0.15	0.43	<0.76	<0.32

* *Not detected by the method used*
[a] *The concentrations of ^{129}I and ^{147}Pm were <1.8 and <0.72 Bq kg^{-1} respectively*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2013

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}Nb	^{95}Zr	^{99}Tc	^{106}Ru
Cumbria											
Silloth	Shrimps	4				<0.08		<0.23	<0.22		<0.74
Silloth	Winkles	4		<25		<0.26		<0.77	<0.63		<2.1
Silloth	Mussels	1		<25							
Parton	Crabs	4				<0.24		<0.36	<0.28		<0.83
Parton	Lobsters	4				<0.07		<0.17	<0.17		<0.60
Parton	Winkles	4				0.58		<0.23	<0.27		<1.1
Whitehaven	*Nephrops*	4			72	<0.07	0.039	<0.14	<0.16	18	<0.63
Whitehaven	Cockles	2				<0.08		<0.10	<0.15		<0.77
Whitehaven	Mussels	2				<0.06	0.050	<0.08	<0.11		<0.51
Whitehaven outer harbour	Mussels	2				0.28		<0.14	<0.16		<0.72
Saltom Bay	Winkles	4				0.67		<0.73	<0.60		<2.1
St Bees	Winkles[a]	4			86	0.89	1.0	<0.22	<0.24	42	<1.9
St Bees	Mussels	2				0.70		<0.27	<0.30		4.5
St Bees	Limpets	4				0.40		<0.18	<0.21		<1.5
Nethertown	Winkles	12	<25	<25	110	1.0	2.3	<0.34	<0.33	27	<3.3
Nethertown	Mussels	4	58	71	88	0.83		<0.40	<0.41	30	7.3
Sellafield coastal area	Crabs[b]	8			140	<0.36	0.17	<0.47	<0.36	4.8	<1.1
Sellafield coastal area	Lobsters	8			160	<0.17	<0.071	<0.30	<0.27	130	<0.86
Sellafield coastal area	*Nephrops*	1				<0.07		<0.15	<0.16	22	<0.57
Sellafield coastal area[c]	Winkles	8			90	1.2	1.2	<0.28	<0.30	33	<4.2
Sellafield coastal area[c]	Mussels	4				0.54	0.23	<0.60	<0.49		<1.7
Sellafield coastal area[c]	Limpets	4			76	0.43	2.8	<0.20	<0.24	74	<1.8
Whitriggs	Shrimps	1				<0.23		<1.1	<0.82		<2.2
Drigg	Winkles	4			110	1.1		<0.19	<0.21	27	<4.2
Ravenglass	Crabs	4				0.20	0.090	<0.30	<0.25	5.3	<0.67
Ravenglass	Lobsters	6				<0.09	0.055	<0.30	<0.25	81	<0.73
Ravenglass	Winkles	2				0.51		<0.13	<0.17		<0.90
Ravenglass	Cockles	4			120	1.0	1.4	<0.18	<0.19	2.4	<1.5
Ravenglass	Mussels	4		<25		0.53		<0.12	<0.16	43	<1.5
Tarn Bay	Winkles	4				0.90		<0.27	<0.31		3.0
Millom	Winkles	2				0.30		<0.28	<0.24		<0.79
Millom	Mussels	4				<0.12		<0.26	<0.26		<0.93
Barrow	Crabs	4				<0.09		<0.34	<0.26		<0.78
Barrow	Lobsters	4				<0.08		<0.32	<0.28	49	<0.77
Roosebeck	Pacific oysters	2				<0.12		<0.41	<0.36		<1.2
Morecambe Bay (Flookburgh)	Shrimps	4			64	<0.11		<0.27	<0.30	0.78	<1.0
Morecambe Bay (Flookburgh)	Cockles	4			61	0.22	0.20	<0.37	<0.26	1.5	<0.66
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2				<0.09		<0.14	<0.17		<0.72
Morecambe Bay (Morecambe)	Mussels	4	53	49	73	<0.12		<0.39	<0.33	65	<1.1
Red Nab Point	Winkles	4				<0.09		<0.13	<0.16		<0.65
Morecambe Bay (Middleton Sands)	Cockles	2				0.24		<0.11	<0.14		<0.60
Knott End	Mussels	2				<0.18		<0.33	<0.39		<1.7
Fleetwood	Whelks	1				<0.07		<0.13	<0.16		<0.62
Ribble Estuary	Shrimps	2			45	<0.06		<0.09	<0.12	0.18	<0.45
Ribble Estuary	Cockles	2				<0.12		<0.09	<0.92		<1.2
Ribble Estuary	Mussels	2				<0.06		<0.07	<0.09		<0.40
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<25							
Dee Estuary	Cockles	4				<0.13		<0.33	<0.32	1.4	<1.2
Wirral	Shrimps	2		<25		<0.05		<0.16	<0.16	0.27	<0.50

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	<0.14	<0.19	<0.08	2.4	<0.35		<0.16	
Silloth	Winkles	4	<0.34	<0.47	<0.21	6.1	<0.76		<0.31	
Silloth	Mussels	1								
Parton	Crabs	4	<0.16	<0.21	<0.09	1.0	<0.44		<0.20	
Parton	Lobsters	4	<0.11	<0.16	<0.06	1.3	<0.32		<0.14	
Parton	Winkles	4	<0.20	<0.32	<0.12	4.7	<0.51		<0.25	
Whitehaven	*Nephrops*	4	<0.12	<0.17	<0.07	2.2	<0.36		<0.18	170
Whitehaven	Cockles	2	<0.13	<0.19	<0.08	<0.10	<0.36		<0.16	
Whitehaven	Mussels	2	<0.09	<0.13	<0.06	<0.05	<0.24		<0.12	
Whitehaven outer harbour	Mussels	2	<0.11	0.34	<0.07	1.3	<0.41		<0.19	
Saltom Bay	Winkles	4	<0.34	<0.45	<0.20	3.3	<0.77		<0.32	
St Bees	Winkles[a]	4	<0.18	<0.34	<0.09	3.6	<0.49	0.45	<0.23	
St Bees	Mussels	2	<0.21	0.47	<0.13	2.3	<0.55		<0.24	
St Bees	Limpets	4	<0.17	0.48	<0.10	4.3	<0.52		<0.25	
Nethertown	Winkles	12	<0.23	<0.42	<0.13	5.3	<0.62	3.0	<0.28	200
Nethertown	Mussels	4	<0.27	0.85	<0.16	2.3	<0.53		<0.23	160
Sellafield coastal area	Crabs[b]	8	<0.21	<0.25	<0.11	1.0	<0.48	0.14	<0.20	130
Sellafield coastal area	Lobsters	8	<0.18	<0.21	<0.09	1.3	<0.39	0.13	<0.17	230
Sellafield coastal area	*Nephrops*	1	<0.12	<0.16	<0.07	2.2	<0.29		<0.13	
Sellafield coastal area[c]	Winkles	8	<0.23	<0.41	<0.13	5.3	<0.63	0.64	<0.31	
Sellafield coastal area[c]	Mussels	4	<0.26	<0.57	<0.15	1.1	<0.68		<0.29	
Sellafield coastal area[c]	Limpets	4	<0.18	0.61	<0.11	4.5	<0.61		<0.30	
Whitriggs	Shrimps	1	<0.39	<0.47	<0.23	1.6	<0.75		<0.30	
Drigg	Winkles	4	<0.16	<0.45	<0.09	3.6	<0.45	0.70	<0.20	210
Ravenglass	Crabs	4	<0.14	<0.16	<0.07	0.65	<0.33		<0.14	120
Ravenglass	Lobsters	6	<0.15	<0.18	<0.08	1.1	<0.35		<0.16	200
Ravenglass	Winkles	2	<0.15	<0.25	<0.09	<4.0	<0.49		<0.25	
Ravenglass	Cockles	4	<0.14	<0.24	<0.08	2.9	<0.38		<0.18	130
Ravenglass	Mussels	4	<0.12	0.56	<0.07	1.1	<0.39		<0.19	
Tarn Bay	Winkles	4	<0.24	<0.42	<0.14	3.6	<0.56		<0.27	
Millom	Winkles	2	<0.14	<0.21	<0.08	3.7	<0.40		<0.20	
Millom	Mussels	4	<0.16	<0.21	<0.09	0.97	<0.41		<0.18	
Barrow	Crabs	4	<0.16	<0.19	<0.09	0.72	<0.38		<0.16	
Barrow	Lobsters	4	<0.15	<0.19	<0.08	1.0	<0.41		<0.19	170
Roosebeck	Pacific oysters	2	<0.21	<0.25	<0.12	0.81	<0.41		<0.17	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.19	<0.28	<0.11	3.8	<0.49		<0.23	
Morecambe Bay (Flookburgh)	Cockles	4	<0.13	<0.17	<0.07	3.2	<0.34		<0.16	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Shrimps	2	<0.14	<0.19	<0.08	4.7	<0.30		<0.14	
Morecambe Bay (Morecambe)	Mussels	4	<0.20	<0.25	>0.11	2.1	<0.42		<0.20	
Red Nab Point	Winkles	4	<0.13	<0.18	<0.08	3.4	<0.30		<0.15	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.11	<0.15	<0.07	2.3	<0.25		<0.12	
Knott End	Mussels	2	<0.28	<0.41	<0.18	1.4	<0.81		<0.36	
Fleetwood	Whelks	1	<0.12	<0.16	<0.06	0.21	<0.32		<0.17	
Ribble Estuary	Shrimps	2	<0.10	<0.12	<0.05	1.5	<0.18		<0.08	
Ribble Estuary	Cockles	2	<0.23	<0.24	<0.12	1.7	<0.48		<0.16	
Ribble Estuary	Mussels	2	<0.08	<0.10	<0.05	0.86	<0.14		<0.06	
Dee Estuary	Cockles	4	<0.20	<0.28	<0.12	1.2	<0.50		<0.22	
Wirral	Shrimps	2	<0.10	<0.13	<0.05	0.88	<0.27		<0.12	

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}Nb	^{95}Zr	^{99}Tc	^{106}Ru
Scotland										
Lewis	Mussels	1[S]			<0.10		<0.24	<0.25		<0.78
Skye	Lobsters	1[S]			<0.10		<0.51	<0.38	4.9	<0.85
Skye	Mussels	1[S]			<0.10		<1.2	<0.57		<0.81
Islay	Crabs	1[S]			<0.10		<2.7	<0.90		<0.89
Islay	Scallops	1[S]			<0.10		<0.17	<0.15		<0.35
Kirkcudbright	Scallops	4[S]			<0.10		<0.20	<0.29	1.1	<0.52
Kirkcudbright	Queens	4[S]			<0.10		<0.21	<0.20	0.74	<0.56
Kirkcudbright	Limpets	1[S]			0.21		<0.26	<0.25		<0.72
Southerness	Winkles	4[S]	<5.0		<0.11	0.20	<0.21	<0.23	20	<0.74
North Solway coast	Crabs	4[S]		66	<0.10	0.17	<0.17	<0.18	1.8	<0.55
North Solway coast	Lobsters	4[S]		52	<0.10	<0.10	<0.23	<0.24	40	<0.79
North Solway coast	Winkles	4[S]			<0.10	0.21	<0.16	<0.18	17	<0.61
North Solway coast	Cockles	1[S]			0.25		<0.21	<0.23		<0.74
North Solway coast	Mussels	4[S]	<5.0	25	<0.10	0.54	<0.15	<0.15	7.2	<0.51
Inner Solway	Shrimps	2[S]	<5.0		<0.10	<0.10	<0.16	<0.18	0.66	<0.59
Isle of Man										
Isle of Man	Lobsters	4			<0.09		<0.30	<0.26	14	<0.83
Isle of Man	Scallops	4			<0.06		<0.13	<0.14		<0.54
Wales										
Conwy	Mussels	2		41	<0.06		<0.15	<0.17		<0.63
North Anglesey	Crabs	2			<0.05		<0.10	<0.12	0.17	<0.49
North Anglesey	Lobsters	2			<0.07		<0.11	<0.14	16	<0.66
Northern Ireland										
Ballycastle	Lobsters	2[N]			<0.15		<1.6	<0.78	5.1	<1.6
County Down	Scallops	2[N]			<0.06		<0.15	<0.16		<0.57
Kilkeel	Crabs	4[N]			<0.06		<0.39	<0.26		<0.56
Kilkeel	Lobsters	4[N]			<0.06		<0.29	<0.22	7.5	<0.57
Kilkeel	Nephrops	4[N]			<0.07		<0.49	<0.31	2.3	<0.74
Minerstown	Winkles	3[N]			<0.08		<0.13	<0.17		<0.77
Minerstown	Toothed winkle	1[N]			<0.14		<0.19	<0.27		<1.4
Carlingford Lough	Mussels	2[N]			<0.09		<0.38	<0.31	1.7	<0.93
Further afield										
Cromer	Crabs	1			<0.07		<0.11	<0.16		<0.66
Southern North Sea	Cockles	1			<0.04		<0.44	<0.22		<0.41
Southern North Sea	Mussels	2			<0.04		<0.15	<0.14	0.22	<0.45
Southern North Sea	Cockles[d]	1			<0.06		<0.63	<0.33	0.14	<0.61
Southern North Sea	Mussels[d]	1			<0.07		<0.79	<0.43		<0.73
English Channel-East	Scallops	1		26	<0.07		<0.17	<0.18		<0.53
English Channel-West	Crabs	2		36	<0.07		<0.18	<0.19		<0.65
English Channel-West	Lobsters	2			<0.06		<0.14	<0.16	<0.21	<0.55
English Channel-West	Scallops	2		31	<0.12		<0.37	<0.34		<1.1
Northern Irish Sea	Crabs	1			<0.14		<0.53	<0.47		<1.5
Northern Irish Sea	Octopuses	1			<0.09		<0.51	<0.36		<0.97

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]	<0.10	<0.20	<0.10	<0.10	<0.41	<0.18	
Skye	Lobsters	1[S]	<0.11	<0.22	<0.10	0.17	<0.44	<0.17	
Skye	Mussels	1[S]	<0.10	<0.21	<0.10	<0.10	<0.50	<0.17	
Islay	Crabs	1[S]	<0.12	<0.22	<0.10	0.18	<0.61	<0.19	
Islay	Scallops	1[S]	<0.10	<0.10	<0.10	0.22	<0.23	<0.12	
Kirkcudbright	Scallops	4[S]	<0.10	<0.15	<0.10	<0.10	<0.32	<0.14	
Kirkcudbright	Queens	4[S]	<0.10	<0.16	<0.10	<0.19	<0.35	<0.15	
Kirkcudbright	Limpets	1[S]	<0.13	<0.22	<0.10	1.3	<0.46	<0.18	
Southerness	Winkles	4[S]	<0.13	<0.23	<0.10	0.80	<0.47	<0.20	
North Solway coast	Crabs	4[S]	<0.11	<0.16	<0.10	0.61	<0.33	<0.14	
North Solway coast	Lobsters	4[S]	<0.13	<0.22	<0.10	0.89	<0.47	<0.19	
North Solway coast	Winkles	4[S]	<0.10	<0.19	<0.10	0.61	<0.39	<0.16	
North Solway coast	Cockles	1[S]	<0.15	<0.24	<0.09	4.7	<0.50	<0.22	
North Solway coast	Mussels	4[S]	<0.11	<0.16	<0.10	1.9	<0.32	<0.15	
Inner Solway	Shrimps	2[S]	<0.11	<0.17	<0.10	2.5	<0.36	<0.16	
Isle of Man									
Isle of Man	Lobsters	4	<0.15	<0.19	<0.09	<0.23	<0.34	<0.16	120
Isle of Man	Scallops	4	<0.11	<0.14	<0.06	0.18	<0.28	<0.14	
Wales									
Conwy	Mussels	2	<0.12	<0.16	<0.07	<0.46	<0.31	<0.15	
North Anglesey	Crabs	2	<0.09	<0.13	<0.05	0.26	<0.23	<0.10	
North Anglesey	Lobsters	2	<0.12	<0.17	<0.07	0.24	<0.34	<0.16	120
Northern Ireland									
Ballycastle	Lobsters	2[N]	<0.29	<0.34	<0.15	0.14	<0.71	<0.26	
County Down	Scallops	2[N]	<0.12	<0.14	<0.06	0.30	<0.28	<0.15	
Kilkeel	Crabs	4[N]	<0.11	<0.14	<0.06	0.15	<0.30	<0.12	
Kilkeel	Lobsters	4[N]	<0.12	<0.14	<0.06	0.15	<0.26	<0.12	
Kilkeel	*Nephrops*	4[N]	<0.14	<0.17	<0.07	0.39	<0.41	<0.17	
Minerstown	Winkles	3[N]	<0.14	<0.18	<0.08	0.22	<0.31	<0.15	
Minerstown	Toothed winkle	1[N]	<0.22	<0.35	<0.14	0.25	<0.66	<0.32	
Carlingford Lough	Mussels	2[N]	<0.17	<0.19	<0.09	0.25	<0.36	<0.14	
Further afield									
Cromer	Crabs	1	<0.13	<0.19	<0.08	<0.08	<0.36	<0.19	
Southern North Sea	Cockles	1	<0.09	<0.09	<0.05	0.09	<0.14	<0.06	
Southern North Sea	Mussels	2	<0.08	<0.11	<0.05	0.08	<0.21	<0.09	
Southern North Sea	Cockles[d]	1	<0.13	<0.16	<0.06	0.24	<0.35	<0.15	
Southern North Sea	Mussels[d]	1	<0.14	<0.18	<0.08	<0.07	<0.41	<0.18	<25
English Channel-East	Scallops	1	<0.11	<0.14	<0.06	<0.05	<0.28	<0.14	
English Channel-West	Crabs	2	<0.12	<0.15	<0.07	<0.06	<0.28	<0.12	
English Channel-West	Lobsters	2	<0.11	<0.14	<0.06	<0.06	<0.28	<0.13	
English Channel-West	Scallops	2	<0.21	<0.24	<0.11	<0.10	<0.40	<0.18	
Northern Irish Sea	Crabs	1	<0.26	<0.35	<0.14	0.44	<0.73	<0.30	
Northern Irish Sea	Octopuses	1	<0.17	<0.20	<0.10	<0.08	<0.37	<0.14	

[a] *The concentration of ^{129}I was <2.0 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <1.8 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, 2013

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		0.0025	0.015	0.18	0.032	*	0.000080
Silloth	Winkles	1		1.1	6.4		13	*	0.017
Maryport	Plaice	4					<0.17		
Parton	Cod	4					<0.19		
Parton	Crabs	4					1.2		
Parton	Lobsters	4					1.6		
Parton	Winkles	1		1.2	6.7	37	14	*	*
Whitehaven	Cod	1		0.00076	0.0039		0.0078	*	*
Whitehaven	Plaice	1		0.0011	0.0057		0.014	*	*
Whitehaven	Skates / rays	1		0.00023	0.0014		0.0025	*	*
Whitehaven	Sole	1		0.0099	0.050		0.090	*	0.00012
Whitehaven	*Nephrops*	1		0.035	0.21		1.3	*	*
Whitehaven	Cockles	1		0.0018	0.013		0.022	*	*
Whitehaven	Mussels	1		0.000081	0.00078	<0.14	0.00054	*	*
Whitehaven outer harbour	Mussels	2					7.2		
Saltom Bay	Winkles	4					12		
St Bees	Winkles	1	0.010	1.1	6.2	35	12	*	*
St Bees	Mussels	2		1.1	5.4	37	11	*	0.010
St Bees	Limpets	1		1.5	8.6		19	*	0.027
Nethertown	Winkles	4	0.047	2.0	11	72	24	0.033	0.015
Nethertown	Mussels	2		1.1	5.1		11	*	0.0090
Sellafield coastal area	Cod	2		0.00035	0.0017		0.0034	*	0.0000060
Sellafield coastal area	Plaice	1		0.0029	0.016		0.034	*	*
Sellafield coastal area	Bass	1					<0.23		
Sellafield coastal area	Grey mullet	1					<0.22		
Sellafield coastal area	Crabs	2	0.0014	0.076	0.37	2.9	1.7	*	0.0017
Sellafield coastal area	Lobsters	2	0.012	0.053	0.22	2.3	3.3	*	0.0073
Sellafield coastal area	*Nephrops*	1		0.021	0.12		0.69	*	0.0011
Sellafield coastal area[a]	Winkles	2	0.016	1.9	10	63	21	*	0.021
Sellafield coastal area[a]	Mussels	1		0.70	3.9	25	8.8	*	0.012
Sellafield coastal area[a]	Limpets	1		1.7	10	56	19	*	0.017
Sellafield offshore area	Cod	1		0.0020	0.011		0.020	*	*
Sellafield offshore area	Dab	2					<0.23		
Sellafield offshore area	Plaice	1	0.00023	0.0029	0.015		0.030	*	0.00010
Sellafield offshore area	Lesser spotted dogfish	1					<0.11		
Sellafield offshore area	Skates / rays	1					<0.22		
River Esk	Brown trout	1					<0.14		
River Calder	Brown trout	1					<0.27		
Whitriggs	Shrimps	1					<0.16		
Drigg	Winkles	1	0.012	1.4	6.9	44	14	*	*
Ravenglass	Cod	1		0.00026	0.0014		0.0029	*	*
Ravenglass	Plaice	1		0.0027	0.010		0.023	*	*
Ravenglass	Crabs	1		0.042	0.25	1.6	1.2	*	0.0026
Ravenglass	Lobsters	1		0.044	0.21	1.6	3.8	*	*
Ravenglass	Winkles	2					15		
Ravenglass	Cockles	1		1.2	6.0	37	17	*	*
Ravenglass	Mussels	1		0.68	3.9	25	8.6	*	*
Tarn Bay	Winkles	1		1.3	6.3	39	13	*	*
Millom	Winkles	2					9.1		
Millom	Mussels	1		0.21	1.2		2.8	*	*
Barrow	Crabs	1		0.018	0.11		0.74	*	0.0010
Barrow	Lobsters	4					1.2		
Roosebeck	Pacific oysters	1		0.13	0.74		0.70	*	*
Morecambe Bay (Flookburgh)	Flounder	1		0.00024	0.0015		0.0038	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0037	0.023	0.18	0.042	*	*
Morecambe Bay (Flookburgh)	Cockles	1		0.31	1.9	9.4	5.2	*	0.0082

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					<0.13		
Morecambe Bay (Morecambe)	Bass	2					<0.16		
Morecambe Bay (Morecambe)	Flounder	4					<0.14		
Morecambe Bay (Morecambe)	Shrimps	2					<0.09		
Morecambe Bay (Morecambe)	Mussels	1		0.29	1.7		3.4	*	*
Red Nab Point	Winkles	1		0.29	1.6		3.0	*	*
Morecambe Bay (Middleton Sands)	Cockles	1		0.52	3.1		8.2	*	0.014
Morecambe Bay (Sunderland Point)	Whitebait	1		0.034	0.22	1.0	0.34	*	*
Knott End	Mussels	1		0.17	0.95		2.0	*	*
Fleetwood	Cod	2					<0.12		
Fleetwood	Plaice	1		0.00057	0.0036		0.0067	*	*
Fleetwood	Whiting	1		0.00018	0.0010		0.0015	*	*
Fleetwood	Whelks	1					<0.20		
Ribble Estuary	Grey mullet	2					<0.26		
Ribble Estuary	Sole	1					<0.11		
Ribble Estuary	Bass	1					<0.11		
Ribble Estuary	Salmon	1					<0.23		
Ribble Estuary	Shrimps	1	0.000091	0.0019	0.013		0.023	*	*
Ribble Estuary	Cockles	1		0.24	1.5		4.0	*	*
Ribble Estuary	Mussels	2					0.77		
Dee Estuary	Cockles	1		0.099	0.68		1.6	*	*
Wirral	Shrimps	2					<0.10		
Scotland									
Shetland	Fish meal (herring)	1[S]		<0.0087	<0.0087		0.060		
Shetland	Fish oil (herring)	1[S]		<0.0024	<0.0024		0.010		
Shetland	Fish oil (salmon)	1[S]		<0.0026	0.0050		0.015		
Minch	Herring	1[S]		0.026	0.20		0.050		
West of Scotland	Mackerel	1[S]		0.031	0.024		0.079		
Minch	Mackerel	1[S]		<0.0052	0.011		0.027		
Lewis	Mussels	1[S]					<0.11		
Skye	Lobsters	1[S]					<0.10		
Skye	Mussels	1[S]					<0.10		
Islay	Crabs	1[S]					<0.10		
Islay	Scallops	1[S]					<0.11		
Kirkcudbright	Plaice	1[S]		<0.00055	0.00066		0.00092		
Kirkcudbright	Scallops	1[S]		<0.0025	0.0063		0.0036		
Kirkcudbright	Queens	1[S]		0.0074	0.038		0.059		
Kirkcudbright	Limpets	1[S]					5.5		
Southerness	Winkles	1[S]		0.21	1.1	5.1	2.0		
North Solway coast	Crabs	1[S]		0.018	0.11	0.76	0.52		
North Solway coast	Lobsters	1[S]		0.013	0.072	0.40	0.37		
North Solway coast	Winkles	1[S]		0.15	0.94		1.6		
North Solway coast	Cockles	1[S]		0.43	2.6		6.9		
North Solway coast	Mussels	1[S]		0.43	2.5	12	5.6		
Inner Solway	Flounder	1[S]		0.0013	0.0069		0.016		
Inner Solway	Salmon	1[S]					<0.10		
Inner Solway	Sea trout	1[S]					<0.13		
Inner Solway	Shrimps	1[S]		0.0024	0.014		0.024		

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}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Isle of Man								
Isle of Man	Cod	1	0.00039	0.0023		0.0046	*	0.000011
Isle of Man	Herring	1	0.000045	0.00025		0.00032	*	*
Isle of Man	Mackerel	1				<0.35		
Isle of Man	Lobsters	4				<0.14		
Isle of Man	Scallops	1	0.016	0.095		0.030	*	*
Wales								
Conwy	Mussels	1	0.039	0.21		0.35	*	*
North Anglesey	Thornback ray	1				<0.23		
North Anglesey	Lesser spotted dogfish	1	0.000078	0.00042		0.0011	*	*
North Anglesey	Plaice	2				<0.07		
North Anglesey	Bass	1				<0.19		
North Anglesey	Crabs	1	0.0027	0.014		0.058	*	*
North Anglesey	Lobsters	2				<0.18		
Northern Ireland								
North coast	Lesser spotted dogfish	2[N]				<0.12		
North coast	Spurdog	2[N]				<0.19		
Ballycastle	Lobsters	2[N]				0.20		
County Down	Scallops	2[N]				<0.18		
Ardglass	Herring	2[N]				<0.14		
Kilkeel	Cod	4[N]				<0.12		
Kilkeel	Plaice	4[N]				<0.11		
Kilkeel	Skates / rays	3[N]				<0.19		
Kilkeel	Thornback ray	1[N]				<0.09		
Kilkeel	Haddock	4[N]				<0.14		
Kilkeel	Crabs	4[N]				<0.10		
Kilkeel	Lobsters	4[N]				<0.09		
Kilkeel	*Nephrops*	1[N]	0.0013	0.0083		0.025	*	*
Minerstown	Winkles	1[N]	0.029	0.18		0.14	*	*
Minerstown	Toothed winkles	1[N]				0.25		
Carlingford Lough	Mussels	2[N]				<0.08		
Glenarm	Brown trout	1				<0.05		
Further afield								
Baltic Sea	Cod	2				<0.06		
Baltic Sea	Herring	2				<0.12		
Barents Sea	Haddock	2				<0.03		
Norwegian Sea	Herring	1				<0.07		
Norwegian Sea	Mackerel	1				<0.22		
Norwegian Sea	Haddock	2				<0.10		
Norwegian processed	Cod	1	0.000014	0.000061		0.00017	*	*
Iceland area	Cod	1				<0.18		
Skagerrak	Cod	2				<0.12		
Skagerrak	Herring	2				<0.24		
Mid North Sea	Cod	2				<0.04		
Mid North Sea	Plaice	2				<0.07		
Cromer	Crabs	1				<0.22		
Gt Yarmouth (retail shop)	Cod	2				<0.11		
Gt Yarmouth (retail shop)	Plaice	2				<0.10		
Southern North Sea	Cod	1				<0.05		
Southern North Sea	Herring	1				<0.06		
Southern North Sea	Skates / rays	1				<0.19		
Southern North Sea	Sole	2				<012		
Southern North Sea	Cockles	1	0.00063	0.0037		0.0053	*	0.00022
Southern North Sea	Mussels	1	0.0020	0.014		0.0061	*	*
Southern North Sea	Cockles[b]	1	0.013	0.092		0.29	*	*
Southern North Sea	Mussels[b]	1	0.00020	0.0014		0.00096	*	*

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-East	Plaice	2			<0.07		
English Channel-East	Whiting	1			<0.18		
English Channel-East	Flounder	1			<0.07		
English Channel-East	Scallops	1	0.00041	0.0022	0.0015	0.000022	0.000027
English Channel-West	Mackerel	2			<0.16		
English Channel-West	Plaice	2			<0.09		
English Channel-West	Whiting	2			<0.17		
English Channel-West	Crabs	1	0.00011	0.00085	0.0012	*	*
English Channel-West	Lobsters	2			<0.14		
English Channel-West	Scallops	1	0.0011	0.0039	0.0015	*	0.00011
Celtic Sea	Whiting	1			<0.18		
Celtic Sea	Common ling	1			<0.05		
Celtic Sea	Haddock	1			<0.15		
Celtic Sea	Pollack	1			<0.19		
Northern Irish Sea	Dab	1			<0.07		
Northern Irish Sea	Lesser spotted dogfish	1			<0.15		
Northern Irish Sea	Skates / rays	1			<0.28		
Northern Irish Sea	Crabs	1			<0.28		
Northern Irish Sea	Octopuses	1			<0.07		

* *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, 2013

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	<0.48		<1.2	<0.34	<3.5	<1.8	<0.46	160	<2.3
Maryport Outer Harbour	Sediment	2	<0.58	<4.9	<1.1	<0.34	<3.4	<1.8	<0.44	68	<1.7
Workington Harbour	Sediment	2	<0.39		<0.88	<0.36	<2.6	<1.4	<0.38	37	<1.7
Harrington Harbour	Sediment	2	<0.46		<0.95	<0.39	<3.1	<1.6	<0.42	147	<1.9
Whitehaven Outer Harbour	Sediment	4	<0.55	<2.0	<1.0	<0.32	<2.8	<1.5	<0.36	67	<1.7
St Bees beach	Sediment	4	1.1		<0.77	<0.22	<2.3	<1.2	<0.29	59	<1.4
Sellafield beach, S of former pipeline	Sediment	2	0.80		<0.64	<0.19	<2.0	<1.0	<0.26	42	<1.2
River Calder – downstream	Sediment	2	<0.34		<0.70	<0.25	<2.2	<1.2	<0.30	56	<1.4
River Calder – upstream	Sediment	2	<0.44		<0.96	<0.34	<2.6	<1.3	<0.40	30	<1.8
Seascale beach	Sediment	4	0.67		<0.72	<0.23	<2.0	<1.0	<0.28	29	<1.3
Ravenglass – Carleton Marsh	Sediment	4	4.4		<1.4	<0.46	<15	<2.4	<0.55	310	<3.7
River Mite Estuary (erosional)	Sediment	4	2.0	57	<1.2	<0.41	<5.8	<2.0	<0.47	230	<2.4
Ravenglass – Raven Villa	Sediment	4	1.9		<1.2	<0.35	<4.4	<1.7	<0.43	100	<2.3
Newbiggin (Eskmeals)	Sediment	4	5.8	80	<1.8	<0.54	<6.7	<2.6	<0.60	280	<2.8
Haverigg	Sediment	2	1.1		<1.0	<0.35	<2.9	<1.5	<0.39	61	<1.6
Millom	Sediment	2	<0.60		<1.4	<0.41	<3.9	<2.0	<0.50	98	<2.1
Low Shaw	Sediment	2	<0.36		<0.82	<0.23	<2.3	<1.2	<0.31	48	<1.5
Walney Channel – N of discharge point	Sediment	2	<0.70		<1.2	<0.36	<3.3	<1.7	<0.44	81	<1.8
Walney Channel – S of discharge point	Sediment	2	<0.69		<1.1	<0.36	<3.1	<1.6	<0.42	68	<1.8
Sand Gate Marsh	Sediment	4	<0.41		<1.0	<0.33	<2.8	<1.5	<0.38	100	<1.9
Kents Bank	Sediment	4	<0.53		<1.5	<0.37	<4.8	<2.4	<0.54	300	<2.5
Lancashire											
Morecambe	Sediment	2	<0.27							10	
Half Moon Bay	Sediment	2	<0.60							110	
Red Nab Point	Sediment	2	<0.51							29	
Potts Corner	Sediment	2	<0.43							17	
Sunderland Point	Sediment	4	<0.38		<1.4	<0.37	<2.7	<1.4	<0.41	67	<1.9
Conder Green	Sediment	4	<0.44		<1.0	<0.38	<2.9	<1.6	<0.42	73	<1.9
Hambleton	Sediment	4	<0.58		<1.3	<0.46	<4.3	<2.2	<0.53	230	<2.4
Skippool Creek	Sediment	4	<0.68		<1.3	<0.47	<4.4	<2.4	<0.59	230	<2.6
Fleetwood	Sediment	4	<0.31		<0.66	<0.21	<1.8	<1.0	<0.27	11	<1.1
Blackpool	Sediment	4	<0.31		<0.69	<0.21	<1.9	<0.98	<0.28	2.6	<0.97
Crossens Marsh	Sediment	4	<1.6		<3.9	<1.2	<12	<6.3	<1.6	200	<5.0
Ainsdale	Sediment	4	<0.26		<0.58	<0.17	<1.6	<0.86	<0.24	4.0	<0.99
Rock Ferry	Sediment	4	<0.53		<1.2	<0.39	<3.6	<1.9	<0.49	130	<2.0
New Brighton	Sediment	4	<0.33		<0.73	<0.21	<2.0	<1.1	<0.29	2.9	<1.0
Scotland											
Campbeltown	Sediment	1[S]	<0.10		<0.17	<0.14	<0.63	<0.20	<0.10	5.0	<0.58
Garlieston	Sediment	1[S]	<0.10		<0.16	<0.13	<0.63	<0.22	<0.10	22	<0.57
Innerwell	Sediment	1[S]	0.45		0.20	<0.13	<0.66	0.70	<0.10	80	<0.68
Carsluith	Sediment	1[S]	0.45		<0.11	<0.11	<0.66	0.31	<0.10	17	<0.64
Skyreburn	Sediment	1[S]	<0.10		<0.16	<0.12	<0.68	<0.22	<0.10	25	<0.66
Kirkcudbright	Sediment	1[S]	1.2		<0.26	<0.17	<1.3	1.2	<0.16	170	<1.3
Balcary Bay	Sediment	1[S]	0.40		<0.10	<0.10	<0.29	0.27	<0.10	64	<0.28
Palnackie Harbour	Sediment	1[S]	0.82		<0.20	<0.25	<1.1	0.96	<0.12	140	<0.99
Gardenburn	Sediment	1[S]	0.66		<0.16	<0.18	<0.60	0.39	<0.12	110	<0.85
Kippford Slipway	Sediment	1[S]	1.7		<0.26	<0.16	2.9	1.7	<0.17	270	<1.4
Kippford Merse	Sediment	1[S]	0.64		<0.19	<0.25	<1.3	<0.58	<0.13	350	<1.3
Kirkconnell Merse	Sediment	1[S]	0.52		<0.21	<0.30	<1.5	<0.58	<0.14	370	<1.3
Southerness	Sediment	1[S]	<0.10		<0.18	<0.17	<0.63	<0.21	<0.10	17	<0.64

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	<1.2	<0.97				190	420	890
Maryport Outer Harbour	Sediment	2	<1.4	<0.74	17	99	530	170	250	630
Workington Harbour	Sediment	2	<0.91	<0.72				29	300	590
Harrington Harbour	Sediment	2	<1.1	<0.84				79	390	690
Whitehaven Outer Harbour	Sediment	4	<0.81	<0.70	14	82	410	140	230	570
St Bees beach	Sediment	4	<0.81	<0.59				140	150	380
Sellafield beach, S of former pipeline	Sediment	2	<0.73	<0.54				130	<150	400
River Calder – downstream	Sediment	2	<0.78	<0.63				52	<140	640
River Calder – upstream	Sediment	2	<1.1	<0.77					150	980
Seascale beach	Sediment	4	<0.73	<0.59				120	180	450
Ravenglass – Carleton Marsh	Sediment	4	3.3	<2.4				1100	1500	1300
River Mite Estuary (erosional)	Sediment	4	2.3	<1.1	65	390	2100	790	1200	1100
Ravenglass – Raven Villa	Sediment	4	1.3	<0.92				390	570	870
Newbiggin (Eskmeals)	Sediment	4	3.6	<1.2	100	570	3300	1200	1500	1200
Haverigg	Sediment	2	<0.89	<0.74				220	530	570
Millom	Sediment	2	<1.4	<0.91				250	530	740
Low Shaw	Sediment	2	<0.84	<0.63				72	<170	510
Walney Channel – N of discharge point	Sediment	2	<1.2	<0.80				180	450	750
Walney Channel – S of discharge point	Sediment	2	<1.1	<0.76				140	<150	680
Sand Gate Marsh	Sediment	4	<0.94	<0.80				78	230	670
Kents Bank	Sediment	4	<1.2	<1.1				140	370	1000
Lancashire										
Morecambe	Sediment	2						8.1		
Half Moon Bay	Sediment	2			10	65		130		
Red Nab Point	Sediment	2						38		
Potts Corner	Sediment	2						14		
Sunderland Point	Sediment	4	<0.90	<1.9				59	200	720
Conder Green	Sediment	4	<1.1	<0.81				75	330	700
Hambleton	Sediment	4	<1.4	<1.1				230	570	1200
Skippool Creek	Sediment	4	<1.4	<1.2				230	530	1100
Fleetwood	Sediment	4	<0.74	<0.51				15	<120	450
Blackpool	Sediment	4	<0.76	<0.43				4.0	<110	<200
Crossens Marsh	Sediment	4	<4.1	<2.3				180	480	1300
Ainsdale	Sediment	4	<0.61	<0.44				2.7	<140	260
Rock Ferry	Sediment	4	<1.3	<0.92				87	360	970
New Brighton	Sediment	4	<0.83	<0.45				2.5	<110	220
Scotland										
Campbeltown	Sediment	1^{S}	<0.14	0.59				0.43		
Garlieston	Sediment	1^{S}	0.41	0.61	3.1	20		37		
Innerwell	Sediment	1^{S}	0.27	1.4	12	110		170		
Carsluith	Sediment	1^{S}	0.36	0.76	12	72		130	200	1400
Skyreburn	Sediment	1^{S}	<0.18	<0.35				13		
Kirkcudbright	Sediment	1^{S}	0.95	2.4				290		
Balcary Bay	Sediment	1^{S}	0.48	0.94	17	92		160		
Palnackie Harbour	Sediment	1^{S}	0.40	0.63	20	120		180		
Gardenburn	Sediment	1^{S}	0.55	0.99				190		
Kippford Slipway	Sediment	1^{S}	1.7	1.5				400		
Kippford Merse	Sediment	1^{S}	1.1	<0.66				350		
Kirkconnell Merse	Sediment	1^{S}	0.62	1.4				240	280	2200
Southerness	Sediment	1^{S}	<0.16	<0.28				20		

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	^{154}Eu
Isle of Man											
Ramsey	Sediment	1	<0.32	<0.70	<0.28	<2.0	<0.99	<0.31	6.7	<1.4	<0.77
Wales											
Rhyl	Sediment	2	<0.60	<1.5	<0.51	<3.8	<2.0	<0.56	63	<2.0	<1.5
Llandudno	Sediment	2	<0.33	<0.75	<0.26	<2.1	<1.1	<0.30	1.7	<1.2	<0.75
Caerhun	Sediment	2	<0.48	<1.2	<0.42	<3.1	<1.7	<0.47	39	<1.9	<1.2
Llanfairfechan	Sediment	2	<0.35	<0.84	<0.26	<2.3	<1.2	<0.34	21	<1.6	<0.81
Northern Ireland											
Carrichue	Mud and sand	1^{N}	<0.27	<2.1		<3.2	<0.80	<0.37	4.0	<2.5	<0.75
Carrichue	Mud and shell	1^{N}	<0.32	<0.90	<0.75	<3.3	<0.75	<0.37	1.7	<1.5	<1.1
Portrush	Sand	2^{N}	<0.20	<1.2	*	<2.0	<0.56	<0.25	0.61	<1.4	<0.62
Oldmill Bay	Mud	2^{N}	<0.30	<1.9	<4.0	<3.7	<0.96	<0.42	18	<2.7	<0.94
Ballymacormick	Mud and sand	2^{N}	<0.27	<1.5	<0.71	<3.1	<0.82	<0.35	11	<2.4	<0.82
Strangford Lough – Nicky's Point	Mud	2^{N}	<0.30	<1.7	<3.4	<3.2	<0.90	<0.42	18	<2.4	<1.0
Dundrum Bay	Mud	2^{N}	<0.55	<3.5	<7.9	<5.4	<1.3	<0.73	17	<3.0	<1.7
Carlingford Lough	Mud	2^{N}	<0.45	<2.7	<5.4	<4.6	<1.2	<0.61	44	<2.7	<1.4

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}							
			^{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	<0.62			1.6			<130	680
Wales										
Rhyl	Sediment	2	<0.88			43			330	1000
Llandudno	Sediment	2	<0.50			1.2			<120	290
Caerhun	Sediment	2	<0.82			22			300	870
Llanfairfechan	Sediment	2	<0.70			16			130	440
Northern Ireland										
Carrichue	Mud	1^{N}		0.13	0.89	1.6	*	*		
Carrichue	Mud and sand	1^{N}	<1.0							
Carrichue	Mud and shell	1^{N}	<0.71			0.73				
Portrush	Sand	2^{N}	<0.77			<0.96				
Oldmill Bay	Mud	2^{N}	<1.2			5.6				
Ballymacormick	Mud and sand	2^{N}	<1.1			8.5				
Strangford Lough – Nicky's Point	Mud	2^{N}	<1.0			6.4				
Dundrum Bay	Mud	2^{N}	<1.3			5.7				
Carlingford Lough	Mud	2^{N}	<1.2	1.7	11	9.1	*	*		

* *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, 2013

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Grass	2	0.083
Burgh Marsh	Grass	2	0.078
Port Carlisle 1	Mud	2	0.084
Port Carlisle 1	Mud and sand	2	0.084
Port Carlisle 2	Grass	4	0.087
Greenend 1	Mud	1	0.090
Greenend 1	Mud and sand	3	0.090
Greenend 2	Grass	4	0.088
Cardurnock Marsh	Grass and marsh	1	0.079
Cardurnock Marsh	Grass	3	0.078
Newton Arlosh	Grass	4	0.095
Silloth harbour	Mud	1	0.097
Silloth harbour	Mud and sand	1	0.099
Silloth harbour	Mud and pebbles	1	0.095
Silloth harbour	Sand and stones	1	0.10
Silloth silt pond	Grass and sand	1	0.085
Silloth silt pond	Grass	3	0.079
Allonby	Sand	4	0.088
Maryport harbour	Mud	1	0.084
Maryport harbour	Sand	1	0.086
Workington harbour	Pebbles and sand	1	0.11
Workington harbour	Stones	1	0.11
Harrington harbour	Sand	2	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven – outer harbour	Sand	2	0.092
Whitehaven – outer harbour	Pebbles and sand	2	0.11
St Bees	Sand	4	0.078
Nethertown beach	Shingle	1	0.12
Nethertown beach	Pebbles	1	0.13
Braystones	Pebbles and sand	1	0.11
Braystones	Shingle	1	0.11
Sellafield dunes	Grass	2	0.11
North of former pipeline on foreshore	Sand	2	0.085
South of former pipeline on foreshore	Sand	2	0.083
River Calder downstream of factory sewer	Grass	2	0.090
River Calder upstream of factory sewer	Grass	2	0.10
Seascale beach	Sand	2	0.093
Seascale beach	Grass	1	0.076
Seascale beach	Pebbles and sand	1	0.097
Seascale	Grass	4	0.085

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	Marsh	1	0.14
Ravenglass – Carleton Marsh	Grass	3	0.14
Ravenglass – River Mite estuary (erosional)	Mud and grass	1	0.15
Ravenglass – River Mite estuary (erosional)	Grass and marsh	1	0.14
Ravenglass – River Mite estuary (erosional)	Grass	2	0.14
Ravenglass – Raven Villa	Salt marsh	4	0.14
Ravenglass – boat area	Sand	1	0.10
Ravenglass – boat area	Sand and shingle	1	0.12
Ravenglass – boat area	Pebbles and sand	1	0.11
Ravenglass – boat area	Sand and stones	1	0.11
Ravenglass – ford	Mud	1	0.11
Ravenglass – ford	Sand and mud	1	0.10
Ravenglass – ford	Sand	2	0.10
Muncaster Bridge	Grass and marsh	1	0.13
Muncaster Bridge	Grass	3	0.12
Ravenglass – salmon garth	Mud	1	0.10
Ravenglass – salmon garth	Sand	1	0.11
Ravenglass – salmon garth	Pebbles and sand	2	0.11
Ravenglass – Eskmeals Nature Reserve	Mud	1	0.12
Ravenglass – Eskmeals Nature Reserve	Mud and salt marsh	2	0.12
Ravenglass – Eskmeals Nature Reserve	Salt marsh	1	0.12
Newbiggin/Eskmeals viaduct	Mud and salt marsh	3	0.11
Newbiggin/Eskmeals viaduct	Salt marsh	1	0.13
Newbiggin/Eskmeals Bridge	Salt marsh	4	0.13
Tarn Bay	Sand	2	0.082
Silecroft	Shingle	1	0.12
Silecroft	Pebbles	1	0.11
Haverigg	Mud and sand	1	0.091
Haverigg	Mud and stones	1	0.098
Millom	Mud	1	0.10
Millom	Mud and stones	1	0.11
Low Shaw	Grass	2	0.087
Askam	Sand	2	0.073
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	1	0.088
Walney Channel, N of discharge point	Mud and sand	1	0.091
Walney Channel, S of discharge point	Mud and sand	2	0.093
Tummer Hill Marsh	Salt marsh	2	0.12
Roa Island	Mud and sand	1	0.099
Roa Island	Pebbles and sand	1	0.095
Greenodd Salt Marsh	Grass	2	0.082
Sand Gate Marsh	Grass	4	0.087
Kents Bank 1	Grass and salt marsh	1	0.092
Kents Bank 2	Grass	3	0.090
High Foulshaw	Grass and mud	1	0.078
High Foulshaw	Grass	3	0.081
Arnside 1	Mud	1	0.085
Arnside 1	Mud and sand	3	0.084
Arnside 2	Grass	4	0.095

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			
Morecambe Central Pier	Sand	1	0.073
Morecambe Central Pier	Pebbles and sand	1	0.079
Half Moon Bay	Mud and sand	1	0.084
Half Moon Bay	Sand and stones	1	0.084
Red Nab Point	Sand	2	0.084
Middleton Sands	Sand	2	0.080
Sunderland Point	Mud	2	0.10
Sunderland Point	Mud and sand	2	0.093
Sunderland	Salt marsh	3	0.092
Sunderland	Grass	1	0.091
Colloway Marsh	Salt marsh	2	0.12
Colloway Marsh	Grass and salt marsh	1	0.13
Colloway Marsh	Grass	1	0.13
Lancaster	Grass	4	0.081
Aldcliffe Marsh	Grass	4	0.098
Conder Green	Mud	2	0.093
Conder Green	Mud and sand	1	0.091
Conder Green	Salt marsh	1	0.084
Pilling Marsh	Salt marsh	2	0.097
Pilling Marsh	Grass and salt marsh	1	0.10
Pilling Marsh	Grass	1	0.098
Knott End	Sand	2	0.075
Heads – River Wyre	Mud and salt marsh	2	0.099
Heads – River Wyre	Grass and mud	2	0.10
Height o' th' hill – River Wyre	Salt marsh	3	0.11
Height o' th' hill – River Wyre	Grass and salt marsh	1	0.10
Hambleton	Grass and mud	1	0.10
Hambleton	Grass	3	0.11
Skippool Creek 1	Salt marsh	2	0.11
Skippool Creek 2	Salt marsh	2	0.11
Skippool Creek 1	Grass	2	0.11
Skippool Creek 2	Grass and mud	1	0.11
Skippool Creek 2	Grass	1	0.10
Skippool Creek 3	Grass	1	0.097
Skippool Creek 3	Wood	3	0.094
Skippool Creek boat 2	Wood	4	0.092
Skippool Creek boat 2 – in vicinity of boats	Mud	4	0.084
Fleetwood Marsh Nature Park	Salt marsh	4	0.11
Fleetwood shore 1	Sand	3	0.079
Fleetwood shore 1	Pebbles and sand	1	0.076
Blackpool	Sand	4	0.068
Crossens Marsh	Salt marsh	3	0.095
Crossens Marsh	Grass	1	0.095
Ainsdale	Sand	4	0.065
Rock Ferry	Mud and sand	4	0.090
New Brighton	Sand	4	0.065
West Kirby	Sand	4	0.071
Little Neston Marsh 1	Grass	2	0.084
Little Neston Marsh 2	Salt marsh	1	0.072
Little Neston Marsh 2	Grass	1	0.076
Flint 1	Grass and sand	1	0.074
Flint 1	Mud	1	0.088
Flint 2	Salt marsh	2	0.091
Scotland			
Piltanton Burn	Salt marsh	4^S	0.061
Garlieston	Mud	4^S	0.068
Innerwell	Mud	4^S	0.076
Bladnoch	Mud	4^S	0.077
Carsluith	Mud	4^S	0.086
Skyreburn Bay (Water of Fleet)	Salt marsh	4^S	0.075
Kirkcudbright	Salt marsh	4^S	0.073
Cutters Pool	Winkle bed	4^S	0.095
Gardenburn	Salt marsh	1^S	0.10
Palnackie Harbour	Mud	1^S	0.074
Kippford – Slipway	Mud	4^S	0.11
Kippford – Merse	Salt marsh	1^S	0.091
Southerness	Winkle bed	4^S	0.060
Kirkconnell Marsh	Salt marsh	1^S	0.090

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Isle of Man			
Ramsey	Sand and stones	1	0.087
Wales			
Prestatyn	Sand	2	0.063
Rhyl	Salt marsh	2	0.086
Llandudno	Pebbles and sand	2	0.087
Caerhun	Grass	2	0.086
Llanfairfechan	Sand and shells	1	0.076
Llanfairfechan	Pebbles and shells	1	0.081
Northern Ireland			
Lisahally	Mud	1[N]	0.068
Donnybrewer	Shingle	1[N]	0.054
Carrichue	Mud	1[N]	0.074
Bellerena	Mud	1[N]	0.064
Benone	Sand	1[N]	0.060
Castlerock	Sand	1[N]	0.058
Portstewart	Sand	1[N]	0.062
Portrush, Blue Pool	Sand	1[N]	0.061
Portrush, White Rocks	Sand	1[N]	0.063
Portballintrae	Sand	1[N]	0.060
Giant's Causeway	Sand	1[N]	0.056
Ballycastle	Sand	1[N]	0.061
Cushendun	Sand	1[N]	0.061
Cushendall	Sand and stones	1[N]	0.069
Red Bay	Sand	1[N]	0.066
Carnlough	Sand	1[N]	0.059
Glenarm	Sand	1[N]	0.054
Half Way House	Sand	1[N]	0.056
Ballygally	Sand	1[N]	0.054
Drains Bay	Sand	1[N]	0.057
Larne	Sand	1[N]	0.066
Whitehead	Sand	1[N]	0.064
Carrickfergus	Sand	1[N]	0.058
Jordanstown	Sand	1[N]	0.057
Helen's Bay	Sand	1[N]	0.062
Groomsport	Sand	1[N]	0.063
Millisle	Sand	1[N]	0.066
Ballywalter	Sand	1[N]	0.069
Ballyhalbert	Sand	1[N]	0.068
Cloghy	Sand	1[N]	0.073
Portaferry	Shingle and stones	1[N]	0.084
Kircubbin	Sand	1[N]	0.088
Greyabbey	Sand	1[N]	0.089
Ards Maltings	Mud	1[N]	0.083
Island Hill	Mud	1[N]	0.074
Nicky's Point	Mud	1[N]	0.076
Strangford	Shingle and stones	1[N]	0.10
Kilclief	Sand	1[N]	0.074
Ardglass	Mud	1[N]	0.082
Killough	Mud	1[N]	0.078
Ringmore Point	Sand	1[N]	0.071
Tyrella	Sand	1[N]	0.076
Dundrum	Sand	1[N]	0.089
Newcastle	Sand	1[N]	0.086
Annalong	Sand	1[N]	0.12
Cranfield Bay	Sand	1[N]	0.088
Mill Bay	Sand	1[N]	0.11
Greencastle	Sand	1[N]	0.078
Rostrevor	Sand	1[N]	0.11
Narrow Water	Mud	1[N]	0.092

[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 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2013

Vessel or location	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
101	Nets	2	0.10
102	Nets	1	<0.19
	Gill nets	1	0.059
	Pots	1	0.032
103	Nets	1	0.32
	Ropes	1	0.17
104	Nets	2	0.21
105	Pots	1	0.043
106	Gill nets	1	0.097
High Saltcoats	Pots in storage used near Ravenglass	2	0.10
High Saltcoats	Pots in storage used near Sellafield Pipe	1	0.18
High Saltcoats	Ropes in storage	1	0.14
Whitehaven	Pots in storage post pressure washing	1	0.029

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2013

Location	Ground type	No. of sampling observations	Mean beta dose rate in tissue, mSv h^{-1}
Whitehaven – outer harbour	Sand	2	0.040
Whitehaven – outer harbour	Pebbles and sand	2	0.020
St Bees	Sand	4	0.045
Sellafield pipeline	Sand	2	0.070
Ravenglass – Raven Villa	Salt marsh	4	0.030
Tarn Bay	Sand	2	0.040

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2013

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{110m}Ag
Cumbria									
Silloth	Seaweed	2	<0.71		<0.45	<0.93	110	<4.2	<0.72
Harrington Harbour	Seaweed	2	<0.93		<0.53	<1.2	150	<5.1	<0.83
St Bees	*Porphyra*[a]	4[F]	<0.09	0.067	<0.25	<0.22	0.77	<1.0	<0.14
St Bees	Seaweed	2	<0.96	<0.53	<0.63	<1.2	370	<5.4	<0.98
Braystones South	*Porphyra*	4[F]	<0.14		<0.18	<0.20	2.8	<0.14	<0.26
Sellafield	*Rhodymenia* spp.	2[F]	<0.34		<0.11	<0.60		<1.5	<0.19
Sellafield	Seaweed	2	<1.1	0.88	<0.65	<1.3	1200	<5.6	<1.0
Seascale	*Porphyra*[b]	52[F]	<0.38		<0.34	<0.58		<3.6	<0.59
Ravenglass	Samphire	1[F]	<0.08		<0.55	<0.37	0.80	<0.96	<0.17
Ravenglass	Seaweed	2	<0.70		<0.44	<0.86	110	<4.1	<0.68
Lancashire									
Half Moon Bay	Seaweed	2	<0.92		<0.55	<1.1	160	<4.8	<0.81
Marshside Sands	Samphire	1[F]	<0.07		<0.40	<0.28		<0.74	<0.12
Sunderland Point	Samphire	1[F]	<0.11		<0.59	<0.43		<1.2	<0.21
Scotland									
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10		<0.34	<0.15	15	<0.30	<0.10
Lerwick	*Fucus vesiculosus*	1[S]	<0.10		<0.92	<0.51	2.9	<0.85	<0.10
Lewis	*Fucus vesiculosus*	1[S]	<0.10		<0.12	<0.13	11	<0.43	<0.10
Islay	*Fucus vesiculosus*	1[S]	0.37		<0.55	<0.33	21	<0.57	0.28
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10		<0.10	<0.15	30	<0.57	<0.10
Port William	*Fucus vesiculosus*	4[S]	<0.10		<0.25	<0.23	79	<0.63	<0.11
Garlieston	*Fucus vesiculosus*	4[S]	<0.12		<0.14	<0.15	43	<0.50	<0.11
Auchencairn	*Fucus vesiculosus*	4[S]	<0.10		<0.18	<0.16	150	<0.42	<0.10
Isle of Man	Seaweed	3	<0.78		<0.52	<0.97	81	<4.7	<0.77
Wales									
Cemaes Bay	Seaweed	2	<0.72		<0.49	<0.88	22	<4.3	<0.66
Porthmadog	Seaweed	2	<0.78		<0.59	<1.1	6.2	<5.1	<0.87
Lavernock Point	Seaweed	2	<0.74		<0.47	<0.95	2.2	<4.6	<0.70
Fishguard	Seaweed	2	<0.48		<0.33	<0.78	2.2	<3.3	<0.54
South Wales, manufacturer A	Laverbread	1[F]	<0.07		<0.21	<0.20		<0.61	<0.11
South Wales, manufacturer C	Laverbread	1[F]	<0.08		<0.19	<0.21		<0.76	<0.14
South Wales, manufacturer D	Laverbread	1[F]	<0.07		<0.37	<0.25		<0.63	<0.12
South Wales, manufacturer E	Laverbread	1[F]	<0.08		<0.08	<0.12		<0.64	<0.11
Northern Ireland									
Portrush	*Fucus spp.*	4[N]	<0.04		<0.13	<0.11		<0.34	<0.08
Portaferry	*Rhodymenia* spp.	4[N]	<0.06		<0.26	<0.19	0.14	<0.52	<0.11
Ardglass	*Fucus vesiculosus*	1[N]	<0.12		<0.28	<0.31		<0.99	<0.20
Ardglass	*Ascophyllum nodosum*	3[N]	<0.07		<0.17	<0.18	170	<0.63	<0.13
Carlingford Lough	*Fucus* spp.	4[N]	<0.06		<0.25	<0.19	28	<0.53	<0.12
Isles of Scilly	Seaweed	1	<1.3		<1.9	<0.90	1.7	<8.0	<1.3

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu
Cumbria								
Silloth	Seaweed	2	<2.6	<0.62	3.3	<1.9		
Harrington Harbour	Seaweed	2	<2.9	<0.73	2.5	<2.1		
St Bees	*Porphyra*[a]	4[F]	<0.17	<0.07	0.60	<0.33	<0.14	0.51
St Bees	Seaweed	2	<3.1	<0.79	<1.6	<2.0		1.1
Braystones South	*Porphyra*	4[F]	<0.08	0.80	<0.36	<0.16		0.33
Sellafield	*Rhodymenia* spp.	2[F]	<0.36	<0.10	2.2	<0.37	<0.15	0.85
Sellafield	Seaweed	2	<3.2	<0.89	3.9	<2.2		1.8
Seascale	*Porphyra*[b]	52[F]	<0.93	<0.38	<1.1	<1.7	<0.86	
Ravenglass	Samphire	1[F]	<0.19	<0.09	0.45	<0.31	<0.12	
Ravenglass	Seaweed	2	<2.4	<0.59	6.1	<1.9		
Lancashire								
Half Moon Bay	Seaweed	2	<2.8	<0.70	3.5	<1.8		
Marshside Sands	Samphire	1[F]	<0.17	<0.07	0.15	<0.36	<0.15	
Sunderland Point	Samphire	1[F]	<0.26	<0.12	0.41	<0.58	<0.24	
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10	<0.10	0.12	<0.19	<0.10	
Lerwick	*Fucus vesiculosus*	1[S]	<0.23	<0.10	<0.10	<0.58	<0.21	
Lewis	*Fucus vesiculosus*	1[S]	<0.13	<0.10	0.73	<0.30	<0.14	
Islay	*Fucus vesiculosus*	1[S]	<0.16	<0.10	<0.10	<0.39	<0.16	
Campbeltown	*Fucus vesiculosus*	1[S]	<0.16	<0.10	0.24	<0.31	<0.16	
Port William	*Fucus vesiculosus*	4[S]	<0.18	<0.10	1.2	<0.42	<0.18	
Garlieston	*Fucus vesiculosus*	4[S]	<0.19	<0.10	6.2	<0.33	<0.15	
Auchencairn	*Fucus vesiculosus*	4[S]	<0.14	<0.10	2.0	<0.27	<0.16	
Isle of Man	Seaweed	3	<2.7	<0.69	<0.61	<2.1	<1.0	
Wales								
Cemaes Bay	Seaweed	2	<2.4	<0.63	<0.55	<1.8		
Porthmadog	Seaweed	2	<3.1	<0.78	<0.64	<2.1		
Lavernock Point	Seaweed	2	<2.5	<0.63	<0.52	<2.0	<1.0	
Fishguard	Seaweed	2	<1.8	<0.44	<0.37	<1.5		
South Wales, manufacturer A	Laverbread	1[F]	<0.13	<0.06	<0.06	<0.24	<0.10	
South Wales, manufacturer C	Laverbread	1[F]	<0.16	<0.08	<0.07	<0.24	<0.11	
South Wales, manufacturer D	Laverbread	1[F]	<0.13	<0.07	0.10	<0.25	<0.09	
South Wales, manufacturer E	Laverbread	1[F]	<0.16	<0.07	0.08	<0.24	<0.10	
Northern Ireland								
Portrush	*Fucus spp.*	4[N]	<0.08	<0.04	<0.09	<0.15	<0.07	
Portaferry	*Rhodymenia* spp.	4[N]	<0.12	<0.05	0.48	<0.24	<0.10	0.060
Ardglass	*Fucus vesiculosus*	1[N]	<0.23	<0.12	0.29	<0.41	<0.19	
Ardglass	*Ascophyllum nodosum*	3[N]	<0.17	<0.08	0.37	<0.36	<0.18	
Carlingford Lough	*Fucus spp.*	4[N]	<0.13	<0.07	0.33	<0.26	<0.14	
Isles of Scilly	Seaweed	1	<4.4	<1.2	<0.91	<2.5	<1.2	

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			2.2			
Harrington Harbour	Seaweed	2			6.3			
St Bees	*Porphyra*[a]	4[F]	2.7	18	8.8	*	0.0091	170
St Bees	Seaweed	2	5.0		2.6			
Braystones South	*Porphyra*	4[F]	1.5	9.9	3.1	*	*	
Sellafield	*Rhodymenia* spp.	2[F]	4.8		14	*	0.024	
Sellafield	Seaweed	2	8.5		7.7			
Seascale	*Porphyra*[b]	52[F]			4.6			
Ravenglass	Samphire	1[F]			1.1			
Ravenglass	Seaweed	2			29			
Lancashire								
Half Moon Bay	Seaweed	2			<0.85			
Marshside Sands	Samphire	1[F]			<0.13			
Sunderland Point	Samphire	1[F]			<0.22			24
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]			<0.10			
Lerwick	*Fucus vesiculosus*	1[S]			<0.14			
Lewis	*Fucus vesiculosus*	1[S]			0.13			
Islay	*Fucus vesiculosus*	1[S]			<0.10			
Campbeltown	*Fucus vesiculosus*	1[S]			<0.10			
Port William	*Fucus vesiculosus*	4[S]			1.5			
Garlieston	*Fucus vesiculosus*	4[S]			10			
Auchencairn	*Fucus vesiculosus*	4[S]			2.1			
Isle of Man	Seaweed	3			<0.71			
Wales								
Cemaes Bay	Seaweed	2			<0.60			
Porthmadog	Seaweed	2			<0.67			
Lavernock Point	Seaweed	2			<0.72			
Fishguard	Seaweed	2			<0.45			
South Wales, manufacturer A	Laverbread	1[F]			<0.05			
South Wales, manufacturer C	Laverbread	1[F]			0.11			
South Wales, manufacturer D	Laverbread	1[F]			<0.12			91
South Wales, manufacturer E	Laverbread	1[F]			0.12			
Northern Ireland								
Portrush	*Fucus spp.*	4[N]			<0.08			
Portaferry	*Rhodymenia* spp.	4[N]	0.34		0.66	*	*	
Ardglass	*Fucus vesiculosus*	1[N]			<0.13			
Ardglass	*Ascophyllum nodosum*	3[N]			<0.21			
Carlingford Lough	*Fucus spp.*	4[N]			<0.16			
Isles of Scilly	Seaweed	1			<0.84			

* *Not detected by the method used*
[a] *The concentration of ^{14}C was 31 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, 2013

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{60}Co	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am
Sellafield 154[b]	Onions	1	<0.06	<0.27	<0.22	<0.10	<0.58	<0.06	<0.05	<0.19	<0.04
Sellafield 154[b]	Potatoes	1	<0.06	<0.21	<0.18	0.40	<0.50	<0.06	<0.05	<0.26	<0.15
Sellafield 154[b]	Soil	1	<0.36	<4.0	<2.3	15	<4.2	<0.52	25	<3.2	<1.5
Sellafield 474[b]	Beetroot	1	<0.04	<0.08	<0.10	<0.16	<0.39	<0.04	<0.04	<0.21	<0.10
Sellafield 474[b]	French dwarf beans	1	<0.07	<0.09	<0.13	<0.13	<0.67	<0.07	<0.06	<0.21	<0.05
Sellafield 474[b]	Potatoes	1	<0.07	<0.10	<0.13	<0.30	<0.57	<0.07	<0.06	<0.28	<0.18
Sellafield 474[b]	Shallots	1	<0.15	<0.56	<0.48	<0.15	<1.5	<0.16	<0.13	<0.50	<0.11
Sellafield 474[b]	Swiss chard	1	<0.24	<0.60	<0.64	0.86	<2.2	<0.24	<0.20	<0.69	<0.17
Sellafield 474[b]	Soil	1	<0.38	<1.6	<1.4	<1.5	<3.8	<0.50	3.6	<2.0	<0.68

[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, 2013

Material and selection[a]		No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}										
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{134}Cs
Milk		4	<2.3	23	<0.07	<0.037	<0.38	<0.26	<0.018	<0.67	<0.16	<0.013	<0.08
Milk	max		<2.7	26		<0.042	<0.40	<0.28		<0.76	<0.17	<0.015	<0.09
Apples		1	<2.0	22	<0.09	0.035	<0.18	<0.20	<0.10	<0.52	<0.11	<0.12	<0.09
Beef kidney		1	<3.8	14	<0.05	<0.051	<0.12	<0.12	<0.15	<0.34	<0.09		<0.06
Beef liver		1	<4.0	28	<0.06	<0.039	<0.13	<0.15	<0.18	<0.47	<0.07	<0.017	<0.06
Beef muscle		1	<2.6	40	<0.06	<0.054	<0.22	<0.20	<0.16	<0.76	<0.18	<0.024	<0.08
Blackberries		1	<2.9	22	<0.06	0.13	<0.11	<0.12	<0.11	<0.44	<0.11	<0.045	<0.07
Courgettes		1	<2.0	6.7	<0.04	0.056	<0.10	<0.08	<0.076	<0.38	<0.10	<0.049	<0.05
Lettuce		1							<0.11				
Mangetout		1							<0.22				
Oats		1	<4.0	38	<0.11	0.14	<0.12	<0.18	<0.39	<0.72	<0.25	<0.076	<0.11
Pheasants		1	<3.1	24	<0.11	<0.040	<0.16	<0.20	0.049	<0.66	<0.20	<0.043	<0.06
Potatoes		1	<2.2	35	<0.10	0.034	<0.23	<0.23	<0.12	<0.69	<0.20	<0.054	<0.07
Radish leaves		1	<2.1	14	<0.10	1.1	<0.10	<0.16	<0.17	<0.57	<0.21	<0.039	<0.10
Sheep muscle		2	<4.1	32	<0.05	<0.050	<0.08	<0.10	<0.17	<0.40	<0.08	<0.036	<0.05
Sheep muscle	max		<4.2	33	<0.06	<0.052		<0.11	<0.19	<0.44	<0.09	<0.049	<0.06
Sheep offal		2	<3.9	49	<0.07	<0.051	<0.13	<0.16	<0.13	<0.57	<0.12	<0.044	<0.07
Sheep offal	max		<4.0	56	<0.09	<0.062	<0.21	<0.25	<0.14	<0.76	<0.17	<0.052	<0.10
Grass		2							<0.19				
Grass	max								0.25				

Material and selection[a]		No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{137}Cs	^{144}Ce	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk		4	<0.10	<0.45				<0.000053	<0.000051	<0.13	<0.00014
Milk	max		<0.12	<0.46				<0.000059	<0.000057	<0.15	<0.00021
Apples		1	<0.06	<0.37				0.000083	0.00024	<0.18	0.00047
Beef kidney		1	0.48	<0.33	0.017	<0.00047	0.017	0.0015	0.0084	<0.35	0.043
Beef liver		1	0.31	<0.30				0.0082	0.046	<0.30	0.044
Beef muscle		1	0.38	<0.44				0.00014	0.00065	<0.35	0.0012
Blackberries		1	<0.06	<0.31				<0.000071	0.00022	<0.30	0.000093
Courgettes		1	0.06	<0.33				<0.000093	0.00030	<0.30	0.00039
Lettuce		1			0.017	0.00086	0.018				
Mangetout		1			<0.00023	<0.00023	0.0013				
Oats		1	<0.08	<0.44				0.00014	0.0013	<0.43	0.0026
Pheasants		1	0.11	<0.39				<0.00015	<0.00011	<0.24	0.000070
Potatoes		1	<0.06	<0.36				<0.000075	0.00059	<0.24	0.00027
Radish leaves		1	<0.05	<0.42				0.00012	0.0013	<0.32	0.0021
Sheep muscle		2	0.60	<0.25				<0.000089	0.00014	<0.34	<0.00017
Sheep muscle	max		0.75	<0.27				<0.00011	0.00016	<0.41	<0.00020
Sheep offal		2	0.62	<0.38				<0.00029	0.00074	<0.41	0.00069
Sheep offal	max		0.75	<0.45				<0.00046	0.0013	<0.45	0.00085
Soil		1			14	0.65	14				

[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*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2013

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	320	<0.24	<0.037	<0.25	<0.27	<0.0036	<0.0045	<3.5	11
River Ehen (100m downstream of sewer outfall)	4	<7.0	<0.30	<0.042	<0.30	<0.25	<0.0021	<0.0016	<0.10	0.54
River Calder (downstream)	4	<3.2	<0.25	<0.072	<0.25	<0.21	<0.0027	<0.0021	<0.037	0.15
River Calder (upstream)	4	<3.1	<0.24	<0.030	<0.25	<0.20	<0.0029	<0.0021	<0.027	0.068
Wast Water	1	<3.3	<0.23			<0.20			<0.020	0.035
Ennerdale Water	1	<3.2	<0.09		<0.10	<0.08			<0.022	<0.041
Devoke Water	1	<3.2	<0.09		<0.10	<0.08			<0.019	<0.036
Thirlmere	1	<3.3	<0.23			<0.21			<0.024	0.034

[a] *The concentration of ^{99}Tc was <0.54 Bq l^{-1}*

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2013

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	<1.6	4.1	<1.4	180	1.7	13	18
Seascale SS 233	1	<1.3	3.4	<1.2	220	5.2	41	19
Seascale SS 209	1	<0.37	<2.0	<0.37	14	0.87	3.6	6.0
Seascale SS 232	1	<1.5	<2.7	<1.4	54	3.0	18	27
Seascale SS 231	1	<2.2	<3.5	<2.1	44	2.5	14	25
Whitehaven SS 201	1	<2.4	<2.0	<2.2	29	<0.45	1.5	2.8

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2007-2013

	Exposure, mSv per year						
Group	2007	2008	2009	2010	2011	2012	2013
Isle of Man	0.006	0.007	0.007	<0.005	<0.005	<0.005	<0.005
Northern Ireland	0.015	0.017	0.012	0.010	0.010	0.011	0.010
Dumfries and Galloway	0.060	0.047	0.047	0.040	0.040	0.046	0.044
Whitehaven	0.009	0.009	0.011	0.010	0.010	0.013	0.010
Sellafield (5 year average consumption)	0.24	0.23	0.20	0.18	0.15	0.14	0.12
Morecambe Bay	0.037	0.042	0.041	0.046	0.034	0.034	0.036
Fleetwood	0.013	0.016	0.013	0.015	0.008	0.008	0.007
North Wales	0.014	0.018	0.015	0.013	0.014	0.014	0.013

Table 2.18. Individual radiation exposures, Sellafield, 2013

Representative person[a]	Exposure, mSv per year							
	Total	Seafood (nuclear industry discharges)[i]	Seafood (other discharges)[j]	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 occupant on a houseboat[e]	**0.076**	**–**	**–**	**–**	**0.076**	**–**	**–**	**–**
***Total dose* – maximum effect of all sources to people in the vicinity of the Sellafield site**								
Adult fish consumer	**0.061[f]**	**0.026**	**0.021**	**–**	**0.014**	**–**	**<0.005**	**<0.005**
***Total dose* – maximum effect of gaseous release and direct radiation sources**								
Mushroom consumer	**0.012**	**–**	**–**	**0.012**	**–**	**–**	**–**	**–**
***Total dose* – maximum effect of liquid release source**								
Adult occupant on a houseboat[e]	**0.076**	**–**	**–**	**–**	**0.076**	**–**	**–**	**–**
Source specfic doses								
Seafood consumer								
Local seafood consumer (habits averaged 2009–13)	0.18[g]	0.085	0.060	–	0.037	–	–	–
Local seafood consumer (habits for 2013)	0.13[h]	0.069	0.031	–	0.032	–	–	–
Whitehaven – seafood consumer	0.010	0.010	–	–	–	–	–	–
Dumfries and Galloway – seafood and wildfowl consumer	0.044	0.036	–	–	0.007	–	–	–
Morecambe Bay – seafood consumer	0.036	0.017	–	–	0.018	–	–	–
Fleetwood – seafood consumer	0.007	0.007	–	–	–	–	–	–
Isle of Man – seafood consumer	<0.005	<0.005	–	–	–	–	–	–
Northern Ireland – seafood consumer	0.010	0.008	–	–	<0.005	–	–	–
North Wales – seafood consumer	0.013	0.008	–	–	0.006	–	–	–
Other groups								
Ravenglass Estuary, marsh user	0.011	–	–	–	0.011	<0.005	–	–
Fisherman handling nets or pots[c]	0.14	–	–	–	0.14	–	–	–
Bait digger and shellfish collector[c]	0.020	–	–	–	0.020	–	–	–
Ribble Estuary houseboat	0.071	–	–	–	0.071	–	–	–
Barrow Houseboat	0.074	–	–	–	0.074	–	–	–
Local consumer at Ravenglass[b]	0.032	–	–	0.032	–	–	–	–
Local consumer of vegetables grown on land with seaweed added	0.009	–	–	0.009	–	–	–	–
Local consumer at LLWR near Drigg[b]	0.015	–	–	0.015	–	–	–	–
Local consumer in the Isle of Man[b]	0.017	–	–	0.017	–	–	–	–
Consumer of laverbread in South Wales	<0.005	–	–	<0.005	–	–	–	–
Inhabitant and consumer of locally grown food[b]	0.021	–	–	0.020	–	–	<0.005	–
Groups with average consumption or exposure								
Average seafood consumer in Cumbria	<0.005	<0.005	–	–	–	–	–	–
Average consumer of locally grown food[d]	0.008	–	–	0.008	–	–	–	–
Typical visitor to Cumbria	<0.005	<0.005	<0.005	–	<0.005	–	–	–
Recreational user of beaches								
North Cumbria	0.011	–	–	–	0.011	–	–	–
Sellafield	0.012	–	–	–	0.012	–	–	–
Lancashire	0.006	–	–	–	0.006	–	–	–
North Wales	0.006	–	–	–	0.006	–	–	–
Isle of Man	0.009	–	–	–	0.009	–	–	–

Table 2.18. continued

Exposed population[a]	Exposure, mSv per year							
	Total	Seafood (nuclear industry discharges)[i]	Seafood (other discharges)[j]	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
Recreational user of mud/saltmarsh areas								
Dumfries and Galloway	<0.005	–	–	–	<0.005	–	–	–
North Cumbria	0.006	–	–	–	0.006	–	–	–
Sellafield	0.015	–	–	–	0.015	–	–	–
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 person 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 highest total dose in 2013 due to Sellafield discharges was for a person living on a houseboat near Barrow in Cumbria*

[f] *The dose due to nuclear industry discharges was 0.040 mSv*

[g] *The dose due to nuclear industry discharges was 0.12 mSv*

[h] *The dose due to nuclear industry discharges was 0.10 mSv*

[i] *May include a very small contribution from LLWR near Drigg*

[j] *Enhanced naturally occurring radionuclides from Whitehaven*

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. 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 Cavendish Dounreay Partnership (formerly called Babcock Dounreay Partnership) was awarded the contract in 2012. All of the nuclear licensed 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.

In April 2012, Babcock Dounreay Partnership (BDP), which has subsequently been renamed as the Cavendish Dounreay Partnership, was awarded the contract to manage the decommissioning and clean-up of the Dounreay site, and became the Parent Body Organisation (PBO) for Dounreay. On 1 September 2014, NDA formally appointed Cavendish Fluor Partnership (CFP) as the new PBO for RSRL.

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, e.g. the Vulcan Naval Reactor Test Establishment (NRTE) adjacent to the Dounreay site.

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

Other minor research sites considered in this section are the non-nuclear site at Culham, Oxfordshire and the Imperial College Reactor Centre near Ascot, Berkshire.

Key points

- *Total doses* for the representative person were less than 2 per cent of the dose limit at all those sites assessed
- Doses, discharges, environmental concentrations and dose rates in 2013 were broadly similar to those in 2012

Dounreay, Highland

- There were small changes in public radiation doses in 2013
- A variation to the site's gaseous discharge authorisation was granted
- Gaseous discharges of krypton-85 were likely to have exceeded the annual authorised limit for the Dounreay Fast Reactor facility in 2013

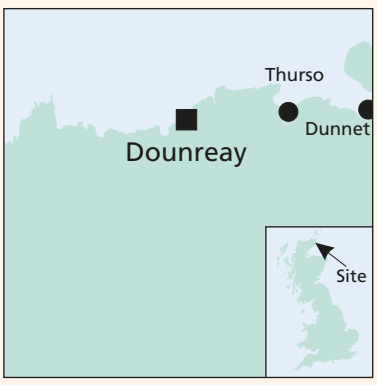
Harwell, Oxfordshire

- *Total dose* for the representative person decreased in 2013
- A previous tenant on the nuclear licensed site surrendered their permit
- Liquid discharges from Harwell to the River Thames at Sutton Courtenay ceased in March 2013
- Liquid discharges to the River Thames generally decreased in 2013

Winfrith, Dorset

- A variation to the site's discharge authorisation was granted to allow the operator greater flexibility for transfers of waste from the site.
- Gaseous and liquid discharges of tritium decreased and liquid discharges of alpha radionuclides increased in 2013

3.1 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. It is currently planned that all redundant facilities will be decommissioned by 2025 (Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2014).

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 licence company (Dounreay Site Restoration Limited, DSRL), before DSRL took over the site management contract. In April 2012, Babcock Dounreay Partnership (BDP), which has subsequently been renamed as the Cavendish Dounreay Partnership, was awarded the contract to manage the decommissioning and clean-up of the Dounreay site, and became the PBO for Dounreay.

During 2013, SEPA continued to determine 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 January 2013, SEPA granted DSRL's authorisation for a Low Level Radioactive Waste disposal facility adjacent to the site. Construction work on Phase 1 of the facility, consisting of one vault for containerised waste and bulk items and a single vault for bagged waste, is nearing completion. It is expected that the facility will begin accepting waste for disposal during the next 12 months.

In October 2013, SEPA varied DSRL's gaseous authorisation to include the discharge stack from the new active analysis laboratory within the list of authorised discharge outlets. No change to the authorised discharge limits was made as a result of the variation.

In October 2013, SEPA were notified by DSRL that samples taken from the Dounreay Fast Reactor (DFR) indicated that the krypton-85 activity present in the reactor cover gas was higher than that present in their historic sample. DSRL had used the historic sample as the basis for the calculation of the krypton-85 content of discharges arising from reactor blow-down operations. As a consequence, DSRL's discharge estimation for the 12 month rolling total of krypton-85 from the DFR facility indicates that discharges were likely to have exceeded the annual authorised limit for this facility. The authorised limit for krypton-85 for the DFR facility (0.4 GBq) is very low when compared to the authorised limit for krypton-85 for the Prototype Fast Reactor (PFR) facility (525,000 GBq). Although the impact on the environment and public health due to the increased krypton-85 discharge from DFR was very low, the discharges and the associated sampling arrangements constituted contraventions of the limitations and conditions of the RSA authorisation held by the operator. This resulted in SEPA issuing a Final Warning Letter to DSRL in relation to the operator's management system and procedures.

In February 2014, DSRL identified an issue relating to the compliance reporting with respect to gaseous iodine-129 discharges from the Fuel Cycle Area (FCA) North stack. DSRL identified an error in its compliance reporting software, which had occurred when work on the software was undertaken in May 2013. The affected discharge remained at less than 4 per cent of the authorised limit. SEPA engaged with DSRL on this issue to ensure the accuracy of future reporting.

In 2013, 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 2012 (Appendix 2).

In July 2013, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Papworth *et al.*, 2014). Three potentially critical pathways for public radiation exposure in the aquatic environment were confirmed. A decrease in the crustacean and mollusc consumption rates has been observed, whilst the fish consumption rate was unchanged and the occupancy rate increased, in comparison with those of the previous survey in 2008. The occupancy rate for those people who regularly visit Oigin's Geo and the rate of handling fishing gear both decreased in 2013. Revised figures for consumption rates, together with 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, Highland was undertaken in 2009 (Clyne *et al.*, 2011b).

Doses to the public

In 2013, the *total dose* from all pathways and sources of radiation was 0.012 mSv (Table 3.1) or approximately 1 per cent of the dose limit. The person most exposed was an adult consuming local green vegetables at high-rates, as opposed to a high-rate consumer of milk (1-year-old infant) in 2012. The *total dose* for an adult consuming local green vegetables at high-rates was unchanged from 2012. The change in dose (from 0.017 mSv in 2012), and the most exposed age group, was mostly due to the contribution of goats' milk not being included in the assessment (which has been assessed in previous years), as milk samples were not available in 2013. If this had been assessed, it is expected that the full dose to a 1-year-old infant would have been the most exposed age group and similar to those values in recent years.

The trend in *total dose* over the period 2004 – 2013 is given in Figure 3.1. The variations in previous 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 for external pathways (both for Geo occupants, who live at or regularly visit Oigin's Geo, and fishermen), give exposures of less than the *total dose* in 2013 (Table 3.1). In 2013, the dose to a consumer of terrestrial foodstuffs was 0.014 mSv or less than 2 per cent of the dose limit for members of the public of 1 mSv. Adults were identified as the most exposed age group and a change from that in 2012 (1-year-old infants). The dose in 2012 was 0.027 mSv and the reason for the decrease, and change in the most exposed age group, in 2013 was the same as that contributing to the maximum *total dose*. The dose to a consumer of fish and shellfish, including external exposure from occupancy over local beaches, was 0.012 mSv. The increase in dose from 0.006 mSv (in 2012) was due to higher occupancy rates (as identified in the recent habits survey) and generally higher dose rates (especially at Dunnet) in 2013.

Gaseous discharges and terrestrial monitoring

DSRL is authorised by SEPA to discharge gaseous wastes to the local environment via stacks to the atmosphere. In comparison to releases in 2012, krypton-85 discharges from the Prototype Fast Reactor (PFR) and the Dounreay Fast Reactor (DFR) facilities increased, due to discharges arising from the repackaging of fuel for long term dry storage and reactor gas blanket blow-down operations undertaken as part of the implementation of the reactor decommissioning work. The discharges from the Dounreay Fast Reactor were likely to have exceeded the annual authorised 12 month rolling limit for this facility in 2013 by 11, 18 and 17 per cent in October, November and December, respectively. This occurred due to the underestimation in the calculation of the content of discharges arising from reactor blow-down operations.

Monitoring conducted in 2013 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. Due to supplier issues, goats' milk samples (which have been analysed in previous years) were not sampled in 2013. The sampling locations for the terrestrial (and marine) monitoring programmes are shown in Figure 3.2 (Dounreay) and Figure 3.3 (north of Scotland). The results for terrestrial samples and radioactivity in air are given in Tables 3.2(a) and (c) and generally show low concentrations of radioactivity. In 2013, low concentrations of caesium-137, strontium-90, cobalt-60, europium-155, uranium, plutonium and americium-241 were reported in samples (many below the LoD). In rabbit, the caesium-137 concentration was 0.41 Bq kg^{-1} (and just above the LoD) in 2013, as in the previous two years. 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 Ministry of Defence's (MoD's) Defence Equipment and Support organisation.

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 1997 by the Scottish Office.

Crabs were sampled from the outfall area, together with mussels and winkles from areas along the coastline. Additionally, seawater and seaweed were sampled as indicator materials. The results for marine samples and gamma dose rates are given in Tables 3.2(a) and (b). Activity concentrations were generally low in 2013 and similar to those in recent years. Gamma dose rates were generally higher in 2013 (in comparison to 2012) with increased rates over the winkle beds at Dunnet and, to a lesser extent, over sand at other locations. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were generally similar to those in recent years. Figure 3.3 also gives time trend information for technetium-99 concentrations (from Sellafield) in seaweed at Sandside Bay (location shown in Figure 3.2), 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 3.2(b)).

During 2013, DSRL continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. In 2013, 8 fragments were recovered from Sandside Bay and 5 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 0.15 kBq and 120 kBq (similar to ranges observed in 2012).

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

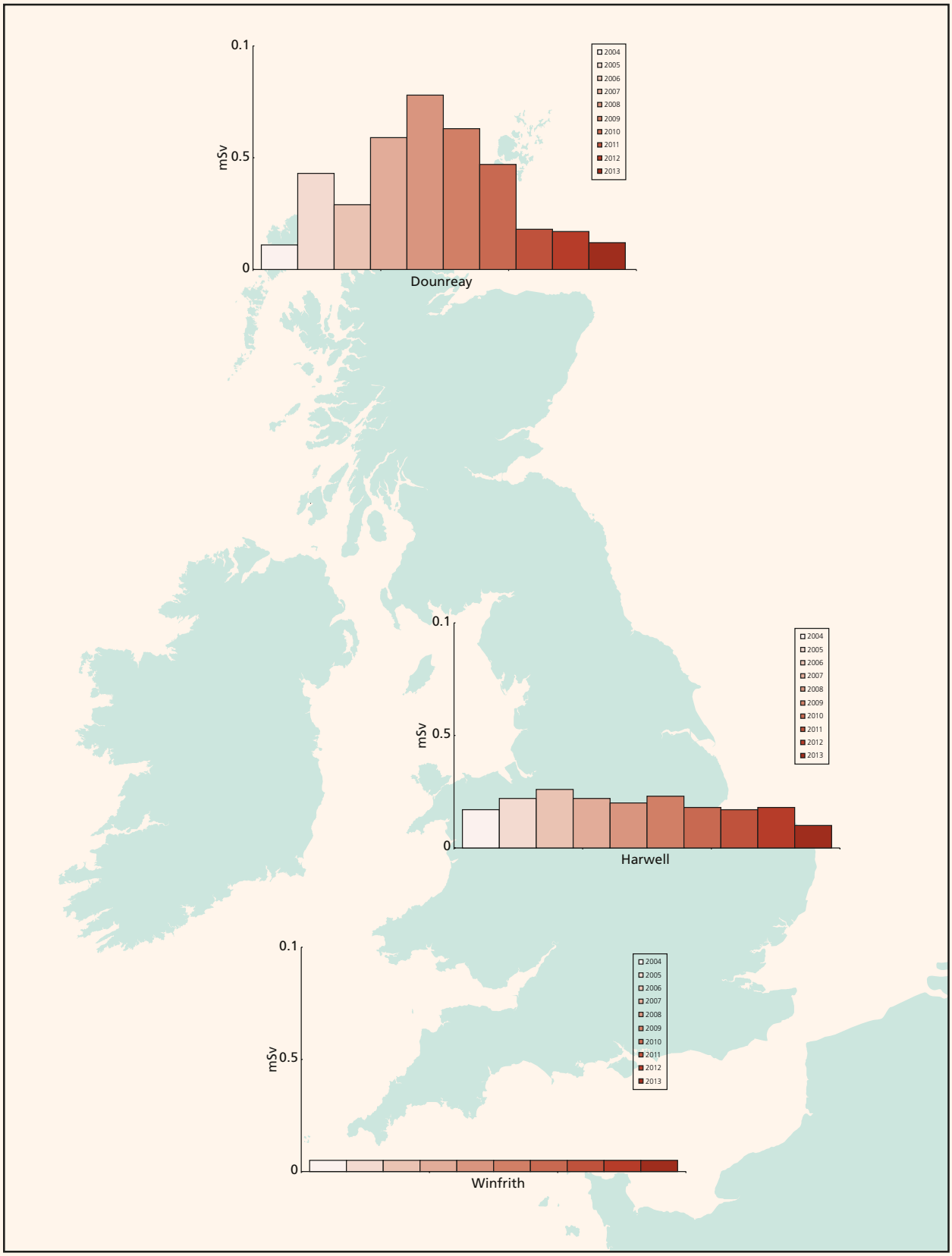


Figure 3.1. *Total dose* at research establishments, 2004-2013
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

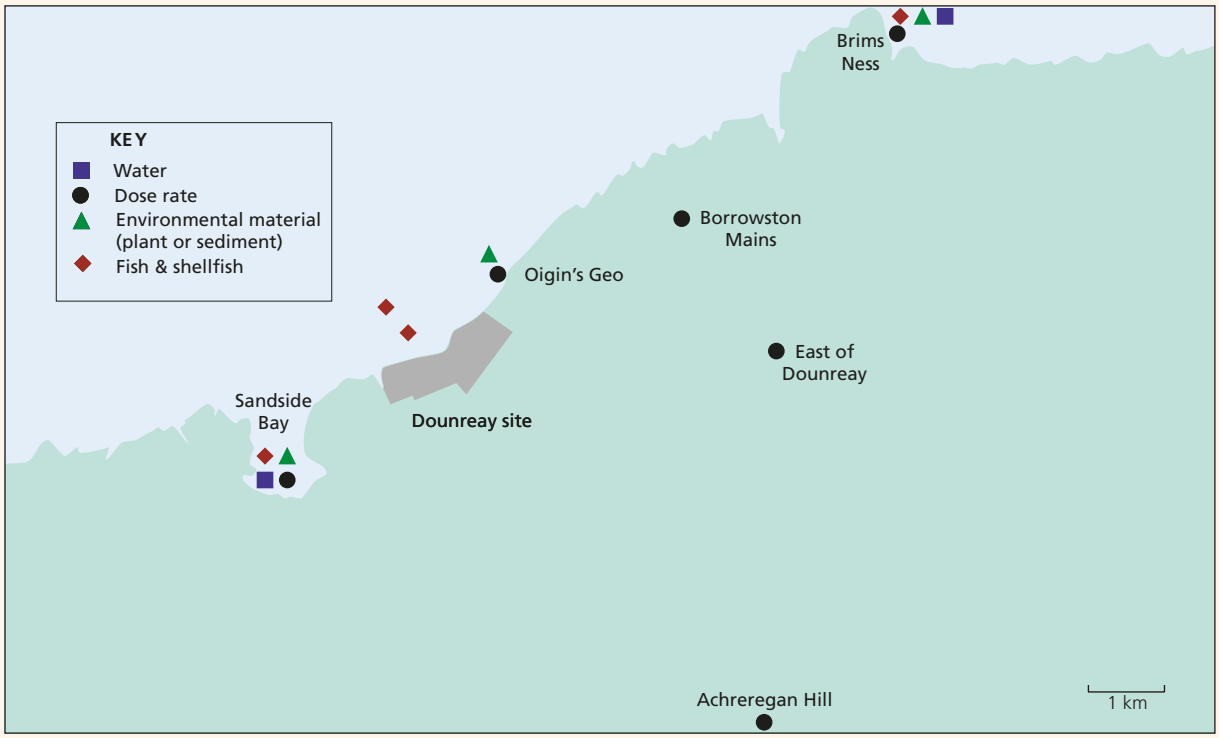


Figure 3.2. Monitoring locations at Dounreay, 2013 (not including farms)

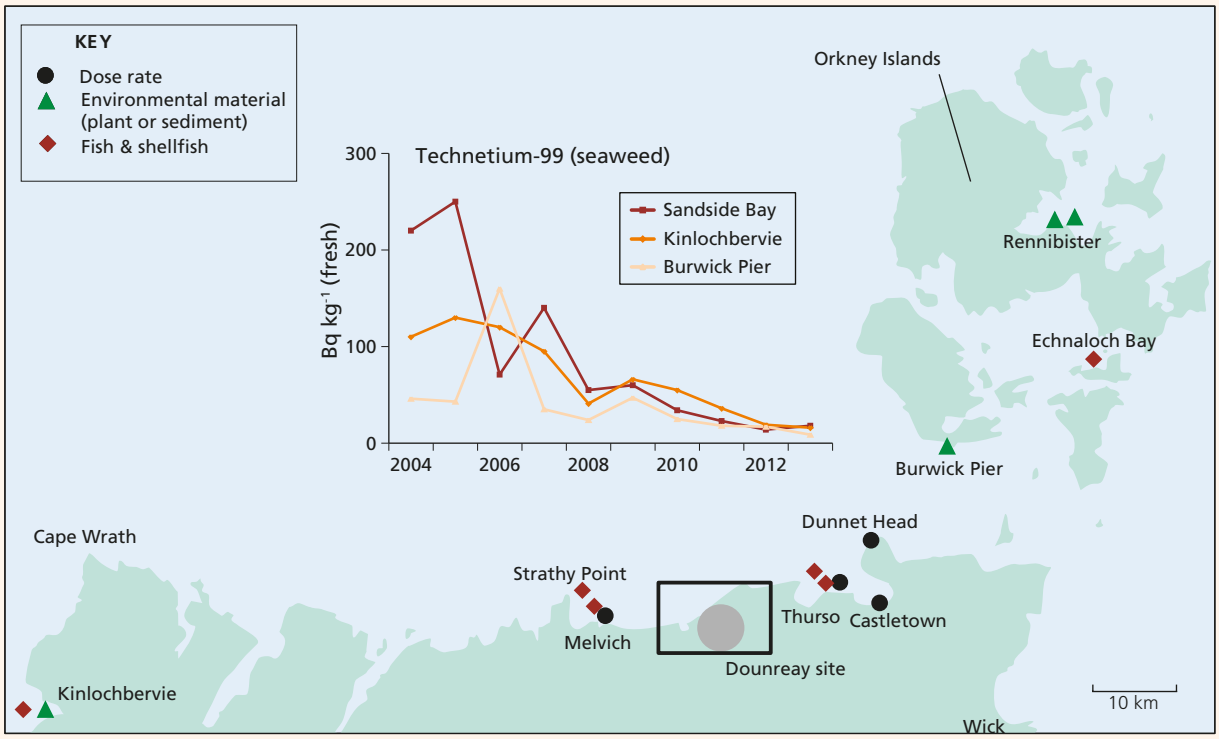


Figure 3.3. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2013 (not including farms)

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)) has published reports in March 2010 and March 2011 and a further report is planned for publication in the near future (Particles Retrieval Advisory Group (Dounreay), 2010; 2011; *in press*).

In 2007, the Food Standards Agency reviewed the Dounreay FEPA Order. A risk assessment, that was peer-reviewed by PHE, 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.

3.2 Harwell, Oxfordshire

The site at Harwell was established in 1946 as Britain's first Atomic Energy Research Establishment and is situated approximately 5 km southwest of the town of Didcot. It originally accommodated five research reactors of various types. The Harwell nuclear licensed site currently forms part of the Harwell Science and Innovation Campus. Decommissioning of redundant nuclear facilities is underway. Two of the reactors have been completely removed, and the fuel has been removed from the remaining three reactors. Environmental Scientific Group Limited, a previous tenant on the Harwell nuclear licensed site, surrendered their permit in 2013. It is expected that decommissioning of all redundant buildings on the site will be completed by 2027 (Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2014). The most recent habits survey was conducted in 2007 (Garrod *et al*., 2008).

* *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.*

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.010 mSv in 2013 (Table 3.1), which was 1 per cent of the dose limit, and down from 0.018 mSv in 2012. The dominant contribution to this dose was direct radiation from the site and the most exposed person was a prenatal child of local inhabitants. The lower dose in 2013 was due to a decrease in the direct radiation from the site. The trend in *total dose* over the period 2004 – 2013 is given in Figure 3.1. The *total doses* remained broadly similar from year to year, and were very low.

Source specific assessments for a high-rate consumer of terrestrial foods, and for an angler, give exposures that were less than the *total dose* (Table 3.1). The dose to an angler was less than 0.005 mSv and a small decrease from 0.005 mSv in 2012, due to overall lower dose rates at Sutton Courtenay in 2013.

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via stacks to the local environment. Gaseous discharges were generally similar to those in 2012. 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 3.4. The results of the terrestrial monitoring programme are shown in Table 3.3(a). The results of tritium and caesium-137 analyses of terrestrial food samples were all below the LoD's.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive wastes from Harwell continued in 2013 to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site. Discharges from Harwell to the River Thames ceased in March 2013 and these wastes are discharged to sewers serving the Didcot STW (from June 2013); treated effluent subsequently enters the River Thames at Long Wittenham. RSRL completed the decommissioning of the treated waste effluent discharge point at Sutton Courtenay (in March 2014). All permitted discharges to the River Thames decreased (with the exception of tritium), in comparison to those in 2012; discharges to the Lydebank Brook were generally similar in 2013. Figure 3.5 shows trends of discharges over time (2000 – 2013) 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 is directed at consumers of freshwater fish and occupancy close to the liquid discharge point. Tritium and cobalt-60 concentrations in all aquatic samples, and caesium-137

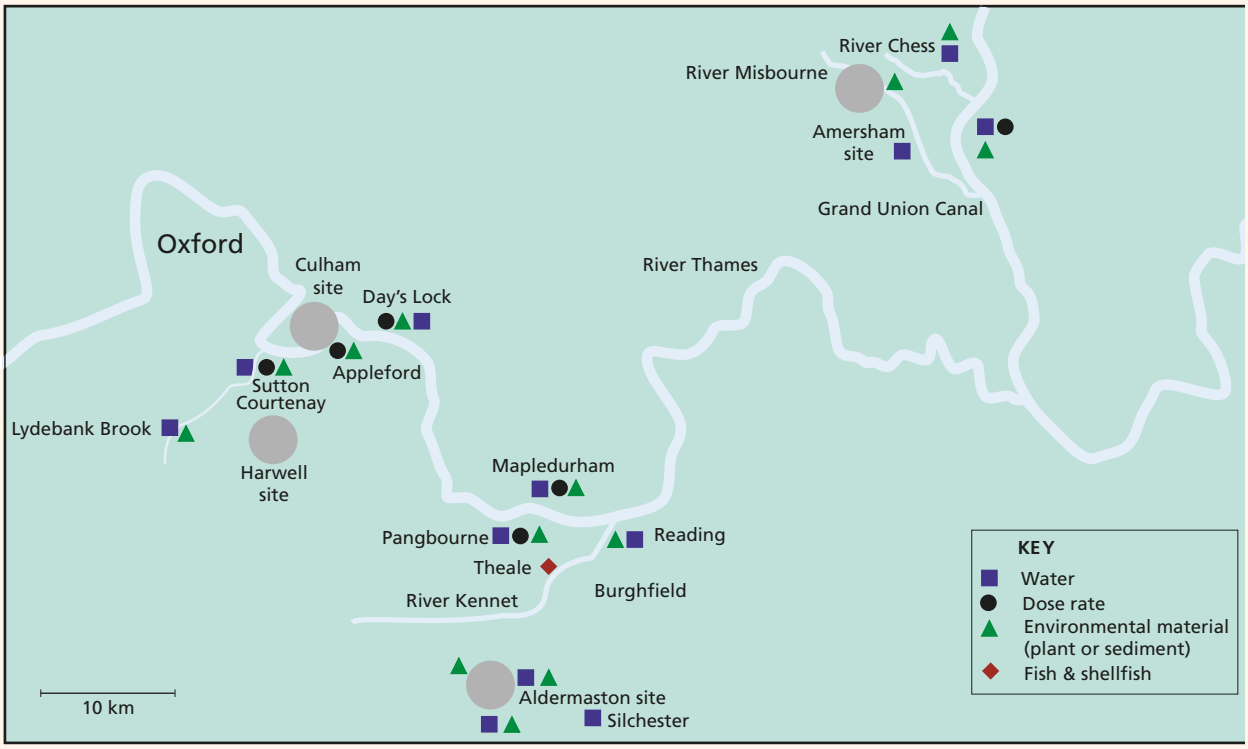


Figure 3.4. Monitoring locations at Thames sites, 2013 (not including farms)

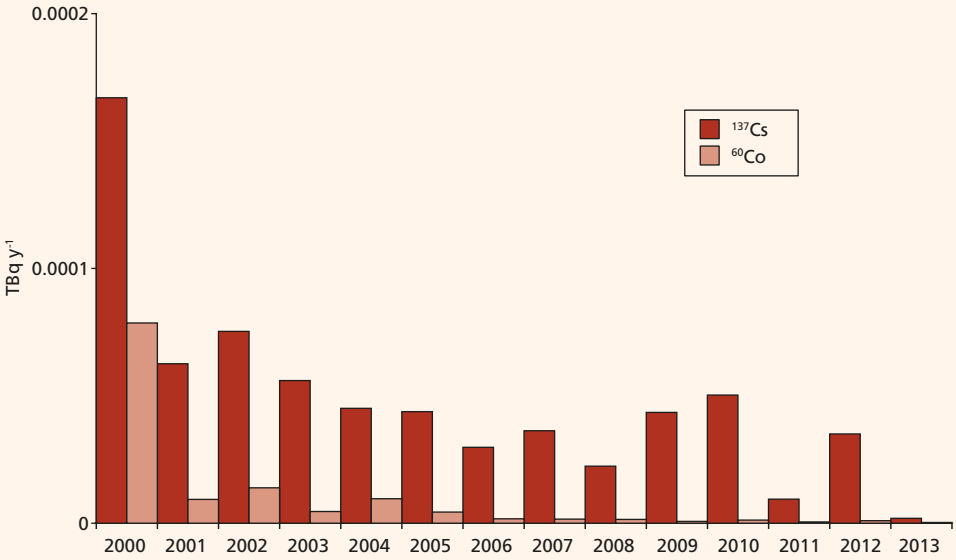
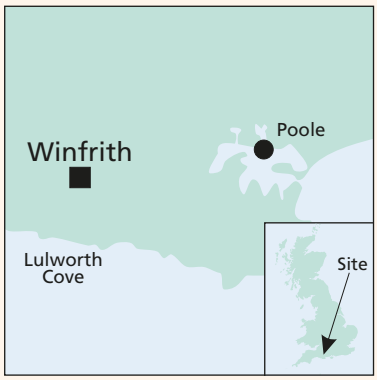


Figure 3.5. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2013

concentrations in freshwater, were below the LoDs. Caesium-137 concentrations in sediments continued to be enhanced above background levels (including those close to the outfall at Sutton Courtenay) in 2013, but were small in terms of any radiological effect. Concentrations of transuranic elements in sediments were mostly below, or at, the LoD. Overall, gamma dose rates were generally similar to those in recent years. A small decrease in the dose rates was measured at Sutton Courtenay in 2013 (in comparison to 2012). 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.

3.3 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. Seven of the reactors have been decommissioned and dismantled. Final decommissioning of both remaining reactors is scheduled to commence in 2014, with the aim to be completed by 2021 (Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2014). In February 2013, the environmental permit was varied by the Environment Agency, allowing the operator greater flexibility for transfers of waste from the site. The most recent habits survey undertaken for Winfrith was in 2003 (McTaggart *et al*., 2004b).

Doses to the public

In 2013, 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. As in 2012, an infant consuming milk at high-rates was the most exposed person at this site. Trends in *total doses* in the area of the south coast (and the Severn Estuary) over time are shown in Figure 6.1. At Winfrith, *total doses* remained broadly similar from year to year, and were very low.

Source specific assessments for a high-rate consumer of locally grown food, and of fish and shellfish, give exposures that were also less than 0.005 mSv in 2012 (Table 3.1). Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via various stacks to the local environment. Discharges of radioactive wastes continued in 2013 at very low rates; tritium discharges decreased from Winfrith (Tradebe Inutec) in comparison to those in 2012. 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 3.6. Data for 2013 are given in Table 3.4(a). Results for terrestrial samples provide little indication of an effect due to gaseous discharges. Carbon-14 concentrations were detected in locally produced foods, above background concentrations, although this is most likely 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.

Liquid waste discharges and aquatic monitoring

Liquid wastes are disposed under permit to deep water in Weymouth Bay. Tritium discharges from Winfrith decreased and alpha radionuclides (inner pipeline) increased, in comparison to those in 2012. Figure 3.7 shows trends of liquid discharges over time (2000 – 2013) for tritium and alpha emitting radionuclides. Over the period, alpha radionuclide discharges have generally decreased since the peak in 2003 (although discharges peaked again in 2013). In comparison, tritium discharges have varied more between years, with periodic peaks in releases (in 2004, 2007 and 2012).

Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Data for 2013 are given in Tables 3.4(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.

3.4 Minor sites

Two minor sites are monitored using a small sampling programme of environmental materials. The results, given in the following sections, show that there was no detected impact on the environment in 2013 due to operation of these sites.

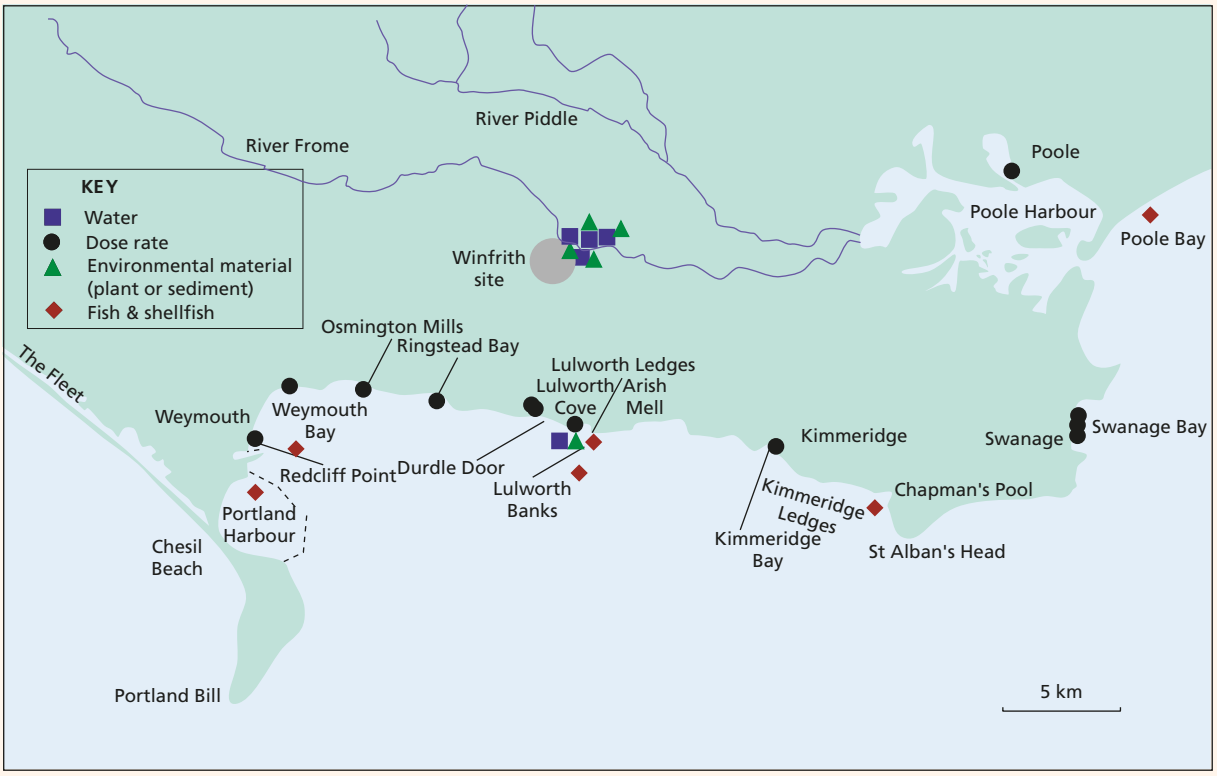


Figure 3.6. Monitoring locations at Winfrith, 2013 (not including farms)

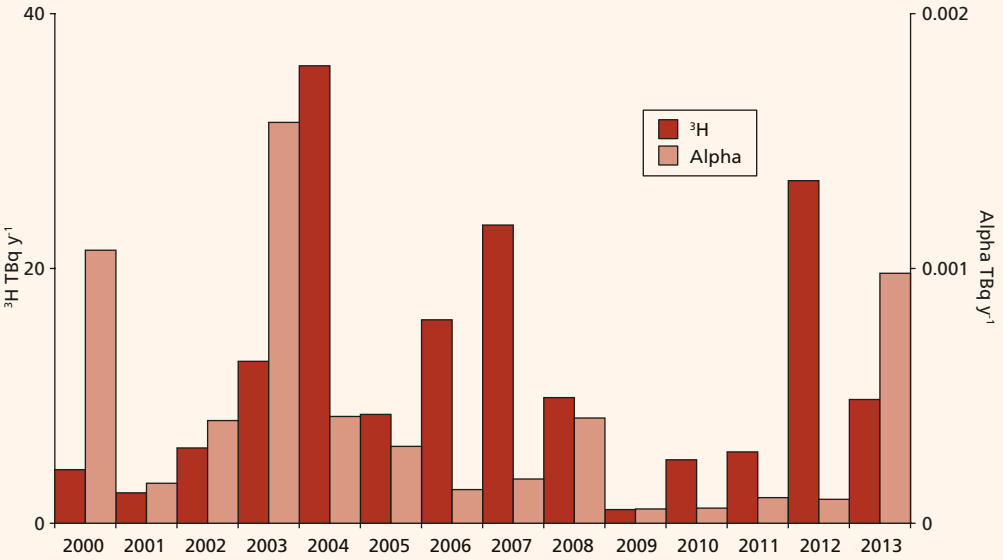
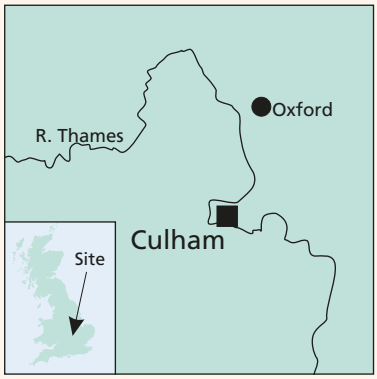


Figure 3.7. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2013

3.4.1 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 (under contract from Euratom). 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 that is expected to take 10 years to complete. The length of future operations is uncertain, but the assumption is that operations will continue until 2018 and the facility is then decommissioned (Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2014).

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 2013, 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 2013. Locations and data are shown in Figure 3.4 and Table 3.5, 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 2013, measurements of tritium were less than the LoD. Overall, no effects due to site operation were detected. The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but were due to past discharges from Harwell, nuclear weapons testing fallout from the 1950's and 1960's and the Chernobyl reactor accident in 1986.

3.4.2 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 for environmental materials.

The Reactor Centre provided facilities for the University and other organisations for research and commercial purposes. Imperial College undertook a review of the future of the Reactor Centre at Silwood Park which concluded that the reactor should be closed and decommissioned for financial reasons. The reactor is now shut down. The aim is that is that the reactor will be de-fuelled and dismantled over a period of ten years with eventual de-licensing of the site by 2023 (Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2014).

In 2013, gaseous and aqueous discharges were very low (Appendix 2). Monitoring of the environmental effects involved the analysis of two grass samples by gamma-ray spectrometry. Activity concentrations in both samples were either close to or less than the limits of detection.

Table 3.1. Individual doses – research sites, 2013

Site	Representative person[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	Drinker of river water	<0.005	–	–	–	<0.005	–	–
Dounreay								
***Total dose* – all sources**	**Green vegetable consumer**	**0.012**	**<0.005**	**0.012**	**–**	**–**	**–**	**–**
Source specific doses	Seafood consumer	0.012	<0.005	–	0.011	–	–	–
	Geo occupant[b]	<0.005	–	–	<0.005	–	–	–
	Consumer of locally grown food	0.014	–	0.013	–	–	<0.005	–
Harwell								
***Total dose* – all sources**	**Prenatal child of local inhabitants (0 – 0.25km)**	**0.010**	**–**	**<0.005**	**–**	**–**	**<0.005**	**0.010**
Source specific doses	Angler	<0.005	<0.005	–	<0.005	–	–	–
	Infant consumer of locally grown food	<0.005	–	<0.005	–	–	<0.005	–
Winfrith								
***Total dose* – all sources**	**Infant milk consumer**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**–**	**<0.005**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–	–
	Infant consumer 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 people unless otherwise stated*

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

Table 3.2(a). Concentrations of radionuclides in food and the environment near Dounreay, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb	^{99}Tc	^{137}Cs
Marine samples									
Cod	Scrabster	2		<0.10	<0.12		<0.18		0.39
Crabs	Pipeline inner zone	4		<0.10	<0.19	<0.77	<0.43	2.3	<0.19
Crabs	Pipeline outer zone	4		<0.10	<0.27	<0.75	<0.63	1.1	<0.10
Crabs	Strathy	4		<0.10	<0.21		<0.35		<0.11
Crabs	Kinlochbervie	4		<0.10	<0.16		<0.23	0.62	<0.10
Crabs	Melvich Bay	4		<0.10	<0.20		<0.36	0.33	<0.10
Winkles	Brims Ness	4		<0.10	<0.25	<0.10	<0.41		<0.12
Winkles	Sandside Bay	4		<0.10	<0.24	0.10	<0.49	1.8	<0.12
Mussels	Echnaloch Bay	4		<0.10	<0.20		<0.43	2.7	<0.10
Mussels	Thurso East Mains	4		<0.10	<0.26		<0.44		0.19
Fucus vesiculosus	Kinlochbervie	4		<0.10	<0.16		<0.20	16	0.22
Fucus vesiculosus	Brims Ness	4		<0.10	<0.15	2.4	<0.12		<0.12
Fucus vesiculosus	Sandside Bay	4		<0.10	<0.12		<0.11	18	<0.13
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.15		<0.15	8.7	<0.11
Sediment	Oigin's Geo	2		<0.10	<0.37		<0.10		3.0
Sediment	Brims Ness	1		<0.10	<0.22		<0.15		0.98
Sediment	Sandside Bay	1		<0.10	<0.20		<0.13		2.0
Sediment	Rennibister	1		<0.10	<0.20		<0.10		11
Seawater	Brims Ness	4	<1.0	<0.10	<0.15		<0.17		<0.10
Seawater	Sandside Bay	4	<1.0	<0.10	<0.16		<0.26		<0.10
Spume	Oigin's Geo	3		<0.50	<0.81		<0.38		<27

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	<0.10	<0.12	0.00084	0.0022	0.0026		
Crabs	Pipeline inner zone	4	<0.11	<0.16	0.0015	0.0093	0.36	<1.2	140
Crabs	Pipeline outer zone	4	<0.13	<0.22	0.0011	0.0080	0.014	<1.3	180
Crabs	Strathy	4	<0.10	<0.15	0.0011	0.0064	0.0043		
Crabs	Kinlochbervie	4	<0.10	<0.13	0.00081	0.0040	0.0056		
Crabs	Melvich Bay	4	<0.11	<0.15	0.00058	0.0044	0.0031		
Winkles	Brims Ness	4	<0.12	<0.19	0.017	0.076	0.087		
Winkles	Sandside Bay	4	<0.11	<0.18	0.012	0.069	0.057		
Mussels	Echnaloch Bay	4	<0.10	<0.14	0.010	0.067	0.033		
Mussels	Thurso East Mains	4	<0.11	<0.19	0.016	0.079	0.052		
Fucus vesiculosus	Kinlochbervie	4	<0.10	<0.14			<0.10		
Fucus vesiculosus	Brims Ness	4	<0.10	<0.13			<0.12	2.0	390
Fucus vesiculosus	Sandside Bay	4	<0.10	<0.11			<0.13	<1.8	480
Fucus vesiculosus	Burwick Pier	4	<0.10	<0.15			<0.14		
Sediment	Oigin's Geo	2	<0.22	<0.39	0.81	3.7	1.4		
Sediment	Brims Ness	1	0.20	0.27	2.1	8.5	6.5		
Sediment	Sandside Bay	1	0.31	<0.25	3.2	14	10		
Sediment	Rennibister	1	<0.11	1.3	0.14	0.45	0.74		
Seawater	Brims Ness	4	<0.10	<0.14			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.14			<0.11		
Spume	Oigin's Geo	3	<0.46	<0.88	13	63	16		

Table 3.2(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											
Beef muscle		1	<5.0	<0.05	<0.10	<0.12	<0.32	<0.11	<0.05	0.16	<0.21
Beef offal		1	<5.0	<0.05	<0.10	<0.20	<0.41	<0.11	<0.05	<0.05	<0.27
Carrots		1	<5.0	<0.05	<0.10	<0.08	<0.35	<0.05	<0.05	<0.05	<0.20
Cereals		1	<5.0	<0.05	0.32	<0.12	<0.28	<0.05	<0.05	0.06	<0.20
Lamb muscle		1	<5.0	<0.05	<0.10	<0.16	<0.37	<0.11	<0.05	0.93	<0.25
Pears		1	<5.0	<0.05	0.21	<0.05	<0.28	<0.05	<0.05	0.05	<0.15
Pheasants		1	<5.0	<0.05	0.30	<0.05	<0.17	<0.05	<0.05	0.10	<0.11
Potatoes		1	<5.0	<0.05	<0.10	<0.08	<0.40	<0.05	<0.05	0.10	<0.25
Rabbit		1	<5.0	<0.05	<0.10	<0.05	<0.37	<0.05	<0.05	0.41	<0.23
Rosehips		2	<5.0	<0.05	0.94	<0.05	<0.22	<0.05	<0.05	0.21	<0.15
Rosehips	max				1.1		<0.25			0.32	<0.17
Rowan berries		1		<0.05	0.50	<0.05	<0.11	<0.05	<0.05	0.09	<0.07
Turnips		1	<5.0	<0.05	0.25	<0.07	<0.31	<0.05	<0.05	0.14	<0.18
Wild mushrooms		1	<5.0	<0.05	<0.10	<0.05	<0.22	<0.07	<0.05	3.1	<0.13
Grass		6	<5.0	<0.05	0.36	<0.15	<0.35	<0.05	<0.05	<0.25	<0.23
Grass	max				0.69	<0.24	<0.44			0.69	<0.30
Soil[c]		6	<5.0	<0.15	1.5	<0.21	<0.56	<0.05	<0.07	16	<0.53
Soil	max			<0.57	1.8	0.54	<0.64		<0.09	19	<0.61
Freshwater	Loch Calder	1	<1.0	<0.01		<0.05	<0.09		<0.01	<0.01	<0.04
Freshwater	Loch Shurrery	1	<1.0	<0.01		<0.01	<0.06		<0.01	<0.01	<0.03
Freshwater	Loch Baligill	1	<1.0	<0.01		<0.03	<0.06		<0.01	<0.01	<0.03
Freshwater	Heldale Water	1	<1.0	<0.01		<0.34	<0.07		<0.01	<0.01	<0.04

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											
Beef muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Beef offal		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Carrots		1					<0.050	<0.050	<0.050		
Cereals		1					<0.050	<0.050	<0.050		
Lamb muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Pears		1					<0.050	<0.050	<0.050		
Pheasants		1							<0.06		
Potatoes		1					<0.050	<0.050	<0.050		
Rabbit		1							<0.11		
Rosehips		2					<0.050	<0.050	<0.050		
Rowan berries		1					<0.050	<0.050	<0.050		
Turnips		1					<0.050	<0.050	<0.050		
Wild mushrooms		1					<0.050	<0.050	<0.050		
Grass		6		0.37	<0.046	<0.36	<0.050	<0.050	<0.052		
Grass	max			1.2	0.058	0.48			<0.060		
Soil[c]		6	1.6	30	1.2	28	<0.050	0.41	<0.17		
Soil	max		1.8	52	2.0	47	0.052	0.61	0.32		
Freshwater	Loch Calder	1							<0.01	<0.011	0.041
Freshwater	Loch Shurrery	1							<0.01	<0.010	0.029
Freshwater	Loch Baligill	1							<0.01	<0.010	0.023
Freshwater	Heldale Water	1							<0.01	<0.010	0.058

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

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

[c] *The concentration of ^{125}Sb was 0.68 Bq kg^{-1}*

Table 3.2(b). Monitoring of radiation dose rates near Dounreay, 2013

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	0.059
Sandside Bay	Winkle bed	2	0.094
Oigin's Geo	Spume/sludge	4	0.16
Brims Ness	Shingle and stones	2	0.086
Melvich	Salt Marsh	2	0.065
Melvich	Sand	2	0.059
Strathy	Sand	2	0.056
Thurso	Riverbank	2	0.086
Acheregan Hill	Soil	2	0.058
Thurso Park	Soil	2	0.079
Borrowston Mains	Soil	2	0.087
East of Dounreay	Soil	2	0.082
Castletown Harbour	Sand	2	0.077
Dunnet Bay	Sand	2	0.062
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 3.2(c). Radioactivity in air near Dounreay, 2013

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	11	<0.010	<0.010	<0.20
Reay	12	<0.010	<0.010	<0.20
Balmore	10	<0.010	<0.010	<0.20

Table 3.3(a). Concentrations of radionuclides in food and the environment near Harwell, 2013

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{60}Co	^{131}I	^{137}Cs	^{238}Pu
Freshwater samples							
Flounder	Woolwich Reach	1	<25	<0.04	*	0.10	
Sediment	Appleford	3[E]		<0.30		7.6	<0.55
Sediment	Outfall (Sutton Courtenay)	4[E]		<0.67		27	<0.42
Sediment	Day's Lock	3[E]		<0.37		11	<0.53
Sediment	Lydebank Brook	4[E]		<1.3		4.2	<0.47
Freshwater	Day's Lock	4[E]	<3.0	<0.31		<0.25	
Freshwater	Lydebank Brook	4[E]	<3.3	<0.29		<0.24	
Freshwater	R Thames (above discharge point)	4[E]	<3.2	<0.24		<0.20	
Freshwater	R Thames (below discharge point)	4[E]	<3.2	<0.25		<0.21	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			^{239}Pu + ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Freshwater samples						
Flounder	Woolwich Reach	1		<0.05		
Sediment	Appleford	3[E]	<0.59	<0.40	<180	210
Sediment	Outfall (Sutton Courtenay)	4[E]	0.67	<1.1	<190	430
Sediment	Day's Lock	3[E]	<0.38	<0.50	<140	260
Sediment	Lydebank Brook	4[E]	<0.61	<1.1	<170	380
Freshwater	Day's Lock	4[E]			<0.064	0.24
Freshwater	Lydebank Brook	4[E]			<0.049	0.17
Freshwater	R Thames (above discharge point)	4[E]			<0.058	0.25
Freshwater	R Thames (below discharge point)	4[E]			<0.051	0.25

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			Organic ^{3}H	^{3}H	^{137}Cs
Terrestrial samples					
Milk		3	<2.5	<2.0	<0.07
Milk	max		<3.2		<0.09
Apples		1	<2.4	<2.4	<0.07
Broad beans		1	<2.2	<2.2	<0.11
Honey		1	<5.3	<5.3	<0.13
Potatoes		1	<2.3	<2.3	<0.07
Raspberries		1	<2.5	<2.5	<0.04
Strawberries		1	<2.0	<2.0	<0.05

* *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 3.3(b). Monitoring of radiation dose rates near Harwell, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Grass and mud	2	0.065
Sutton Courtenay	Mud	2	0.076
Day's Lock	Grass	2	0.067

Table 3.4(a). Concentrations of radionuclides in food and the environment near Winfrith, 2013

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		<0.06		<0.07	
Bass	Weymouth Bay	2		<0.07		0.19	
Crabs	Chapman's Pool	1		<0.10		<0.08	0.000075
Crabs	Lulworth Banks	1	25	<0.06		0.05	0.000071
Pacific Oysters	Poole	1		<0.10		<0.10	
Cockles	Poole	1		<0.13		<0.10	
Whelks	Poole Bay	1		<0.04		<0.04	0.00018
Whelks	Lyme Regis	1		<0.13		<0.11	0.00012
Scallops	Lulworth Ledges	1		<0.07		<0.06	0.00063
Scallops	Portland Harbour	1		<0.08		<0.07	
Seaweed	Lulworth Cove	1[E]		<0.68	1.1	<0.47	
Seaweed	Bognor Rock	2[E]		<0.96	2.1	<0.64	
Seawater	Lulworth Cove	1[E]		<0.40		<0.32	

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		<0.18				
Bass	Weymouth Bay	2		<0.15				
Crabs	Chapman's Pool	1	0.00062	0.00065	*	*		
Crabs	Lulworth Banks	1	0.00050	0.00091	*	0.0000080		
Pacific Oysters	Poole	1		<0.08				
Cockles	Poole	1		<0.09				
Whelks	Poole Bay	1	0.0015	0.0016	*	*		
Whelks	Lyme Regis	1	0.0012	0.0013	0.000026	0.000033		
Scallops	Lulworth Ledges	1	0.0042	0.0016	*	*		
Scallops	Portland Harbour	1		<0.08				
Seaweed	Lulworth Cove	1[E]		<0.65				
Seaweed	Bognor Rock	2[E]		<0.70				
Seawater	Lulworth Cove	1[E]		<0.31			<1.9	4.6

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		4	<2.2	<2.0	22	<0.07		
Milk	max		<2.3		23	<0.08		
Apples		1	<2.6	<2.6	19	<0.07		
Beetroot		1	<2.7	<2.7	12	<0.05		
Blackberries		1	<2.0	<2.0	11	0.09		
Broad beans		1	<2.9	<2.9	23	<0.04		
Cabbage		1	<2.8	<2.8	6.7	<0.09		
Honey		1	<3.4	<3.4	75	0.47		
Grass		2	<2.7	<2.7	20	<2.7		
Grass	max		<2.9	<2.7	26	5.3		
Sediment	North of site (Stream A)	1[E]				0.57	<130	<160
Sediment	R Frome (upstream)	1[E]				2.5	120	180
Sediment	R Frome (downstream)	1[E]				2.7	110	170
Sediment	R Win, East of site	1[E]				<0.21	<100	170
Freshwater	North of site (Stream A)	2[E]		17		<0.23	<0.047	0.17
Freshwater	R Frome (upstream)	2[E]		<3.2		<0.19	<0.042	0.15
Freshwater	R Frome (downstream)	2[E]		<3.1		<0.25	<0.045	0.12
Freshwater	R Win, East of site	2[E]		<3.9		<0.21	<0.060	0.20

* *Not detected by the method used*

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

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

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

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

Table 3.4(b). Monitoring of radiation dose rates near Winfrith, 2013

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand	1	0.055
Red Cliffe Point to Black Head	Pebbles	1	0.054
Osmington Mills	Rock and stones	1	0.059
Ringstead Bay	Pebbles and sand	1	0.053
Durdle Door	Shingle	1	0.057
St Oswald's Head	Pebbles and sand	1	0.057
Lulworth Cove	Sand and stones	1	0.059
Kimmeridge Bay	Pebbles and rock	1	0.089
Swanage Bay 1	Sand	1	0.052
Swanage Bay 2	Sand	1	0.054
Swanage Bay 3	Sand	1	0.056
Poole Harbour	Sand	1	0.048

Table 3.5. Concentrations of radionuclides in the environment near Culham, 2013

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)	1	<2.8				<0.21	<0.029	0.22
Freshwater	River Thames (downstream)	1	<2.8				<0.20	<0.090	0.25
Grass	1 km East of site perimeter	1	<24	18	<2.2	<0.14	<0.35		200
Sediment	River Thames (upstream)	1					13		
Sediment	River Thames (downstream)	1					12		
Soil	1 km East of site perimeter	1	<8.0	<8.1	<7.8	<2.0	4.7		460

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

4. Nuclear power stations

Key points

- *Total doses* for the representative person were less than 3 per cent of the dose limit for all sites assessed
- Electricity production continued at one Magnox station (Wylfa), one PWR station (Sizewell B) and seven AGR stations in 2013
- All the English EDF stations were issued with new radioactive substances permits that came into effect on 1 January 2013
- Discharges, environmental concentrations and dose rates in 2013 were broadly similar to those in 2012
- 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

- *Total dose* for the representative person decreased in 2013
- Gaseous discharges decreased from Oldbury

Bradwell, Essex

- *Total dose* for the representative person continued to be low (as in 2012)

Chapelcross, Dumfries and Galloway

- *Total dose* for the representative person increased in 2013
- A revised authorisation was issued for both gaseous and liquid discharges

Dungeness, Kent

- *Total dose* for the representative person increased in 2013
- Liquid tritium and sulphur-35 discharges increased from Dungeness B

Hartlepool, County Durham

- *Total dose* for the representative person increased in 2013
- Gaseous discharges of argon-41 and liquid discharges of tritium and other radionuclides decreased in 2013
- Environmental concentrations of some natural radionuclides were enhanced, though not related to power station operation

Heysham, Lancashire

- *Total dose* for the representative person increased in 2013
- Gaseous discharges of tritium and carbon-14 decreased from Heysham 2. Liquid discharges of tritium increased from Heysham 1

Hinkley Point, Somerset

- *Total dose* for the representative person increased in 2013
- Permits and a planning consent were granted relating to site preparation and construction activities at the Hinkley Point C site in 2013
- Liquid discharges of tritium and 'other' radionuclides from Hinkley A, and tritium and sulphur-35 from Hinkley B, increased in 2013

Hunterston, North Ayrshire

- *Total dose* for the representative person decreased in 2013
- Liquid discharges of beta radionuclides decreased from Hunterston A and tritium increased from Hunterston B in 2013

Sizewell, Suffolk

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

Torness, East Lothian

- Liquid discharges of sulphur-35 increased in 2013

Trawsfynydd, Gwynedd

- *Total dose* for the representative person increased in 2013
- Liquid discharges of caesium-137 decreased in 2013

Wylfa, Isle of Anglesey

- *Total dose* for the representative person decreased in 2013
- There were small changes in public radiation doses from gaseous and liquid discharges
- Power generation from the Magnox station is to continue beyond 2013
- Gaseous discharges of tritium, carbon-14 and particulate beta decreased, and liquid discharges of tritium increased, in 2013

This section considers the results of environment and food monitoring by the Environment Agency, Food Standards Agency and SEPA from nuclear power stations. There is 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). Some of these stations are being decommissioned.

Eleven of the 19 nuclear power stations are older Magnox power stations, owned by the NDA. The NDA (set up under the Energy Act 2004) is a non-departmental public body, with a remit to secure the decommissioning and clean-up of the UK's civil public sector nuclear licensed sites. In April 2014, the NDA published a business plan which summarises the programme of work at each of the sites during 2014/17 (Nuclear Decommissioning Authority, 2014).

In 2012, the NDA announced its competition for the Parent Body Organisation contracts for Magnox Limited. In March 2014, the NDA announced that the Cavendish Fluor Partnership, a joint venture between Cavendish Nuclear (a wholly-owned subsidiary of Babcock International Group plc) and Fluor Corporation, has been selected as the preferred bidder in the competition to take ownership of Magnox Limited. In 2013, Magnox Limited managed ten nuclear sites and was owned and operated by Energy Solutions on behalf of the NDA. Only one Magnox station (Wylfa) continued to generate electricity, others are in the process of de-fuelling or decommissioning.

Calder Hall is being decommissioned; it 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 EDF Energy Nuclear Generation Limited in 2013; these are 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 2013.

All the English EDF stations were issued with new EPR 10 template radioactive substances permits in late 2012 and these came into effect on 1 January 2013. This was an Environment Agency-initiated variation. There were no changes in limits, other than removal of the limits on off-site transfer to give more flexibility to the operator in utilising waste routes (subject to demonstration of BAT). These permits were all subsequently varied (in April 2013) to include an improvement condition relating to the Eels (England and Wales) Regulations 2009 (Statutory Instruments, 2009).

Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency in England and Wales, and by SEPA in Scotland. In 2013, 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 in England and Wales, and by SEPA in Scotland.

The medium-term trends in dose, discharges and environmental concentrations at these sites were considered in a 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. It ceased electricity generation in 1989 and de-fuelling was completed in 1992. Decommissioning is still in progress and radioactive wastes are still generated by these operations. In November 2013, the Environment Agency varied the permit for Berkeley to change some points of reference for liquid discharges from the site. This variation of permit included the replacement of the old active effluent treatment plant with a new liquid effluent compliance plant (using the same outlet and discharge point), the introduction of approved minor outlets and the removal of unused gaseous discharge outlets. However, there was no change to the limits for both gaseous and liquid discharges. Current plans are for the site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2079, earlier than previously planned (Nuclear Decommissioning Authority, 2014).

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 in February 2012, with the closure of Reactor 1. Reactor 2 was previously shut-down in 2011. A post operation and de-fuelling

safety case was submitted to ONR in 2012. Current plans are for the site to be de-licensed (released from regulatory control), with final site clearance to be achieved by 2101 (Nuclear Decommissioning Authority, 2014). The new EPR 10 template radioactive substances permit (issued on 1 January 2013) was varied by the Environment Agency in early 2014. The variation was to remove the use of the site's incinerator/oil burner as a permitted activity.

Berkeley and Oldbury sites are considered together for the purposes of environmental monitoring because the effects from both sites contribute to 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 0.010 mSv in 2013 (Table 4.1), which was 1 per cent of the dose limit, and down from 0.014 mSv in 2012. The lower value in 2013 was due to a decrease in the dominant contributor (external exposure over intertidal areas) mostly because gamma dose rates were measured on different types of substrate (near the Oldbury site) from one year to the next. In 2013, adults were identified as the most exposed age group (as in 2012). The trend in the *total dose* over the period 2004 – 2013 is given in Figure 4.1. Any longer-term variations in *total doses* with time are attributable to changes in the contribution from direct radiation from the site.

The source specific assessment for a high-rate consumer of locally grown foods gives an exposure that was less than the *total dose* in 2013. The dose to a high-rate consumer of locally grown foods 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). The increase in dose from less than 0.005 mSv (in 2012) was due to enhanced carbon-14 concentrations in milk in 2013. The dose to a consumer of fish and shellfish was estimated to be 0.012 mSv, which was approximately 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 Limited at Cardiff, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The dose in 2012 was 0.018 mSv, and the reason for the change in 2013 was the same as that for the *total dose*.

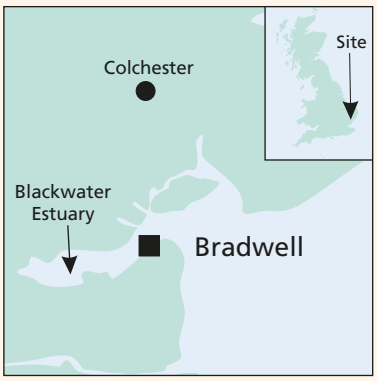
Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. Discharges from Oldbury were generally lower in comparison to those in 2012, following on from the cessation of power generation of Reactor 1 in 2012. 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 2013 are given in Table 4.2(a). As in previous years, sulphur-35 was detected at very low levels in some of the terrestrial food samples, and carbon-14 was detected in locally produced foods at concentrations above background values (although this may be due to natural variation). Some carbon-14 concentrations in foodstuffs (including milk) increased by small amounts in comparison to those in 2012. 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 historical discharges from the GE Healthcare Limited radiopharmaceutical plant in Cardiff (see Section 6). Data for 2013 are given in Tables 4.2(a) and (b). 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 been generally consistent over the last 6 years (Figure 4.2). As in recent years, tritium concentrations in fish were measured below the LoD and detected in lower concentrations in shrimps compared to those in 2012. In previous years, these activities have been relatively high and were likely to be mainly due to historical discharges from GE Healthcare Limited, 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 de-fuelling was completed in 2006. The focus for the site is now the completion of decommissioning projects. The current plan is to deliver the site into a state of Care and Maintenance by 2015. Thereafter the site will be de-licensed (released from regulatory control) with final site

clearance to be achieved by 2092, earlier than previously planned (Nuclear Decommissioning Authority, 2014). The most recent habits survey was undertaken in 2007 (Tipple *et al*., 2008).

Doses to the public

The *total dose* from all pathways and sources of radiation was less than 0.005 mSv in 2013 (Table 4.1), which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv, and unchanged from 2012. The dose assessment identifies a prenatal child of local green vegetable consumers as the most exposed person. The majority of the dose was received from the consumption of vegetables by their adult parent. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. Any variations in *total dose* with time were attributed to changes in the estimate of direct radiation.

The source specific assessment for a high-rate consumer of fish and shellfish gives an exposure that was less than the *total dose* in 2013. The dose to a high-rate consumer of locally grown foods was estimated to be 0.005 mSv, which was 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The increase in dose from less than 0.005 mSv (in 2012) was due to enhanced carbon-14 concentrations in milk in 2013.

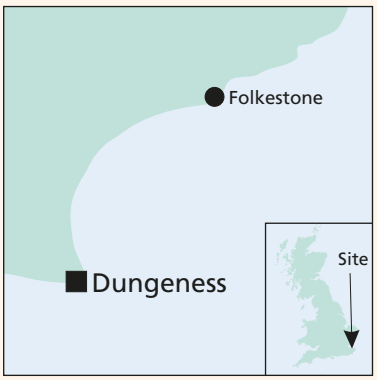
Gaseous discharges and terrestrial monitoring

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 2013 are given in Table 4.3(a). Activity concentrations were low in terrestrial food samples, although some enhancements of carbon-14 concentrations in some terrestrial samples (including milk) were apparent. The gross alpha and beta activities in freshwater (public supplies) 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 2012, and were substantially below the EU reference level for tritium of 100 Bq l^{-1}. The water in the ditches is not known to be used as a source of drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged into the River Blackwater estuary. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. Seaweeds were analysed as an environmental indicator material and leaf beet was collected because it is eaten locally and grows in areas that become tidally inundated. Data for 2013 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. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source; however concentrations were generally similar to those for 2012. There is an overall decline in caesium-137 concentrations in sediments over the last decade (Figure 4.2), and the reported activity concentration is the lowest value in 2013. 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 neighbouring sites; the A station was powered by two Magnox reactors and the B station has two AGRs. Discharges are made via separate and adjacent outfalls and stacks, but for the purposes of environmental monitoring these are considered together. Dungeness A ceased generating electricity in 2006. De-fuelling of both Magnox reactors was completed in 2012, with the spent fuel being dispatched to Sellafield (Cumbria) for reprocessing. Current plans are for the Dungeness A site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2097, earlier than previously planned (Nuclear Decommissioning Authority, 2014). A case is being made for Dungeness B to continue generation beyond 2018. The most recent habits survey was undertaken in 2010 (Clyne *et al*., 2011c).

Doses to the public

In 2013, 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 up from 0.015 mSv in 2012. As in recent years, this is almost entirely due

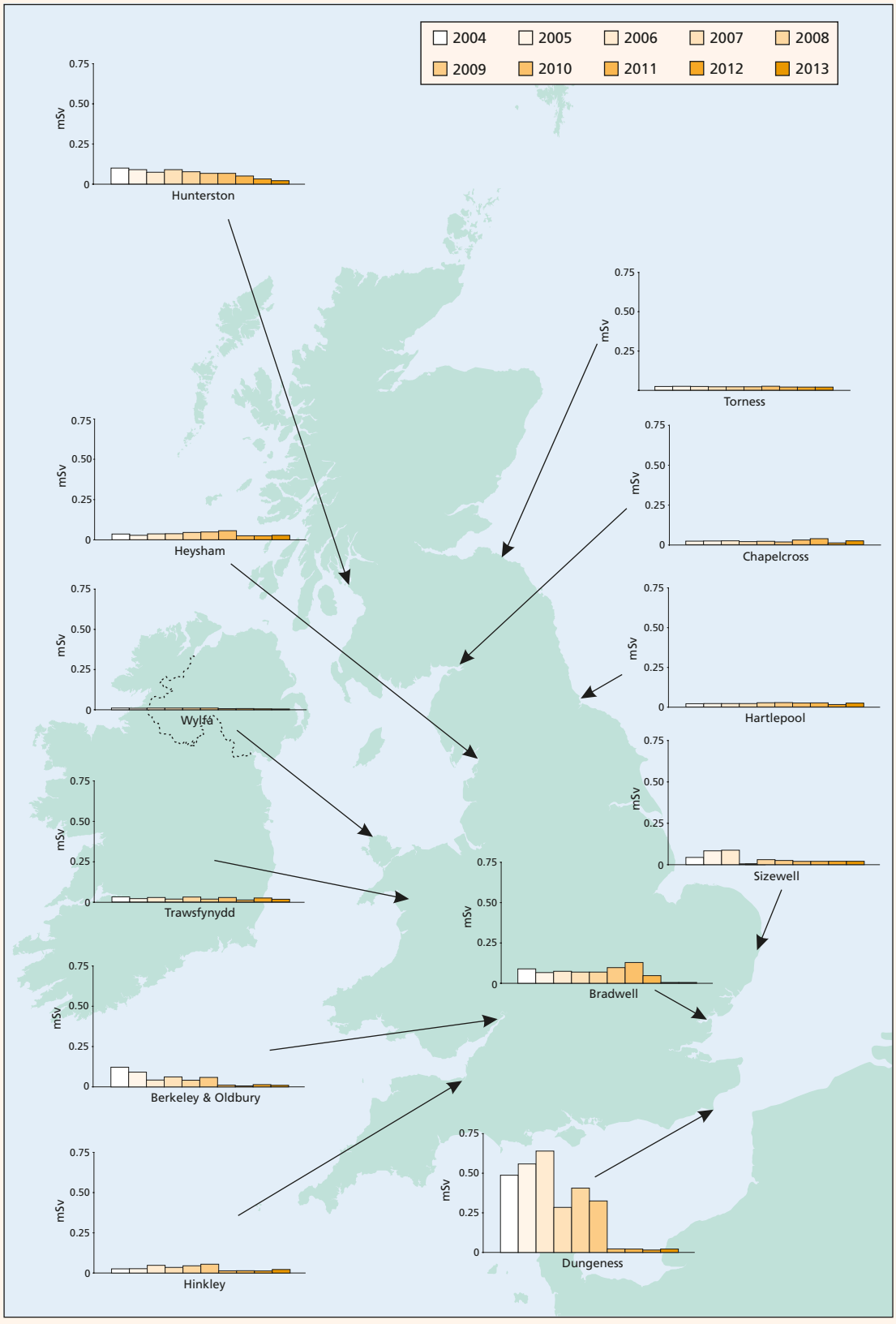


Figure 4.1. *Total dose* at nuclear power stations, 2004-2013
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

to direct radiation from the site. An adults living near to the site was the most exposed person. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. *Total doses* ranged between 0.015 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 a high-rate consumer of locally grown foodstuffs, for a local bait digger, and for a houseboat occupant give exposures that were less than the *total dose*. The dose to a high-rate consumer of locally grown foods was estimated to be 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). The increase in dose from 0.005 mSv (in 2012) was due to enhanced carbon-14 concentrations in milk in 2013. The dose to a local bait digger (who consumes large quantities of fish and shellfish and spends long periods of time in the location being assessed) was 0.007 mSv in 2013, which was less than 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). The change in dose (from 0.012 mSv in 2012) was mostly because gamma dose rates were measured on different types of substrate (at Dungeness East) from one year to the next.

Gaseous discharges and terrestrial monitoring

The main focus of the terrestrial sampling was analyses of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. The results of monitoring for 2013 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the LoD. As in previous years, low concentrations of sulphur-35 were detected in some samples and carbon-14 was detected in locally produced foods at concentrations above background values; carbon-14 concentrations in milk increased by small amounts in comparison to those in 2012. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium and sulphur-35 from Dungeness B increased by a small amount, in comparison to releases in 2012, which correlates with an increase in operational hours. Marine monitoring included gamma dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2013 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. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. The low concentrations of transuranic nuclides in scallops were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood in 2013. 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 LoD. Gamma dose rates were generally difficult to distinguish from the natural background.

4.4 Hartlepool, County Durham

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 new EPR 10 template radioactive substances permit (issued on 1 January 2013) was varied by the Environment Agency in September 2013. The variation incorporated provisions related to non-radioactive discharges from the solid waste incinerator on the site and a further improvement condition requiring the operator to develop and implement an improvement programme to demonstrate that the solid waste incinerator and waste oil burner will be able to meet stricter emission limits, equivalent to those for plant burning non-radioactive waste under the Industrial Emissions Directive 2010 (European Parliament and Council of the European Union, 2010). The most recently published habits survey was conducted in 2008 (Garrod *et al*., 2009).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.024 mSv in 2013 (Table 4.1), which was approximately 2 per cent of the dose limit, and up from 0.015 mSv in 2012. The increase in *total dose* (from 2012) was mostly due to higher direct radiation from the site in 2013. The most exposed person was an adult living near to the site whose dose was from direct radiation (from the site) and, to a lesser extent, external exposure from activity in sand and sediment on local beaches. The trend in *total dose* over the period 2004 – 2013 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 of fish and shellfish, give exposures that were less than the *total dose*. The dose to a local fish and shellfish consumer, including external radiation but excluding naturally occurring radionuclides,

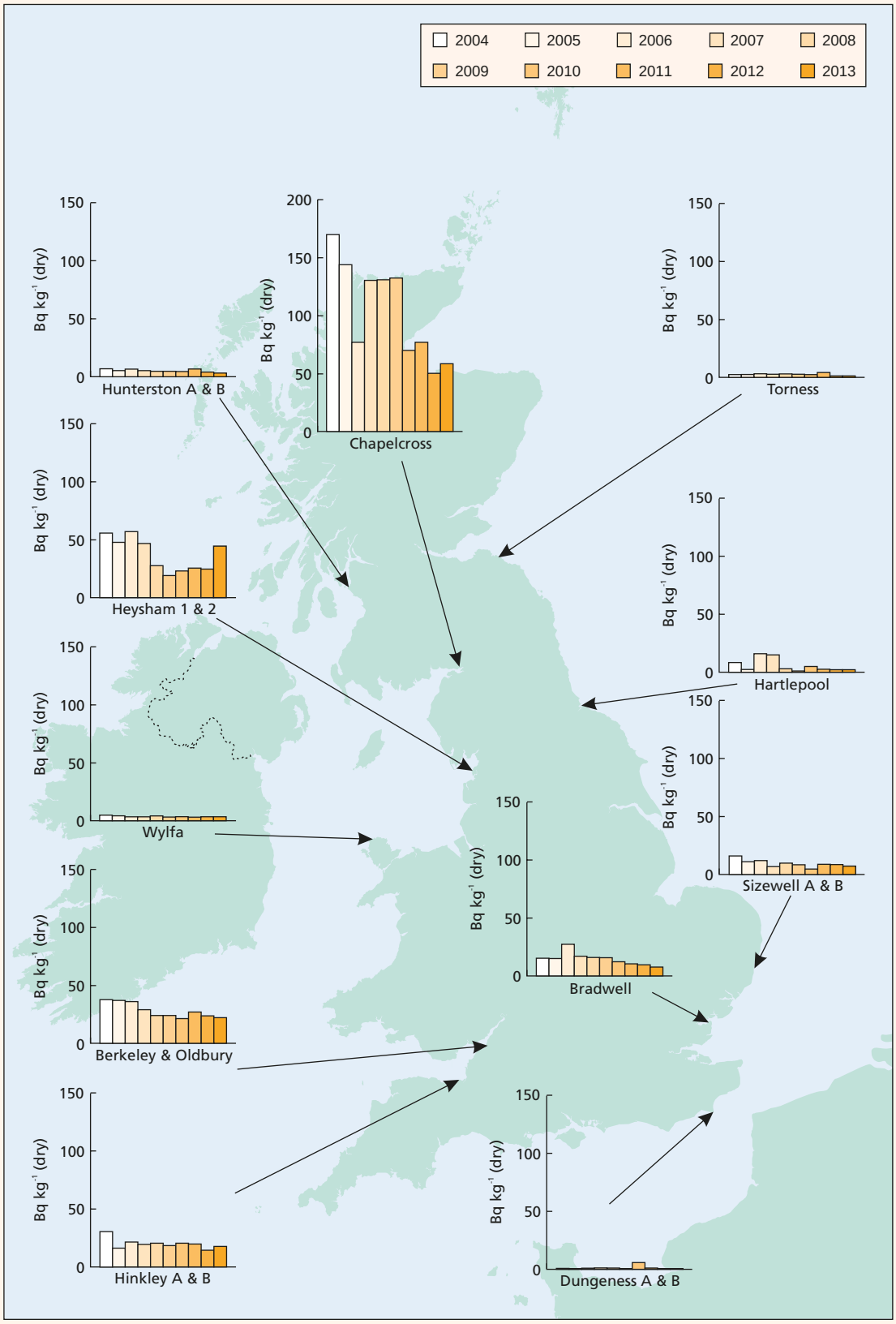


Figure 4.2. Caesium-137 concentration in marine sediments near nuclear power stations between 2004-2013

was 0.007 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This dose was similar to that in 2012 (0.008 mSv). Lower gamma dose rates in 2013 decreased the dose received from collecting sea coal at Carr House to 0.007 mSv (from 0.009 mSv in 2012).

As in 2012, a source specific assessment was undertaken in 2013 to determine the exposure from naturally occurring radionuclides, as a consequence of the reported polonium-210 concentrations in mollusc samples. In 2013, winkle samples collected for South Gare (inside the Tees Estuary entrance) consisted of a mixture including

some winkles from the estuary entrance near Paddy's Hole. The area in the close proximity of Paddy's Hole was unlikely to sustain a high-rate consumption of winkles, as it is an extremely localised area which contains oil and other wastes. In addition, the most recent habits survey undertaken in 2008 did not identify any consumption of molluscs from Paddy's Hole. However, in the event that some of these molluscs were a constituent of the diet of a high-rate consumer of fish and shellfish, the dose from naturally occurring radionuclides was assessed to be 0.049 mSv, in addition to that from artificial radionuclides. This estimate assumes that the median concentrations for naturally occurring radionuclides at background (Appendix 1, Table X4.1) be subtracted from the total concentrations as measured in 2013.

Gaseous discharges and terrestrial monitoring

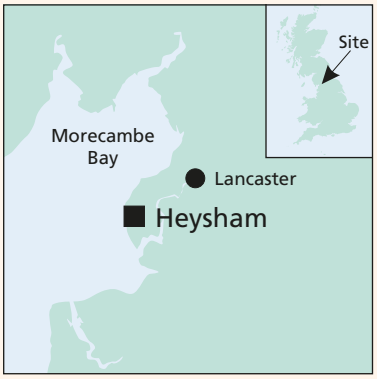
Gaseous radioactive waste is discharged via stacks to the local environment. Discharges of argon-41 decreased in comparison to releases in 2012. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. Samples of water are also taken from a borehole and public water supplies. Data for 2013 are given in Table 4.5(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, although small enhancements of sulphur-35 concentrations (just above the LoD) were measured in a few terrestrial samples. Also, a few carbon-14 concentrations were enhanced relative to the default values used to represent background levels in 2013. 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. Discharges of tritium and 'other' radionuclides decreased in 2013, in comparison to those in 2012. Results of the aquatic monitoring programme conducted in 2013 are shown in Tables 4.5(a) and (b). Small enhancements of carbon-14 concentrations, above expected background, were observed in seafood samples. 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 increased by a small amount in 2013 (the activity concentration in 2012 was the lowest value reported 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 2.9). They are less than 1 per cent of the equivalent concentrations near Sellafield. Iodine-131 was again positively detected in seaweed samples collected around the mouth of the River Tees Estuary in 2013. The detected values, as 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. However, caesium-137 concentrations in sediment have remained low over the last 6 years (Figure 4.2). Overall, gamma dose rates in 2013 were generally similar to those in 2012.

In 2013, the reported polonium-210 concentration in winkles from South Gare was 20 Bq kg^{-1} and enhanced above the value expected due to natural sources. These samples (collected inside the Tees Estuary entrance) consisted of a mixture including some winkles collected from the estuary entrance near Paddy's Hole. The polonium-210 concentration is consistent with previously reported values in winkles from Paddy's Hole, obtained from sampling and analysis undertaken between in 2004 and 2006. The enhanced levels of polonium-210 were believed to be due to a combination of waste slag from local iron and steel industries, used in sea defences, and/or the build up of naturally occurring gamma-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time.

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. The most recent habits survey was undertaken in 2011 (Garrod *et al.*, 2012).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.028 mSv in 2013 (Table 4.1), or less than 3 per cent of the dose limit for members of the public, and up from 0.025 mSv in 2012. The higher value in 2013 was mostly due to a small increase in the americium-241

concentrations in molluscs. The most exposed person was an adult who was a high-rate consumer of molluscs. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. Any changes in *total doses* from 2004 – 2010 were attributable to environmental variability (in measurements of gamma dose rates); thereafter relatively lower *total doses* were estimated due to a lower occupancy rate over local beaches.

Source specific assessments for high-rate terrestrial food consumption, and from external exposure for turf cutting over salt marsh, give exposures that were less than the *total dose* (Table 4.1). The estimated dose from terrestrial food consumption in 2013 was 0.012 mSv, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv. The increase in dose from 0.008 mSv (in 2012), was mostly due to enhanced carbon-14 concentrations in milk in 2013. The dose to a local fisherman, who was considered to consume a large amount of seafood and was exposed to external radiation over intertidal areas, was 0.036 mSv in 2013, which was less than 4 per cent of the dose limit for members of the public of 1 mSv (Table 4.1), and similar to that in 2012 (0.034 mSv). The reason for the small increase in dose in 2013 is the same as that contributing to maximum *total dose*.

Gaseous discharges and terrestrial monitoring

Discharges of tritium and carbon-14 at Heysham 2 decreased in 2013, compared with 2012; other discharges of 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 2013 are given in Table 4.6(a). The effects of gaseous disposals were difficult to detect in 2013, although carbon-14 concentrations in foodstuffs were all above the default values used to represent background levels in 2013, and some concentrations increased (including milk) in comparison to those in 2012. Small enhancements of concentrations of sulphur-35 were measured in some samples, but activities of cobalt-60 were below the LoD.

Liquid waste discharges and aquatic monitoring

Discharges of tritium increased from Heysham 1, compared with those in 2012; other discharges of radionuclides (including those from Heysham 2) 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 2013 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2012 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at levels typical of recent years, caused by discharges from Sellafield. Small increases in concentrations of Sellafield-derived americium-241 (and plutonium radionuclides) were observed in mollusc samples (Middleton Sands) in 2013. Concentrations of caesium-137 in sediments, largely due to Sellafield, are generally in decline (Figure 4.2), albeit with an increase in 2013 compared to that in recent years. Gamma dose rates over intertidal sediment were generally similar to measurements in recent years.

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 stations that include two Magnox reactors and two AGRs, respectively. Hinkley Point A started electricity generation in 1965 and ceased in 2000. This station completed de-fuelling in 2004 and is undergoing decommissioning. Current plans are for the site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2090, earlier than previously planned (Nuclear Decommissioning Authority, 2014). It is estimated that power generation will continue at Hinkley Point B until at least 2023. Environmental monitoring covers the effects of the two power stations together.

The Environment Agency issued three environmental permits, on the 13 March 2013, for the new nuclear power station at Hinkley Point C covering (i) disposal and discharge of radioactive wastes, (ii) operation of standby power supply systems using diesel generators and (iii) discharge cooling water and liquid effluents into the Bristol Channel. On 19th March 2013, the Secretary of State for Energy and Climate Change granted a planning consent order to EDF Energy to build and operate Hinkley Point C and associated development. The decision follows the submission of EDF Energy's application to the Infrastructure Planning Commission (now the Planning Inspectorate) in 2011. More information can be found at: www.environment-agency.gov.uk/hinkleypoint.

The most recent habits survey was conducted in 2010 (Clyne *et al.*, 2011a).

Doses to the public

In 2013, the *total dose* from all pathways and sources of radiation was 0.022 mSv (Table 4.1), or approximately 2 per cent of the dose limit, and up from 0.013 mSv in 2012. The higher value in 2013 was due to an increase from external exposure over intertidal areas. An adult who spent a large amount of time over sediments was the most exposed person. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. In 2010, the decrease in *total dose* (and continued thereafter) was attributed to lower gamma dose rates over local beaches.

A source specific assessment for a high-rate consumer of locally grown food gave an exposure that was less than the *total dose* (Table 4.1). The dose to this consumer was 0.015 mSv in 2013. The increase in dose (from 0.007 mSv in 2012) was mostly due to higher carbon-14 concentrations in milk resulting in a dose increase of ~0.007 mSv, and to a lesser extent, carbon-14 concentrations in domestic fruit (giving dose increase of ~0.002 mSv) in 2013. The dose to a local fisherman, who consumed a large amount of seafood and was exposed to external radiation over intertidal areas, was 0.031 mSv in 2013, which was approximately 3 per cent of the dose limit for members of the public of 1 mSv. This estimate also includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1). The increase in dose from 0.018 mSv (in 2012) was due to higher gamma dose rates at Stolford.

Gaseous discharges and terrestrial monitoring

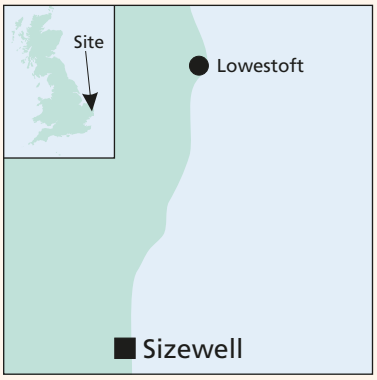
Gaseous radioactive waste is discharged via separate stacks to the local environment. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. Data for 2013 are 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 LoD. Sulphur-35 from Hinkley Point B was detected at low concentrations in some of the food samples. Carbon-14 concentrations in all foods were higher than the default values used to represent background levels. Some carbon-14 concentrations in foodstuffs increased by a small amounts (including milk, apples and blackberries), in comparison to those in 2012. Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water.

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 from Hinkley Point A, and tritium and sulphur-35 from Hinkley B, increased in 2013 in comparison to those in 2012. In 2013, Hinkley A commenced draining and cleaning of fuel pond of Reactor 1; this led to increased discharges from the site. This work was concluded with the complete draining and stabilisation of the pond in early 2014. The increase in discharges of tritium from Hinkley B was due to the increased power generation in 2013. 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 historical discharges from the GE Healthcare Limited plant at Cardiff.

The environmental results for 2013 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 2013 were similar in comparison to those in recent years. Further information on tritium concentrations in seawater from the Bristol Channel is given in Section 8.9. 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 Limited at Cardiff, weapons tests and Chernobyl fallout. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. The dose rates at Stolford increased in comparison to those in 2012. 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, powered by one PWR, 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 de-fuelling (expected completion in 2014) as part of the site's decommissioning plan. Current plans are for the Sizewell A site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2097, earlier than previously planned (Nuclear Decommissioning Authority, 2014). The new EPR 10 template radioactive substances permit (issued on 1 January 2013) was varied by the Environment Agency in early 2014. The variation was to remove the use of site's incinerator/oil burner as a permitted activity. The most recent habits survey was conducted in 2010 (Garrod *et al*., 2011).

Doses to the public

As in recent years, the *total dose* from all pathways and sources was 0.021 mSv in 2013 (Table 4.1) or approximately 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 person was an adult living in the vicinity of the site. The trend in *total dose* over the period 2004 – 2013 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, thereafter any variations were due to the change in the contribution from direct radiation from the site.

Source specific assessments for both a high-rate consumer of locally grown foodstuffs, and of fish and shellfish, and of external exposure for houseboat occupancy, give exposures that were less than the *total dose* in 2013 (Table 4.1). The dose to a consumer of locally grown foods was 0.008 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv. The dose in 2012 was less than 0.005 mSv, the increase was mostly due to higher carbon-14 concentrations in milk resulting in a dose increase of ~0.005 mSv in 2013. The dose to a houseboat dweller from external exposure was 0.018 mSv. The increase from 0.010 mSv in 2012 was due to higher dose rates from mud at Southwold Harbour in 2013.

Gaseous discharges and terrestrial monitoring

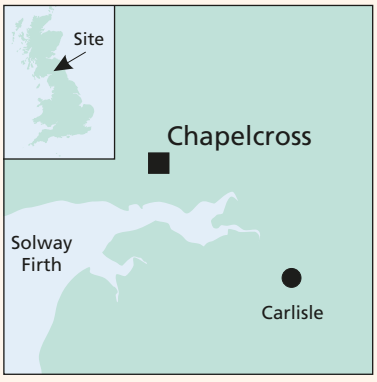
Gaseous wastes are discharged via separate stacks to the local environment. Discharges of carbon-14 at Sizewell B decreased in 2013, compared with 2012, following the refuelling outage in early 2013; other discharges of radionuclides were similar (including those from Sizewell A). The results of the terrestrial monitoring in 2013 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 2013. Tritium concentrations in local freshwater were all low, including those measured at the Leisure Park (positively detected in previous years). Carbon-14 concentrations were detected in locally produced foods, above background concentrations, and these increased by a small amounts (including milk), in comparison to those in 2012. 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. Caesium-137 discharges decreased from Sizewell B in comparison to those in 2012, due to improvements in abatement control features on site in 2013. In the aquatic programme, analysis of seafood, sediment, and seawater, and measurements of gamma dose rates were conducted in intertidal areas. Data for 2013 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 LoD. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Overall, gamma radiation dose rates over intertidal areas were difficult to distinguish from the natural background, although the dose rates at Southwold Harbour increased in comparison to those in recent years, most likely due to natural variation.

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. De-fuelling of the reactors began in 2008 and was completed during 2013. The major hazards on the site will now be addressed early during decommissioning, by 2017. Current plans are for the site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2095, earlier than previously planned (Nuclear Decommissioning Authority, 2014).

In May 2013, SEPA revised the authorisation for Chapelcross. The revision reduced the limit of gaseous discharges of tritium, removed the limits for argon-41 and sulphur-35 and introduced a new limit for "all other radionuclides". In addition, the limit for liquid discharges of tritium was increased by a small amount, whilst the limit was reduced for alpha discharges. The limit for beta discharges was removed and a new limit was introduced for "non-alpha radionuclides".

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2010 (Clyne *et al*., 2013a). In 2012, a habits survey was also conducted to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast (Garrod *et al*., 2013a). The results of this survey are used to determine the potential exposure pathways relating to permitted liquid discharges from the Sellafield nuclear licensed 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 0.024 mSv in 2013 (Table 4.1), which was approximately 2 per cent of the dose limit. As in recent years, an infant who was a high-rate consumer of milk was the most exposed person. The increase in dose from 0.011 mSv (in 2012) was attributed to the inclusion of the LoD for americium-241 activity in food in the 2013 assessment. In line with the rules on use of the results for dose calculations, americium-241 was included because detectable activity was observed in other samples (soil) from the terrestrial environment in 2013. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for a high-rate consumer of locally grown food and seafood (crustaceans), and for a salmon and wildfowl consumer, give exposures that were less than the *total dose* in 2013 (Table 4.1). The annual dose for a high-rate terrestrial food consumer was estimated to be 0.018 mSv in 2013. The reason for the increase in dose (from 0.010 mSv in 2012) in 2013 is the same as those contributing to the maximum *total dose*.

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 discharges 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 2013 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 previous years. The maximum concentration of carbon-14 in milk was 16 Bq l^{-1} and the lowest maximum value over the last 5 years (20 - 35 Bq l^{-1}). Americium-241 concentrations in all terrestrial food samples were below the LoD in 2013. The results for terrestrial foods show the effects of discharges from Chapelcross in the concentrations of tritium in a range of foods, and these were mostly at or below the LoD. As in 2012, the level of tritium was measured well above the detection limit in one freshwater sample (Gullielands Burn). Activity concentrations in air samples at locations near to the site were below the LoD (Table 4.9(c)).

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 2013 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 small increases were measured for plutonium radionuclides and americium-241 in sediment taken close to the pipeline in 2013. Concentrations of technetium-99 in biota were generally similar to those observed in recent years. Concentrations of caesium-137 in sediments, largely due to Sellafield, are generally in decline (Figure 4.2). 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 2013 (as for the interim years). 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 and is now being decommissioned by Magnox Limited.

Decommissioning activities have continued throughout 2013 at Hunterston A. The decommissioning activities include the ongoing draining and cleaning of the cartridge (nuclear fuel) cooling pond and the construction and commissioning of new facilities for the retrieval, conditioning and long term storage of legacy higher activity waste. It is anticipated that the first package of retrieved higher activity waste will be transferred into the new Intermediate Level Radioactive Waste Store (ILWS) during 2014. Current plans are for the Hunterston A site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2080, earlier than previously planned (Nuclear Decommissioning Authority, 2014).

In 2014, SEPA issued a new authorisation to Magnox Limited in relation to decommissioning work at Hunterston A. The new authorisation became operative on 1 July 2014 and replaced the previous three authorisations that were individually applied to liquid, gaseous and solid radioactive waste disposals. The discharge limits in the new authorisation have been significantly reduced compared to the previous authorisations. This reduction reflects the actual discharges that were being made whilst still providing Magnox Limited with sufficient flexibility to undertake its decommissioning activities. Further information on the new authorisation can be found on the SEPA website; the new discharge limits will be included in future RIFE reports.

Hunterston B is powered by a pair of AGRs. Although the authorisation for Hunterston B was varied in 2012 to revise the list of authorised gaseous discharge outlets (by inserting both Reactor 3 and Reactor 4 Pressure Vessel Relief Valves and allowing the routine testing of valve functionality by deliberately releasing reactor gas through each of the valves on a rolling programme in order to demonstrate nuclear safety), this testing did not occur in 2013.

In December 2013, EDF Energy applied to SEPA to vary Hunterston B's authorisation in order to allow radioactive waste to be disposed of by transfer to any waste permitted person, both within the UK and overseas, and to be able to accept radioactive waste from other EDF Energy stations for the purposes of bulking up low volume wastes before final disposal. It is estimated that power generation will continue at Hunterston B until at least 2023.

Environmental monitoring in the area considers the effects of both Hunterston A and Hunterston B sites together. The most recent habits survey was undertaken in 2012, to determine the consumption and occupancy rates by members of the public (Rumney *et al.*, 2013a).

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.021 mSv in 2013 (Table 4.1), which was approximately 2 per cent of the dose limit, and down from 0.032 mSv in 2012. The dose was mainly from direct radiation from the site, and the most exposed person was a prenatal child of local inhabitants. The trend in *total dose* over the period 2004 – 2013 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 both a high-rate consumer of locally grown food and of local seafood give exposures that were generally similar to those in 2012 and less than the *total dose* in 2013 (Table 4.1). The estimated dose to a terrestrial food consumer was 0.009 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (0.007 mSv in 2012). The dose to a fish and shellfish consumer was less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

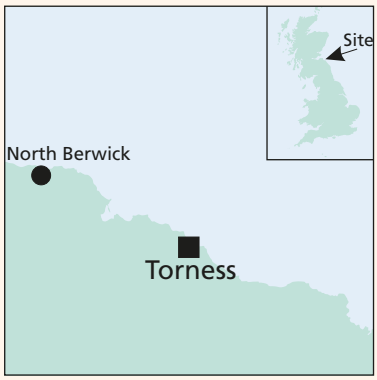
Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. There is a substantial terrestrial monitoring programme which includes the analyses of a comprehensive range of wild and locally produced foods. In addition, air, freshwater, grass and soil are sampled to provide background information. The results of terrestrial food and air monitoring in 2013 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 those in previous years. A few of the carbon-14 concentrations were higher than the default values used to represent background levels (apples and honey). Activity concentrations in air at locations near to the site were either at or below the LoD (Table 4.10(c)).

Liquid waste discharges and aquatic monitoring

Authorised liquid discharges from both Hunterston stations are made to the Firth of Clyde via the Hunterston B station's cooling water outfall. Discharges of tritium increased from Hunterston B, in comparison to those releases in 2012, due to an increase in power generation in 2013. Liquid discharges from Hunterston A are primarily associated with ongoing decommissioning of the cartridge (nuclear fuel) cooling pond and consequently vary depending on the type and progress of the decommissioning activities being carried out. Discharges from Hunterston A in 2013 were less than those in 2012. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials.

The results of aquatic monitoring in 2013 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 lobsters, technetium-99 concentrations continued to remain low in 2013 and were similar to those reported in 2012. Small concentrations (above the LoD) of activation products (silver-110m and cobalt-60) were also detected in some foodstuffs, that were likely to have originated from the site, but these were of negligible radiological significance. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Gamma dose rates were generally similar to those in 2012.

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

In December 2013, EDF Energy applied to SEPA to vary the authorisation for Torness in order to allow radioactive waste to be disposed of by transfer to any waste permitted person, both within the UK and overseas, and to be able to accept radioactive waste from other EDF Energy stations for the purposes of bulking up low volume wastes before final disposal. No changes are proposed to the limits of gaseous or liquid discharges. The gaseous and liquid discharges from the site are given in Appendix 2.

EDF has continued with a programme to inject carbonyl sulphide (COS) into both reactors to reduce the amount of carbon deposition within the reactors from pre-injection levels. As expected, this has resulted in increases of sulphur-35 in liquid discharges (and to a lesser extent in gaseous discharges). The discharge levels remain within the authorised limits.

The most recent habits survey was undertaken in 2011 (Clyne *et al.,* 2013b).

Doses to the public

In 2013, 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, and unchanged from the previous 2 years. Direct radiation was the dominant contributor to the dose and the most exposed person was an adult. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both a high-rate consumer of locally grown foods and of local fish and shellfish give exposures that were less than the *total dose* in 2013 (Table 4.1). The estimated dose to a terrestrial food consumer was 0.006 mSv, which was approximately 0.6 per cent of the dose limit for members of the public of 1 mSv, and unchanged from 2012. The dose to a fish and shellfish consumer was less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops, fruit, and game as well as grass and soil samples, were measured for a range of radionuclides. Air sampling at two locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2013 are given in Tables 4.11(a) and (c). As in recent 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 2013, 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 either at or below the LoD (Table 4.11(c)).

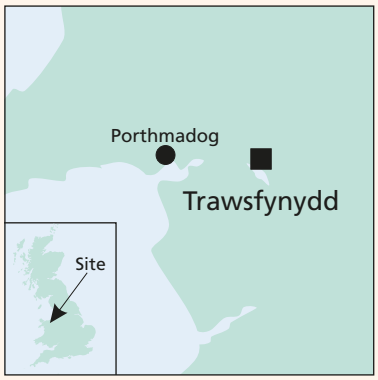
Liquid waste discharges and aquatic monitoring

Discharges of sulphur-35 increased by a small amount, in comparison to those releases in 2012. 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 2013 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 in environmental indicator samples. These were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2012. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). 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 inland, on the northern bank of a lake in the heart of Snowdonia National Park, North Wales and was powered by twin Magnox reactors. Trawsfynydd ceased to generate electricity in 1991. De-fuelling of the reactors was completed in 1995 and the station is being decommissioned. The focus for the site is now the completion of decommissioning projects. The aim is to deliver the Trawsfynydd site into a state of Care and Maintenance by 2016. Current plans are for the site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2083, earlier than previously planned (Nuclear Decommissioning Authority, 2014). Monitoring is conducted on behalf of Natural Resources Wales and 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 0.017 mSv in 2013 (Table 4.1), which was less than 2 per cent of the dose limit, and down from 0.025 mSv in 2012. The lower value in 2013 was due to a decrease in the direct radiation from the site. An infant living near to the site was the most exposed person. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments were undertaken for a high-rate consumer of locally grown foods and for an angler (Table 4.1). The dose to an angler (who consumes large quantities of fish and spends long periods of time in the location being assessed) was 0.013 mSv in 2013, 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 0.010 mSv in 2012 resulted from higher caesium-137 concentrations in lake sediments in 2013.

The dose to an infant consuming terrestrial food was 0.035 mSv or less than 4% of the dose limit. The increase in dose from the value in 2012 of <0.005 mSv was due to the inclusion of a LoD value for americium-241 in milk in accordance with the assessment procedures.

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, including those for local milk, crops and animal samples, are shown in Table 4.12(a). Concentrations of activity in all terrestrial foods were low. As in 2012, concentrations of carbon-14 in 2013 were generally higher than the default values used to represent background levels. As in previous years, measured activities for caesium-137 in terrestrial foods were mostly below, or at the LoD. The most likely source of small amounts of total radiocaesium (in sheep samples) is fallout from Chernobyl and weapon tests, though it is conceivable that a small contribution may be made by re-suspension 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 re-suspension of activity in sediment from the lake shore contributing to increased exposure from transuranic radionuclides in 2013.

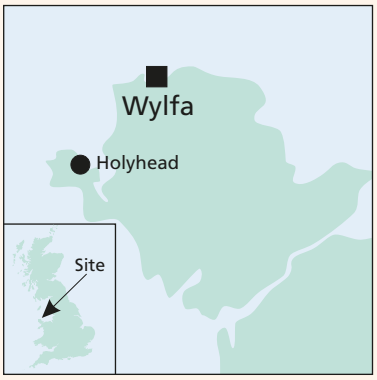
Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. Discharges of caesium-137 decreased in comparison to those in 2012. 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 2013 are given in Tables 4.12(a) and (b). The majority of activity concentrations in fish and sediments result from historical discharges. Concentrations of radiocaesium in fish in 2013 were similar to those in 2012. Concentrations in the water column are predominantly 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 previous years' monitoring, it has been demonstrated that these concentrations increase with depth beneath the sediment surface. Caesium-137 concentrations in the lake sediments increased overall in comparison to those in 2012, but were similar to those in most recent years. In 2013, sediment concentrations of strontium-90, americium-241 and plutonium radionuclide at one location (fish farm) were higher than those in 2012 (but similar to those in 2011), but overall, sediment activity concentrations in 2013 were similar to those in other recent years. Strontium-90 and transuranic concentrations in fish continued to be very low in 2013 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 recent years (but similar to those in 2011). 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 the latter part of the last decade, with sustained reductions in discharges of caesium-137, there was a general progressive decrease in these concentrations in sediments, with the lowest concentrations reported in 2010. In years thereafter, there has been an overall small increase in activity concentrations, but with no discernible trend as yet.

4.12 Wylfa, Isle of Anglesey



Wylfa Power Station is located on the north coast of Anglesey and has two Magnox reactors (Reactor 1 and 2). It was the last and largest power station of its type to be built in the UK and commenced electricity generation in 1971. Wylfa Site's Reactor 2 ceased generating electricity in 2012. The ONR approved changes to the operating rules at Wylfa Power Station, allowing the transfer of partially used fuel from its shutdown reactor to the one remaining operational reactor (from Reactor 2 to Reactor 1), enabling electricity generation to continue beyond its original closure date. Reactor 1 is currently expected to generate electricity until the end of 2015; pending Periodic Safety Case (PSR) submission by the operator, consent from the regulator (ONR) and approval from the NDA and DECC. In November 2013, a decision report was published by ONR, issuing consent for Magnox Limited to start decommissioning Wylfa power station within the next five years (Office for Nuclear Regulation, 2013). Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is conducted on behalf of Natural Resources Wales and the Welsh Government.

In October 2013, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Garrod *et al*., 2014). A decrease in the crustacean and mollusc consumption rates has been observed, together with an increase in the fish consumption rate, in comparison with those of the previous survey in 2009. The occupancy rate also increased in 2013. Revised figures for consumption rates, together with 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 less than 0.005 mSv in 2013 (Table 4.1), which was less than 0.5 per cent of the dose limit, and down from 0.006 mSv 2012. The most exposed person was a local adult who spends a large amount of time over sediments and was a change from that in 2012 (an adult consuming marine plants and algae). The decrease in *total dose* (from

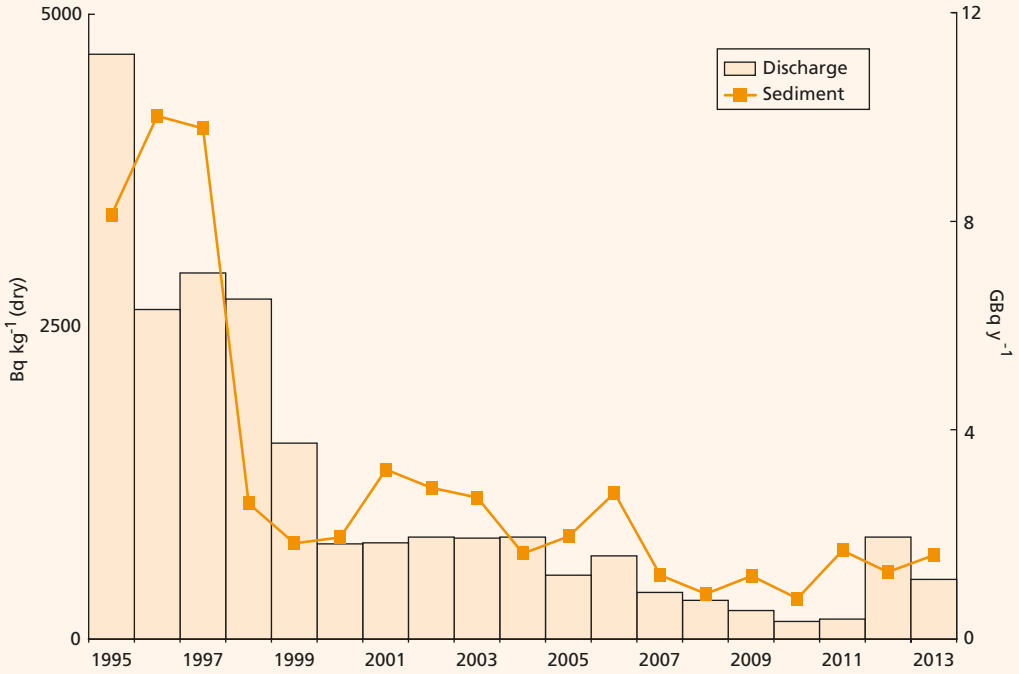


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2013

2012) was mostly due to a lower consumption rate of molluscs in 2013. The trend in *total dose* over the period 2004 – 2013 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for a high-rate consumer of both locally grown foods and of fish and shellfish give exposures that were more than the *total dose* in 2013 (Table 4.1). The dose to a consumer of locally grown foods was 0.010 mSv, which was 1 per cent of the dose limit for members of the public of 1 mSv. The dose in 2012 was less than 0.005 mSv, the increase was mostly due to higher carbon-14 concentrations in milk (~0.005 mSv), and to a lesser extent, sulphur-35 concentrations in milk (~0.001 mSv) in 2013. The dose to a high-rate consumer of fish and shellfish (including external radiation) was 0.007 mSv. The reason for the small decrease in dose in 2013 (from 0.009 mSv in 2012) is the same as that contributing to maximum *total dose*.

Gaseous discharges and terrestrial monitoring

Discharges of tritium, carbon-14 and particulate beta decreased by small amounts, in comparison to releases in 2012. 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 2013 are given in Table 4.13(a). Sulphur-35 was detected at very low concentrations in some of the food samples (including milk). Carbon-14 was detected in locally produced foods, with some elevated above those concentrations expected for background levels. Some carbon-14 and sulphur-35 concentrations in foodstuffs increased by a small amounts (including milk), in comparison to those in 2012. Overall the effects of discharges are low. Gross alpha and beta activities in surface water (public supply) were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium increased by a small amount in comparison to releases in 2012. 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 2013 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 2013 were similar to those in 2012, including technetium-99 derived from Sellafield. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Where comparisons can be made (from similar ground types and locations), gamma dose rates were generally similar in comparison to those in recent years.

Table 4.1. Individual doses – nuclear power stations, 2013

Site	Representative person[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**	**Adult occupant over sediment**	**0.010**	**<0.005**	**<0.005**	**0.010**	**–**	**–**
Source specific doses	Seafood consumer	0.012	<0.005	–	0.012	–	–
	Infant inhabitant and consumer of locally grown food	0.008	–	0.008	–	<0.005	–
Bradwell							
***Total dose* – all sources**	**Prenatal child of green vegetable consumers**	**<0.005**	**–**	**<0.005**	**–**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitant and consumer of locally grown food	0.005	–	0.005	–	<0.005	
Dungeness							
***Total dose* – all sources**	**Local adult inhabitant (0.5–1km)**	**0.021**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	0.007	<0.005	–	<0.005	–	–
	Houseboat occupant	0.017	–	–	0.017	–	–
	Infant inhabitant and consumer of locally grown food	0.009	–	0.008	–	<0.005	–
Hartlepool							
***Total dose* – all sources**	**Local adult inhabitant (0–0.25km)**	**0.024**	**–**	**–**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer[b]	0.007	<0.005	–	0.006	–	–
	Infant inhabitant and consumer of locally grown food	0.007	–	0.007	–	<0.005	–
	Sea coal collector	0.007	–	–	0.007	–	–
Heysham							
***Total dose* – all sources**	**Adult mollusc consumer**	**0.028**	**0.018**	**–**	**0.010**	**–**	**–**
Source specific doses	Seafood consumer	0.036	0.017	–	0.018	–	–
	Turf cutter	0.016	–	–	0.016	–	–
	Infant inhabitant and consumer of locally grown food	0.012	–	0.010	–	<0.005	–
Hinkley Point							
***Total dose* – all sources**	**Adult occupant over sediment**	**0.022**	**<0.005**	**<0.005**	**0.021**	**<0.005**	**<0.005**
Source specific doses	Seafood consumer	0.031	<0.005	–	0.031	–	–
	Infant inhabitant and consumer of locally grown food	0.015	–	0.015	–	<0.005	–
Sizewell							
***Total dose* – all sources**	**Local adult inhabitant (0–0.25km)**	**0.021**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupant	0.018	–	–	0.018	–	–
	Infant inhabitant and consumer of locally grown food	0.008	–	0.008	–	<0.005	–

Table 4.1. continued

Site	Representative person[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 consumer**	**0.024**	**<0.005**	**0.024**	**<0.005**	**–**	**–**
Source specific doses	Salmon and wildfowl consumer	<0.005	<0.005	<0.005	<0.005	–	–
	Crustacean consumer	<0.005	<0.005	–	–	–	–
	Infant inhabitant and consumer of locally grown food	0.018	–	0.017	–	<0.005	–
Hunterston							
***Total dose* – all sources**	**Prenatal child of local inhabitants (0.25–0.5km)**	**0.021**	**–**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitant and consumer of locally grown food	0.009	–	0.008	–	<0.005	–
Torness							
***Total dose* – all sources**	**Local adult inhabitant (0.5–1km)**	**0.020**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitant and consumer of locally grown food	0.006	–	0.006	–	<0.005	–
Wales							
Trawsfynydd							
***Total dose* – all sources**	**Infant local inhabitant (0.25–0.5km)**	**0.017**	**–**	**0.017**	**–**	**<0.005**	**–**
Source specific doses	Angler	0.013	<0.005	–	0.008	–	–
	Infant inhabitant and consumer of locally grown food	0.035	–	0.035	–	<0.005	–
Wylfa							
***Total dose* – all sources**	**Adult occupant over sediment**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**–**	**–**
Source specific doses	Seafood consumer	0.007	<0.005	–	<0.005	–	–
	Infant inhabitant and consumer of locally grown food	0.010	–	0.009	–	<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 people 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, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25			<0.10	0.20	
Mullet	River Severn	2	<32			<0.08	0.32	
Elvers	River Severn	1	<25			<0.06	<0.06	
Shrimps	Guscar	2	33	22		<0.04	0.25	0.00015
Seaweed	Pipeline	2[E]			1.2	<0.54	<0.63	
Sediment	Hills Flats	2[E]					15	
Sediment	1km south of Oldbury	2[E]				<0.98	23	
Sediment	2km south west of Berkeley	2[E]				<0.93	23	
Sediment	Sharpness	2[E]					13	
Seawater	Local beach	2[E]				<0.27	<0.21	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Salmon	Beachley	2		<0.16				
Mullet	River Severn	2		<0.07				
Elvers	River Severn	1		<0.05				
Shrimps	Guscar	2	0.00083	0.00067	*	*		
Seaweed	Pipeline	2[E]		<0.63				
Sediment	Hills Flats	2[E]		<0.71				
Sediment	1km south of Oldbury	2[E]		<1.2				
Sediment	2km south west of Berkeley	2[E]		<1.2				
Sediment	Sharpness	2[E]		<0.69				
Seawater	Local beach	2[E]		<0.27			<1.6	7.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		8	<2.1	24	<0.28	<0.08		
Milk	max		<2.4	28	<0.35	<0.09		
Apples		1	<2.6	18	<0.20	<0.05		
Beetroot		2	<2.2	16	<0.20	<0.08		
Beetroot	max			19		<0.09		
Blackberries		1	<2.3	19	0.20	<0.24		
Cabbage		1	<2.2	8.3	0.40	<0.08		
Honey		1	<3.6	74	<0.20	<0.10		
Runner beans		1	<2.1	21	1.2	<0.09		
Wheat		1	<3.3	95	0.60	<0.09		
Freshwater	Gloucester and Sharpness Canal	2[E]	<3.1		<0.16	<0.20	<0.049	0.21
Freshwater	Public supply	2[E]	<3.1		<0.41	<0.20	<0.047	<0.20

* *Not detected by the method used*

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

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

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

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

Table 4.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud and salt marsh	2	0.086
2 km south west of Oldbury	Mud and salt marsh	2	0.081
Guscar Rocks	Mud and salt marsh	1	0.085
Guscar Rocks	Salt marsh	1	0.090
Lydney Rocks	Mud and salt marsh	2	0.099
Sharpness	Mud and salt marsh	2	0.080
Hills Flats	Mud and salt marsh	2	0.082

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2013

Material	Location	No. of sampling observations	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			0.10		
Bass	Pipeline	1			0.40		
Thornback ray	Pipeline	1			0.25		
Lobsters	West Mersea	1			<0.07		
Native oysters	Tollesbury N. Channel	1			<0.09	0.00018	0.00094
Pacific oysters	Goldhanger Creek	2			<0.09		
Winkles	Pipeline	2			<0.20		
Winkles	Heybridge Basin	2			<0.14		
Seaweed	Waterside	2[E]		2.4	<0.48		
Leaf beet	Tollesbury	1			<0.04		
Samphire	Tollesbury	1			0.16		
Sediment	Pipeline	2[E]	<2.0		4.7		
Sediment	Waterside	2[E]	<2.0		6.3		
Sediment	West Mersea Beach Huts	2[E]	<2.0		1.0		
Sediment	West Mersea Boatyard	2[E]	<2.0		6.1		
Sediment	Maldon	2[E]	<2.0		19		
Sediment	N side Blackwater Estuary	2[E]	<2.0		9.1		
Seawater	Bradwell	2[E]			<0.24		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Sole	Bradwell	2	<0.11				
Bass	Pipeline	1	<0.16				
Thornback ray	Pipeline	1	<0.19				
Lobsters	West Mersea	1	<0.07				
Native oysters	Tollesbury N. Channel	1	0.0045	*	0.00012		
Pacific oysters	Goldhanger Creek	2	<0.15				
Winkles	Pipeline	2	<0.20				
Winkles	Heybridge Basin	2	<0.29				
Seaweed	Waterside	2[E]	<0.65				
Leaf beet	Tollesbury	1	<0.04				
Samphire	Tollesbury	1	<0.05				
Sediment	Pipeline	2[E]	<1.1				
Sediment	Waterside	2[E]	<1.2				
Sediment	West Mersea Beach Huts	2[E]	<0.47				
Sediment	West Mersea Boatyard	2[E]	<0.72				
Sediment	Maldon	2[E]	<1.2				
Sediment	N side Blackwater Estuary	2[E]	<1.3				
Seawater	Bradwell	2[E]	<0.26			<3.5	15

Table 4.3(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk			3	<2.3	21		<0.07		
Milk		max		<2.5	24				
Apples			1	<2.1	9.2		<0.07		
Blackberries			1	<2.2	14		<0.05		
Cabbage			1	<3.0	11		<0.07		
Carrots			1	<2.1	11		<0.16		
Lucerne			1	<3.7	32		<0.12		
Potatoes			1	<2.7	35		<0.06		
Rabbit			1	<2.9	35		<0.08		
Wheat			1	<4.0	87		<0.10		
Freshwater	Public supply, N side Estuary		1[E]	<3.7		<0.20	<0.22	<0.05	0.29
Freshwater	Public supply, S side Estuary		1[E]	<3.3		<0.16	<0.21	<0.050	0.25
Freshwater	Coastal ditch 1		1[E]	<4.3			<0.31	<0.90	3.4
Freshwater	Coastal ditch 2		1[E]	<4.2			<0.20	<0.60	3.0
Freshwater	Coastal ditch 3		1[E]	<6.4			<0.31	<0.60	11
Freshwater	Coastal ditch 4		1[E]	6.0			<0.24	<0.60	21

* *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, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Sand	1	0.084
Bradwell Beach	Shells and silt	1	0.090
Beach opposite power station, N side of estuary	Mud	1	0.075
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.078
Waterside	Mud	1	0.072
Waterside	Mud and salt marsh	1	0.074
Maldon	Mud	1	0.073
Maldon	Mud and salt marsh	1	0.066
West Mersea Beach Huts	Sand and mud	1	0.072
West Mersea Beach Huts	Pebbles and sand	1	0.074
West Mersea	Mud	1	0.069
West Mersea	Mud and shells	1	0.068

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Pipeline	2		<25		<0.04			0.14
Bass	Pipeline	1		<25		<0.08			0.28
Sole	Pipeline	2	<25	<25		<0.09			<0.11
Crabs	Eastbourne / Folkestone landed	1				<0.05			<0.05
Shrimps	Pipeline	2	<25	<25	33	<0.07			<0.07
Scallops	Pipeline	2				<0.07	0.043		<0.06
Sea kale	Dungeness Beach	1				<0.05			0.05
Seaweed	Folkestone	2[E]				<0.53		1.4	<0.41
Sediment	Rye Harbour 1	2[E]				<0.59			<0.66
Sediment	Camber Sands	2[E]				<0.27			<0.19
Sediment	Pilot Sands	2[E]				<0.30			<0.21
Seawater	Dungeness South	2[E]		<3.3		<0.28			<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	2			<0.04				
Bass	Pipeline	1			<0.22				
Sole	Pipeline	2			<0.20				
Crabs	Eastbourne / Folkestone landed	1			<0.12				
Shrimps	Pipeline	2			<0.17				
Scallops	Pipeline	2	0.00051	0.0026	0.0014	*	0.00011		
Sea kale	Dungeness Beach	1			<0.04				
Seaweed	Folkestone	2[E]			<0.56				
Sediment	Rye Harbour 1	2[E]	<0.75	<0.49	<0.93				590
Sediment	Camber Sands	2[E]			<0.36				
Sediment	Pilot Sands	2[E]			<0.34				
Seawater	Dungeness South	2[E]			<0.27			<3.3	16

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<2.6	26	<0.26	<0.05	<0.06		
Milk	max		<2.8	28	<0.28	<0.06			
Blackberries		1	<2.2	15	<0.60	<0.04	0.07		
Kale		1	<2.7	17	<1.1	<0.05	<0.04		
Potatoes		1	<2.5	16	<0.20	<0.10	<0.09		
Rape oil		1	<7.1	120	2.5	<0.14	<0.12		
Sea kale		1	<2.6	5.6	1.4	<0.05	0.08		
Wheat		1	<3.4	100	0.50	<0.12	<0.09		
Grass		1				<0.16	<0.19		
Freshwater	Long Pits	2[E]	<3.4		<0.28	<0.23	<0.20	<0.041	0.17
Freshwater	Pumping station Well number 1	1[E]	<3.4		<0.27	<0.24	<0.20	<0.047	0.18
Freshwater	Pumping station Well number 2	1[E]	<3.4		<0.20	<0.31	<0.24	<0.057	0.13
Freshwater	Reservoir	1[E]	<3.4		<0.26	<0.20	<0.18	<0.056	0.12

* *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, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Pebbles and sand	1	0.055
Littlestone-on-Sea	Sand and shingle	1	0.064
Greatstone-on-Sea	Sand and mud	1	0.059
Greatstone-on-Sea	Sand and shingle	1	0.072
Dungeness East	Mud and shingle	1	0.056
Dungeness East	Sand and shingle	1	0.060
Dungeness South	Sand and shingle	1	0.055
Dungeness South	Shingle	1	0.061
Jurys Gap	Sand	1	0.067
Jurys Gap	Sand and shingle	1	0.080
Rye Bay	Sand and mud	2	0.070

Table 4.5(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2013

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	^{137}Cs	^{210}Pb
Marine samples										
Plaice	Pipeline	2	<25	<25	22	<0.08		*	0.20	
Cod	Pipeline	2				<0.06		*	0.23	
Crabs	Pipeline	2			28	<0.06		*	<0.06	
Winkles	South Gare	2	30	<25		<0.16		*	<0.14	1.5
Mussels	South Gare	2				<0.08		*	<0.07	
Mussels	Seal Sands	1			44					
Seaweed	Pilot Station	2[E]				<0.57	3.4	8.5	<0.44	
Sediment	Old Town Basin	2[E]				<0.38			1.7	
Sediment	Seaton Carew	2[E]				<0.27			<0.22	
Sediment	Paddy's Hole	2[E]				<0.41			2.4	
Sediment	North Gare	2[E]				<0.21			<0.18	
Sediment	Greatham Creek	2[E]				<0.49			1.6	
Sea coal	Old Town Basin	2[E]				<0.43			<0.55	
Sea coal	Carr House Sands	2[E]				<0.54			1.7	
Seawater	North Gare	2[E]		<3.6		<0.27			<0.22	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Plaice	Pipeline	2				<0.12				
Cod	Pipeline	2				<0.17				
Crabs	Pipeline	2		0.00033	0.0020	0.0020	*	*		
Winkles	South Gare	2	20	0.0037	0.026	0.016	*	*		
Mussels	South Gare	2				<0.13				
Seaweed	Pilot Station	2[E]				<0.60				
Sediment	Old Town Basin	2[E]				<0.50				
Sediment	Seaton Carew	2[E]				<0.36				
Sediment	Paddy's Hole	2[E]				<0.63				
Sediment	North Gare	2[E]				<0.43				
Sediment	Greatham Creek	2[E]				<0.75				
Sea coal	Old Town Basin	2[E]				<0.56				
Sea coal	Carr House Sands	2[E]				<0.66				
Seawater	North Gare	2[E]				<0.30			<3.2	13

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		4	<2.2	23	<0.29	<0.07	<0.08		
Milk	max		<2.3	25	<0.35	<0.08	<0.09		
Apples		1	<2.6	11	<0.20	<0.04	<0.04		
Beetroot		1	<2.5	21	<0.10	<0.07	<0.06		
Blackberries		1	<2.2	11	<0.20	<0.08	<0.07		
Cabbage		1	<2.5	8.6	0.40	<0.06	<0.05		
Honey		1	<3.4	90	<0.10	<0.08	<0.08		
Potatoes		1	<2.2	21	0.30	<0.05	<0.06		
Runner beans		1	<2.2	12	<0.20	<0.09	<0.09		
Wheat		1	<3.6	120	2.0	<0.10	<0.09		
Freshwater	Public supply	2[E]	<3.1		<0.42	<0.22	<0.19	<0.085	0.17
Freshwater	Borehole, Dalton Piercy	2[E]	<3.1		<0.56	<0.27	<0.21	<0.13	0.17

* *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, 2013

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.070
Fish Sands	Pebbles and sand	1	0.069
Old Town Basin	Sand and mud	1	0.075
Old Town Basin	Sand and coal	1	0.072
Carr House	Sand and coal	1	0.067
Carr House	Coal	1	0.068
Seaton Carew	Sand	1	0.062
Seaton Carew	Pebbles and sand	1	0.063
Seaton Sands	Sand	1	0.064
Seaton Sands	Sand and pebbles	1	0.066
North Gare	Sand	2	0.061
Paddy's Hole	Stones and mud	1	0.17
Paddy's Hole	Pebbles and stones	1	0.18
Greatham Creek Bird Hide	Mud	1	0.087

Table 4.6(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2013

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	^{125}Sb	^{137}Cs	^{155}Eu
Marine samples											
Flounder	Flookburgh	3			58	<0.06			<0.19	10	<0.15
Flounder	Morecambe	4	<25	<27		<0.07	<0.024	0.25	<0.19	5.7	<0.17
Plaice	Flookburgh	1				<0.08			<0.22	5.3	<0.21
Whiting	Morecambe	4				<0.07			<0.19	4.9	<0.16
Bass	Morecambe	2				<0.09			<0.26	10	<0.22
Whitebait	Sunderland Point	1				<0.06	<0.046		<0.17	3.5	<0.19
Shrimps	Flookburgh	4			64	<0.11		0.78	<0.28	3.8	<0.23
Shrimps	Morecambe	2				<0.09			<0.19	4.7	<0.14
Cockles	Middleton Sands	2				0.24			<0.15	2.3	<0.12
Cockles[b]	Flookburgh	4			61	0.22		1.5	<0.17	3.2	<0.16
Winkles	Red Nab Point	4				<0.09			<0.18	3.4	<0.15
Mussels	Morecambe	4	53	49	73	<0.12		65	<0.25	2.1	<0.20
Wildfowl	Morecambe	1				<0.07			<0.16	0.48	<0.13
Samphire	Sunderland Point	1				<0.11			<0.26	0.41	<0.24
Seaweed	Half Moon Bay	2[E]				<0.92		160	<2.8	3.5	
Sediment	Half Moon Bay	2[E]				<0.60				110	
Sediment	Pott's Corner	2[E]				<0.43				17	
Sediment	Morecambe Central Pier	2[E]				<0.27				10	
Sediment	Red Nab Point	2[E]				<0.51				29	
Sediment	Sunderland Point	4[E]				<0.38			<1.4	67	<1.9
Sediment	Conder Green	4[E]				<0.44			<1.6	73	<0.81
Sediment	Sand Gate Marsh	4[E]				<0.41			<1.5	100	<0.80
Seawater	Half Moon Bay	1								0.04	
Seawater	Heysham Harbour	2[E]		15		<0.28				<0.24	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Flounder	Flookburgh	3	0.00024	0.0015		0.0038	*	*		
Flounder	Morecambe	4				<0.14				
Plaice	Flookburgh	1				<0.20				
Whiting	Morecambe	4				<0.13				
Bass	Morecambe	2				<0.16				
Whitebait	Sunderland Point	1	0.034	0.22	1.0	0.34	*	*		
Shrimps	Flookburgh	4	0.0037	0.023	0.18	0.042	*	*		
Shrimps	Morecambe	2				<0.09				
Cockles	Middleton Sands	2	0.52	3.1		8.2	*	0.014		
Cockles[b]	Flookburgh	4	0.31	1.9	9.4	5.2	*	0.0082		
Winkles	Red Nab Point	4	0.29	1.6		3.0	*	*		
Mussels	Morecambe	4	0.29	1.7		3.4	*	*		
Wildfowl	Morecambe	1				<0.07				
Samphire	Sunderland Point	1				<0.22				24
Seaweed	Half Moon Bay	2[E]				<0.85				
Sediment	Half Moon Bay	2[E]	10	65		130				
Sediment	Pott's Corner	2[E]				14				
Sediment	Morecambe Central Pier	2[E]				8.1				
Sediment	Red Nab Point	2[E]				38				
Sediment	Sunderland Point	4[E]				59			200	720
Sediment	Conder Green	4[E]				75			330	700
Sediment	Sand Gate Marsh	4[E]				78			230	670
Seawater	Heysham Harbour	2[E]				<0.29			<3.0	14

Table 4.6(a). continued

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	^{155}Eu	Gross alpha	Gross beta
Terrestrial samples											
Milk			6	<2.6	26	<0.30	<0.07	<0.09	<0.20		
Milk		max		<3.4	30	<0.35	<0.09	0.14	<0.23		
Apples			1	<2.5	15	<0.20	<0.04	<0.04	<0.13		
Barley			1	<5.6	98	1.0	<0.11	<0.12	<0.21		
Beetroot			1	<2.6	15	<0.20	<0.10	<0.09	<0.19		
Blackberries			1	<2.7	26	<0.20	<0.08	<0.06	<0.14		
Brussel sprouts			1	<2.6	23	1.1	<0.07	<0.07	<0.18		
Cabbage			1	<2.7	8.5	0.60	<0.05	<0.04	<0.26		
Honey			1	<7.4	110	<0.20	<0.08	<0.09	<0.42		
Potatoes			1	<2.5	24	<0.20	<0.08	<0.08	<0.17		
Freshwater	Lancaster		2[E]	<3.0		<0.34	<0.30	<0.25		<0.025	<0.035

* *Not detected by the method used*

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

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

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

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

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

Table 4.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2013

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass	2	0.082
Sand Gate Marsh	Grass	4	0.087
High Foulshaw	Grass and mud	1	0.078
High Foulshaw	Grass	3	0.081
Arnside 1	Mud	1	0.085
Arnside 1	Mud and sand	3	0.084
Arnside 2	Grass	4	0.095
Morecambe Central Pier	Sand	1	0.073
Morecambe Central Pier	Pebbles and sand	1	0.079
Half Moon Bay	Mud and sand	1	0.084
Half Moon Bay	Sand and stones	1	0.084
Red Nab Point	Sand	2	0.084
Middleton Sands	Sand	2	0.080
Sunderland	Salt marsh	3	0.092
Sunderland	Grass	1	0.091
Sunderland Point	Mud	2	0.10
Sunderland Point	Mud and sand	2	0.093
Colloway Marsh	Salt marsh	2	0.12
Colloway Marsh	Grass and salt marsh	1	0.13
Colloway Marsh	Grass	1	0.13
Lancaster	Grass	4	0.081
Aldcliffe Marsh	Grass	4	0.098
Conder Green	Mud	2	0.093
Conder Green	Mud and sand	1	0.091
Conder Green	Salt marsh	1	0.084

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2013

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	Stolford	1	30	27	26	<0.16			0.37
Grey mullet	Stolford	1	<25	<25	27	<0.04			0.41
Shrimps	Stolford	2	51	53	29	<0.06			0.16
Limpets	Stolford	1		31	23	<0.09			0.22
Porphyra	Stolford	2				<0.03			0.49
Seaweed	Pipeline	2[E]				<1.0		3.3	<0.72
Sediment	Watchet Harbour	2[E]				<0.47	<2.1		3.9
Sediment	Pipeline	2[E]				<0.45	<2.0		12
Sediment	Stolford	2[E]				<0.79	<2.0		22
Sediment	Steart Flats	2[E]				<0.51	<2.0		13
Sediment	River Parrett	2[E]				<1.4	<2.0		24
Sediment	Weston-Super-Mare	2[E]				<0.38	<2.0		3.0
Sediment	Burnham-On-Sea	2[E]				<0.34	<2.0		2.9
Sediment	Kilve	2[E]				<0.34	<2.0		1.3
Sediment	Blue Anchor Bay	2[E]				<0.33	<2.0		1.3
Seawater	Pipeline	2[E]				<0.31	<0.050		<0.26

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	Stolford	1			<0.11				
Grey mullet	Stolford	1			<0.05				
Shrimps	Stolford	2	0.00014	0.00091	0.0012	*	0.0000065		
Limpets	Stolford	1			<0.07				
Porphyra	Stolford	2			<0.09				
Seaweed	Pipeline	2[E]			<0.74				
Sediment	Watchet Harbour	2[E]			<0.61				
Sediment	Pipeline	2[E]			<0.65				
Sediment	Stolford	2[E]			<1.2				
Sediment	Steart Flats	2[E]			<0.71				
Sediment	River Parrett	2[E]			<1.7				
Sediment	Weston-Super-Mare	2[E]			<0.50				
Sediment	Burnham-On-Sea	2[E]			<0.42				
Sediment	Kilve	2[E]			<0.48				
Sediment	Blue Anchor Bay	2[E]			<0.44				
Seawater	Pipeline	2[E]			<0.30			<1.9	8.5

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	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<2.7	31	<0.27	<0.06	<0.07		
Milk	max		<4.7	37	<0.30	<0.08	<0.08		
Apples		1	<2.0	46	<0.20	<0.05	<0.05		
Blackberries		1	<4.0	15	<0.60	<0.05	<0.04		
Carrots		1	<2.5	13	<0.20	<0.10	<0.08		
Honey		1	<4.1	120	<0.20	<0.07	<0.08		
Lettuce		1	<2.7	9.5	0.20	<0.27	<0.28		
Potatoes		1	<2.4	22	0.30	<0.09	<0.09		
Spinach/Chard		1	<2.8	13	<0.40	<0.06	<0.05		
Wheat		1	<3.4	95	0.80	<0.11	<0.12		
Freshwater	Durleigh Reservoir	2[E]	<3.1		<0.22	<0.21	<0.19	<0.044	0.19
Freshwater	Ashford Reservoir	2[E]	<3.1		<0.17	<0.23	<0.20	<0.040	<0.10

* *Not detected by the method used*

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

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

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

[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, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Sand and mud	4	0.070
Burnham	Sand and mud	4	0.067
River Parrett	Mud	1	0.070
River Parrett	Mud and salt marsh	2	0.075
Steart Flats	Mud	2	0.077
Steart Flats	Mud and shingle	2	0.080
Stolford	Mud and rock	4	0.096
Hinkley Point	Mud and stones	1	0.089
Hinkley Point	Rock and mud	3	0.089
Kilve	Rock and mud	2	0.091
Kilve	Rock and stones	2	0.091
Watchet Harbour	Rock and mud	4	0.096
Blue Anchor Bay	Sand and mud	2	0.072
Blue Anchor Bay	Sand and shingle	1	0.076
Blue Anchor Bay	Pebbles and sand	1	0.068

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2013

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu
Marine samples							
Cod	Sizewell	2	<25		0.24		
Skates/rays	Sizewell	2	<25		0.34		
Crabs	Sizewell	2		28	0.11	0.000056	0.00041
Lobsters	Sizewell	1			0.22	0.000099	0.00068
Pacific oysters	Butley Creek	1			<0.06		
Pacific oysters	Blyth Estuary	1			0.04		
Mussels	River Alde	2	<25		<0.05		
Sediment	Rifle range	2[E]			<0.21		
Sediment	Aldeburgh	2[E]			<0.33		
Sediment	Southwold	2[E]			7.0		
Seawater	Sizewell	2[E]	<6.4		<0.27		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Cod	Sizewell	2	<0.08				
Skates/rays	Sizewell	2	<0.10				
Crabs	Sizewell	2	0.00061	*	0.000034		
Lobsters	Sizewell	1	0.0011	*	0.000026		
Pacific oysters	Butley Creek	1	<0.05				
Pacific oysters	Blyth Estuary	1	<0.03				
Mussels	River Alde	2	<0.05				
Sediment	Rifle range	2[E]	<0.28				
Sediment	Aldeburgh	2[E]	<0.57				
Sediment	Southwold	2[E]	<0.78				890
Seawater	Sizewell	2[E]	<0.28			<4.2	13

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		4	<2.6	22	<0.28	<0.08		
Milk	max		<2.9	28	<0.32	<0.11		
Apples		1	<2.4	20	<0.20	<0.04		
Blackberries		1	<2.0	15	<0.20	<0.03		
Cabbage		1	<2.3	6.4	<0.30	<0.05		
Honey		1	<8.2	69	<0.10	<0.17		
Onions		1	<2.5	16	0.30	<0.04		
Potatoes		1	<2.6	19	<0.20	0.07		
Runner beans		1	<2.0	13	<0.20	<0.04		
Wheat		1	<7.3	120	0.80	<0.10		
Freshwater	Nature Reserve	2[E]	<3.2		<0.25	<0.24	<0.049	0.20
Freshwater	The Meare	2[E]	<3.2		<0.27	<0.22	<0.064	0.30
Freshwater	Leisure Park	2[E]	<3.6		<0.32	<0.25	<0.051	0.32

* *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, 2013

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	2	0.059
Dunwich	Shingle and mud	1	0.060
Dunwich	Pebbles	1	0.056
Rifle Range	Sand	1	0.056
Rifle Range	Sand and shingle	1	0.063
Aldeburgh	Shingle and mud	1	0.058
Aldeburgh	Sand and shingle	1	0.058
Southwold Harbour	Mud	1	0.077
Southwold Harbour	Mud and salt marsh	1	0.076

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2013

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	^{99}Tc	^{106}Ru	^{125}Sb	^{137}Cs
Marine samples											
Flounder	Inner Solway	2		46	<0.10	<0.10	<0.50	0.23	<0.86	<0.24	9.1
Salmon	Inner Solway	1	<5.0		<0.10		<0.19		<0.60	<0.17	0.26
Sea trout	Inner Solway	1	<5.0		<0.10		<0.43		<0.94	<0.26	2.5
Shrimps	Inner Solway	2	<5.0		<0.10	<0.10	<0.18	0.66	<0.59	<0.17	2.5
Cockles	North Solway	1			0.25		<0.23		<0.74	<0.24	4.7
Mussels	North Solway	4	<5.0	25	<0.10	0.54	<0.15	7.2	<0.51	<0.16	1.9
Winkles	Southerness	4	<5.0		<0.11	0.20	<0.23	20	<0.74	<0.23	0.80
Fucus vesiculosus	Pipeline	4			<0.12	5.1	<0.22	60	<0.51	<0.17	4.2
Fucus vesiculosus	Browhouses	4			<0.12		<0.13		<0.47	<0.16	9.1
Sediment	Pipeline	4	<5.0		0.64		<0.26		<0.92	<0.47	151
Sediment	Powfoot	1			<0.10		<0.17		<0.74	<0.26	36
Sediment	Redkirk	1			<0.10		<0.17		<0.70	<0.24	30
Sediment	Southerness	1			<0.10		<0.18		<0.63	<0.21	17
Seawater	Pipeline	4	<2.0		<0.10		<0.14		<0.51	<0.16	<0.10
Seawater	Southerness	4	<2.3		<0.10		<0.16		<0.45	<0.14	<0.12

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}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples										
Flounder	Inner Solway	2	<0.12	<0.19	0.0013	0.0069		0.016		
Salmon	Inner Solway	1	<0.10	<0.15				<0.10		
Sea trout	Inner Solway	1	<0.14	<0.25				<0.13		
Shrimps	Inner Solway	2	<0.11	<0.16	0.0024	0.014		0.024		
Cockles	North Solway	1	<0.14	<0.22	0.43	2.6		6.9		
Mussels	North Solway	4	<0.11	<0.15	0.43	2.5	12	5.6		
Winkles	Southerness	4	<0.13	<0.20	0.21	1.1	5.1	2.0		
Fucus vesiculosus	Pipeline	4	<0.11	<0.25	0.43	2.5		3.1	6.3	390
Fucus vesiculosus	Browhouses	4	<0.10	<0.24				11	13	390
Sediment	Pipeline	4	<0.42	<1.2	19	111		210		
Sediment	Powfoot	1	<0.20	<0.40	2.4	16		27		
Sediment	Redkirk	1	<0.18	<0.28	1.6	11		14		
Sediment	Southerness	1	<0.16	<0.28				20		
Seawater	Pipeline	4	<0.10	<0.13				<0.10		
Seawater	Southerness	4	<0.10	<0.14	0.00019	0.0015		0.00084		

Table 4.9(a). continued

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{3}H	^{14}C	^{35}S	^{90}Sr	^{95}Zr	^{134}Cs
Terrestrial samples									
Milk			12	<6.2	<15	<0.50	<0.10	<0.14	<0.05
Milk		max		<11	16	<0.54		<0.24	<0.06
Apples			2	<6.0	17	<0.75	<0.13	<0.06	<0.05
Apples		max		7.0	18	<1.0	0.17		
Beetroot			1	<5.0	<15	<0.50	0.20	<0.14	<0.05
Cabbage			1	<5.0	15	<0.50	0.15	<0.07	<0.05
Carrots			1	<5.0	<15	<0.50	<0.10	<0.13	<0.05
Cauliflower			1		<15	<0.50	<0.10	<0.11	<0.05
Duck			2	<5.0	28	<1.0	<0.10	<0.24	<0.08
Duck		max			32	<1.3		<0.35	<0.09
Goose			4	<5.0	26	<0.96	<0.10	<0.23	<0.08
Goose		max			28	<1.1		<0.38	<0.11
Leeks			1	<5.0	<15	<0.50	<0.10	<0.05	<0.05
Onions			1	<5.0	<15	<0.50	<0.10	<0.12	<0.05
Pheasant			2	<5.0	29	<0.64	<0.10	<0.21	<0.07
Pheasant		max			33	<0.76		<0.23	
Potatoes			1	<5.0	17	<0.50	<0.10	<0.10	<0.05
Rosehips			1		36	<0.50	0.41	<0.09	<0.05
Wild blackberries			1	5.2	20	<0.50	0.62	<0.05	<0.05
Grass			4	<8.3	25	<0.62	0.36	<0.19	<0.05
Grass		max		11	37	<0.97	0.42	<0.34	<0.07
Soil			4	<9.2	<18	<2.5	1.1	<0.19	<0.06
Soil		max		22	23	<2.9	2.0	<0.27	
Freshwater	Purdomstone		1	1.9				<0.02	<0.01
Freshwater	Winterhope		1	1.4				<0.03	<0.01
Freshwater	Black Esk		1	1.0				<0.02	<0.01
Freshwater	Gullielands Burn		1	32				<0.03	<0.01

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
				^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples								
Milk			12	<0.05		<0.05		
Milk		max		<0.06		<0.08		
Apples			2	<0.05		<0.06		
Apples		max				<0.07		
Beetroot			1	0.10		<0.06		
Cabbage			1	<0.05		<0.08		
Carrots			1	<0.05		<0.07		
Cauliflower			1	<0.05		<0.06		
Duck			2	0.61		<0.11		
Duck		max		0.99		<0.12		
Goose			4	0.43		<0.11		
Goose		max		1.3		<0.15		
Leeks			1	<0.05		<0.06		
Onions			1	<0.05		<0.06		
Pheasant			2	0.18		<0.10		
Pheasant		max		0.23		<0.11		
Potatoes			1	<0.05		<0.08		
Rosehips			1	0.08		<0.09		
Wild blackberries			1	<0.05		<0.05		
Grass			4	<0.08		<0.10	<0.73	430
Grass		max		0.14		<0.14	1.2	530
Soil			4	7.6	1.4	<0.42	160	1800
Soil		max		12	1.6	0.81	170	2300
Freshwater	Purdomstone		1	<0.01		<0.01	0.022	0.090
Freshwater	Winterhope		1	<0.01		<0.01	0.015	0.079
Freshwater	Black Esk		1	<0.01		<0.01	<0.011	0.042
Freshwater	Gullielands Burn		1	<0.01		<0.01	<0.017	0.24

[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, 2013

Location	Material or Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.060
Glencaple Harbour	Mud and sand	4	0.078
Priestside Bank	Salt marsh	4	0.066
Powfoot Merse	Mud	4	0.068
Pipeline	Sand	4	0.087
Pipeline	Salt marsh	4	0.084
Dumbretton	NA	1	0.067
Battlehill	Sand	4	0.076
Dornoch Brow	Mud and sand	4	0.075
Dornoch Brow	Salt marsh	4	0.077
Browhouses	NA	4	0.072
Redkirk	NA	4	0.065
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, 2013

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	12	<0.010	<0.014	<0.20
Kirtlebridge	10	<0.010	<0.011	<0.20
Brydekirk	9	<0.010	<0.015	<0.20

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag
Marine samples									
Cod	Millport	2			<0.10	<0.10	<0.14		<0.10
Hake	Millport	2			<0.10	<0.10	<0.16		<0.10
Crabs	Millport	2			<0.10	<0.10	<0.20	1.1	<0.10
Nephrops	Millport	2			<0.11	<0.10	<0.24		<0.11
Lobsters	Largs	1			<0.10	<0.10	<0.11	17	<0.10
Squat lobsters	Largs	4			<0.10	<0.10	<0.21	25	<0.11
Mussels	Hunterston	1			<0.10	<0.10	<0.11		<0.10
Winkles	Pipeline	2			<0.15	0.32	<0.21		1.2
Scallops	Largs	4			<0.10	<0.10	<0.22		<0.10
Oysters	Hunterston	1			<0.10	<0.10	<0.20		0.27
Fucus vesiculosus	N of pipeline	2			<0.10	<0.10	<0.15		<0.10
Fucus vesiculosus	S of pipeline	2			<0.31	<0.25	<0.15		<0.13
Sediment	Millport	1			<0.10	<0.10	<0.13		<0.10
Sediment	Gull's Walk	1			<0.10	<0.10	<0.16		<0.10
Sediment	Ardneil Bay	1			<0.10	<0.10	<0.25		<0.11
Sediment	Fairlie	1			<0.10	<0.10	<0.13		<0.10
Sediment	Pipeline	1			<0.10	<0.10	<0.15		<0.10
Seawater	Pipeline	2	5.9	<0.50	<0.11	<0.10	<0.21		<0.11
Seawater	S of pipeline	2	2.7	<0.65	<0.10	<0.10	<0.22		<0.11

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine samples									
Cod	Millport	2	<0.11	<1.1	<0.10	<0.12			<0.11
Hake	Millport	2	<0.12	<1.3	<0.10	<0.13			<0.13
Crabs	Millport	2	<0.18	<0.24	<0.11	<0.17	0.00072	0.0045	0.018
Nephrops	Millport	2	<0.22	<0.43	<0.11	<0.18			<0.12
Lobsters	Largs	1	<0.10	0.37	<0.10	<0.11			0.28
Squat lobsters	Largs	4	<0.21	0.52	<0.11	<0.17	0.0038	0.019	0.047
Mussels	Hunterston	1	<0.12	0.28	<0.10	<0.10			0.16
Winkles	Pipeline	2	<0.20	0.26	<0.11	<0.14	0.022	0.091	0.040
Scallops	Largs	4	<0.21	0.18	<0.12	<0.20	0.0046	0.031	0.0073
Oysters	Hunterston	1	<0.20	0.11	<0.10	<0.17			<0.11
Fucus vesiculosus	N of pipeline	2	<0.13	0.37	<0.10	<0.13			<0.10
Fucus vesiculosus	S of pipeline	2	<0.14	5.7	<0.11	<0.13			<1.2
Sediment	Millport	1	<0.12	3.3	<0.10	<0.17			<0.16
Sediment	Gull's Walk	1	<0.14	4.2	<0.10	<0.13			0.50
Sediment	Ardneil Bay	1	<0.24	2.1	<0.18	<0.35			<0.33
Sediment	Fairlie	1	<0.12	2.3	<0.10	<0.17			<0.16
Sediment	Pipeline	1	<0.14	4.0	<0.11	<0.23			<0.22
Seawater	Pipeline	2	<0.24	<0.10	<0.13	<0.21			<0.12
Seawater	S of pipeline	2	<0.22	<0.10	<0.10	<0.17			<0.11

Table 4.10(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{110m}Ag
Terrestrial Samples								
Milk		5	<5.0	<15	<0.53	<0.05	<0.10	<0.05
Milk	max			17	<0.68	<0.05		<0.06
Apples		1	<5.0	24	<0.50	<0.05	0.19	<0.05
Beef muscle		1	<5.0	43	<0.68	<0.05	<0.10	<0.05
Cabbage		1	<5.0	<15	<0.50	<0.05	0.11	<0.05
Carrots		1	<5.0	<15	<0.50	<0.05	0.24	<0.05
Eggs		1	<5.0	30		<0.05	<0.10	<0.05
Honey		1	<5.0	97	<1.3	<0.05	<0.10	<0.05
Leeks		1	<5.0	<15	<0.50	<0.05	0.23	<0.05
Pheasant		3	<5.0	<19	<1.9	<0.05	0.22	<0.06
Pheasant	max			<20	<2.1		0.41	<0.07
Potatoes		1	<5.0	<22	<0.50	<0.05	<0.10	<0.05
Rabbit		2	<5.0	19	<1.1	<0.07	<0.16	<0.10
Rabbit	max			21	<1.4	<0.09	0.21	<0.12
Rosehips		1	<5.0	<28	<0.50	<0.05	0.89	<0.05
Rowan berries		1	<5.0	31	<0.50	<0.05	0.13	<0.05
Wild blackberries		1	<5.0	<15	<0.50	<0.05	0.19	<0.05
Grass		3	<5.0	<24	<0.51	<0.05	0.27	<0.05
Grass	max			30	<0.54		0.35	
Soil		3	<5.0	<15	<4.3	<0.05	0.74	<0.07
Soil	max				<6.2		1.2	<0.08
Freshwater	Knockenden	1	<1.0			<0.01		<0.01
Freshwater	Loch Ascog	1	<1.0			<0.01		<0.01
Freshwater	Munnoch Reservoir	1	<1.0			<0.01		<0.01
Freshwater	Camphill	1	<1.0			<0.01		<0.01
Freshwater[d]	Outerwards	1	<1.0			<0.01		<0.01

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples							
Milk		5	<0.06		<0.05		
Milk	max		<0.07		<0.06		
Apples		1	<0.05		<0.07		
Beef muscle		1	0.08		<0.08		
Cabbage		1	<0.05		<0.05		
Carrots		1	0.08		<0.06		
Eggs		1	<0.05		<0.09		
Honey		1	0.28		<0.07		
Leeks		1	<0.05		<0.07		
Pheasant		3	0.26		<0.08		
Pheasant	max		0.36		<0.09		
Potatoes		1	0.08		<0.07		
Rabbit		2	0.32		<0.11		
Rabbit	max		0.39		<0.13		
Rosehips		1	0.10		<0.07		
Rowan berries		1	<0.05		<0.09		
Wild blackberries		1	<0.05		<0.08		
Grass		3	0.12		<0.10	<0.64	420
Grass	max		0.17		<0.11	<0.76	470
Soil		3	8.7	0.57	<0.18	120	1100
Soil	max		9.7	0.71	<0.21	140	1400
Freshwater	Knockenden	1	<0.01		<0.01	<0.010	0.036
Freshwater	Loch Ascog	1	<0.01		<0.01	<0.010	0.086
Freshwater	Munnoch Reservoir	1	<0.01		<0.01	<0.010	0.037
Freshwater	Camphill	1	<0.01		<0.01	<0.010	0.023
Freshwater[d]	Outerwards	1	<0.01			<0.010	0.061

[a] *Except for milk, seawater and freshwater 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 ^{54}Mn was <0.09 Bq l^{-1}*

Table 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	Stones	2	0.065
Kilchatten Bay	Sand	2	<0.049
Millport	Sand	2	<0.047
Gull's Walk	Mud	2	0.062
0.5 km north of pipeline	Sand	2	0.052
0.5 km south of pipeline	Sand and stones	2	0.063
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	0.047
Milstonford	NA	2	0.055
Biglies	NA	2	0.059
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, 2013

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	10	<0.011	<0.019	<0.21
West Kilbride	12	<0.010	0.012	<0.20
Low Ballees	10	<0.012	<0.030	<0.26

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2013

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{137}Cs
Marine samples								
Cod	White Sands	2	<0.10	<0.10	<0.12		<0.10	0.21
Bass	Pipeline	1	<0.10	<0.10	<0.27		<0.12	0.49
Crabs[d]	Torness	1	<0.10	<0.10	<0.10	0.64	<0.10	<0.10
Lobsters	Torness	1	<0.10	<0.10	<0.11	15	<0.10	<0.10
Nephrops	Dunbar	2	<0.10	<0.10	<0.19		<0.10	0.14
Winkles	Pipeline	2	<0.15	<0.28	<0.32		4.7	<0.15
Fucus vesiculosus	Pipeline	2	0.66	0.88	<0.20		<0.50	<0.14
Fucus vesiculosus	Thornton Loch	2	<0.20	<0.10	<0.18	10	<0.10	<0.67
Fucus vesiculosus	White Sands	2	<0.10	<0.10	<0.19		<0.10	<0.11
Fucus vesiculosus	Pease Bay	2	<0.10	<0.10	<0.18		<0.10	<0.10
Fucus vesiculosus	Coldingham Bay	2	<0.10	<0.10	<0.12		<0.10	<0.11
Sediment	Dunbar	1	<0.10	<0.10	<0.23		<0.10	1.5
Sediment	Barns Ness	1	<0.10	<0.10	<0.22		<0.10	1.7
Sediment	Thornton Loch	1	<0.10	<0.10	<0.16		<0.10	0.77
Sediment	Heckies Hole	1	<0.10	<0.10	<0.20		<0.10	2.9
Sediment	Belhaven Bay	1	<0.10	<0.10	<0.18		<0.10	0.72
Salt marsh	Coldingham Bay	1	<0.10	<0.10	<0.21		<0.10	0.94
Seawater[e]	Pipeline	2	<0.10	<0.10	<0.15		<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	<0.11			<0.11		
Bass	Pipeline	1	<0.23			<0.13		
Crabs[d]	Torness	1	<0.10			<0.10		
Lobsters	Torness	1	<0.12			<0.10		
Nephrops	Dunbar	2	<0.16	0.00066	0.0060	0.0071		
Winkles	Pipeline	2	<0.20			<0.13	<2.2	130
Fucus vesiculosus	Pipeline	2	<0.19			<0.12		
Fucus vesiculosus	Thornton Loch	2	<0.15			<0.11		
Fucus vesiculosus	White Sands	2	<0.13			<0.10		
Fucus vesiculosus	Pease Bay	2	<0.14			<0.10		
Fucus vesiculosus	Coldingham Bay	2	<0.11			<0.10		
Sediment	Dunbar	1	0.58			<0.24		
Sediment	Barns Ness	1	1.2			<0.26		
Sediment	Thornton Loch	1	<0.19			<0.17		
Sediment	Heckies Hole	1	<0.29			<0.31		
Sediment	Belhaven Bay	1	<0.20			<0.20		
Salt marsh	Coldingham Bay	1	0.62			0.21		
Seawater[e]	Pipeline	2	<0.13			<0.10		

Table 4.11(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	^{90}Sr	^{95}Nb	^{110m}Ag
Terrestrial Samples								
Milk		1	<5.0	<15	<0.58	<0.10	<0.12	<0.05
Apples		1	<5.0	16	<0.50	<0.10	<0.05	<0.05
Beetroot		1	<5.0	<15	<0.50	0.16	<0.05	<0.05
Broccoli		1	<5.0	<15	<0.50	<0.10	<0.08	<0.06
Cabbage		1	<5.0	<15	<0.50	0.13	<0.05	<0.05
Carrots		1	<5.0	<15	<0.50	<0.10	<0.07	<0.05
Partridge		1	<5.0	39		<0.10	<0.06	<0.05
Potatoes		1	<5.0	19	<0.50	<0.10	<0.14	<0.05
Rabbit		1	<5.0	34	<0.60	<0.10	<0.07	<0.05
Rhubarb		1	<5.0	<15	<0.50	0.15	<0.05	<0.05
Rosehips		1	<5.0	28	<0.50	0.51	<0.07	<0.05
Rowan berries		1	<5.0	30	<0.50	0.28	<0.05	<0.05
Squash		1	<5.0	<15	<0.50	0.18	<0.05	<0.05
Turnips		1	<5.0	<15	<0.50	0.25	<0.10	<0.10
Venison		1	<5.0	32	<0.66	<0.10	<0.11	<0.06
Wild Blackberries		1	<5.0	16	<0.50	0.16	<0.09	<0.05
Wood Pigeon		1	<5.0	35	<0.71	0.22	<0.09	<0.05
Grass		3	<5.0	34	<0.50	0.31	<0.16	<0.05
Grass	max			50		0.47	<0.23	
Soil		3	<5.0	<15	<4.2	0.51	<0.10	<0.07
Soil	max				<5.1	0.52	<0.15	
Freshwater	Hopes Reservoir	1	<1.0				<0.01	<0.01
Freshwater	Thorter's Reservoir	1	<1.0				<0.01	<0.01
Freshwater	Whiteadder	1	<1.0				<0.01	<0.01
Freshwater	Thornton Loch Burn	1	<1.0				<0.01	<0.01

Material	Location or Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples							
Milk		1	<0.05		<0.05		
Apples		1	<0.05		<0.05		
Beetroot		1	<0.05		<0.05		
Broccoli		1	<0.06		<0.09		
Cabbage		1	<0.05		<0.07		
Carrots		1	<0.05		<0.05		
Partridge		1	0.12		<0.09		
Potatoes		1	0.15		<0.08		
Rabbit		1	<0.05		<0.12		
Rhubarb		1	<0.05		<0.05		
Rosehips		1	<0.05		<0.11		
Rowan berries		1	<0.05		<0.06		
Squash		1	<0.05		<0.05		
Turnips		1	<0.10	<0.10	<0.10		
Venison		1	2.9		<0.10		
Wild Blackberries		1	<0.05		<0.77		
Wood Pigeon		1	0.07		<0.09		
Grass		3	<0.05		<0.10	<1.0	420
Grass	max				<0.13	1.2	500
Soil		3	3.3	1.0	<0.20	170	1400
Soil	max		3.6	1.3	<0.22	190	1200
Freshwater	Hopes Reservoir	1	<0.01		<0.01	0.013	0.035
Freshwater	Thorter's Reservoir	1	<0.01		<0.01	0.022	0.067
Freshwater	Whiteadder	1	<0.01		<0.01	0.012	0.056
Freshwater	Thornton Loch Burn	1	<0.01		<0.01	<0.013	0.10

[a] *Except for milk and seawater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The concentration of ^{14}C was 36 Bq kg^{-1}*
[e] *The concentrations of ^{3}H and ^{35}S were <15 and <0.85 Bq l^{-1} respectively*

Table 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2013

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Sediment	2	0.059
Dunbar Inner Harbour	Sand	2	0.082
Belhaven Bay	Salt marsh	2	<0.047
Barns Ness	Mud, sand and stones	2	0.053
Skateraw	Sand	2	<0.049
Thornton Loch	Sand	2	0.055
Pease Bay	Sand	2	0.058
St Abbs Head	Mud	2	0.089
Coldingham Bay	Sand	2	<0.047
West Meikle Pinkerton	Sediment	2	0.066
Mean beta dose rates on fishing gear			µSv h^{-1}
Torness	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2013

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	10	<0.011	0.016	<0.20
Cockburnspath	9	<0.010	0.016	<0.20

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2013

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	4			<0.29	0.62	<0.31	41	<0.91
Rainbow trout	Trawsfynydd Lake	6			<0.09		<0.09	2.6	<0.30
Pike	Trawsfynydd Lake	1			<0.07		<0.09	64	<0.21
Sediment	Lake shore	2[E]			<0.52	<2.0	<0.52	490	
Sediment	Bailey Bridge	2[E]			<2.5	20	<2.4	280	
Sediment	Fish farm	1[E]			7.2	13	<0.84	2200	4.8
Sediment	Footbridge	2[E]			<0.76	<2.0	<0.69	260	
Sediment	Cae Adda	2[E]			<0.41	<2.0	<0.36	130	
Freshwater	Public supply	2[E]	<3.2	<0.29	<0.27		<0.27	<0.23	
Freshwater	Gwylan Stream	2[E]	<3.2	<0.38	<0.23		<0.24	<0.20	
Freshwater	Hot Lagoon	2[E]	<3.2	<0.27	<0.23		<0.24	<0.20	
Freshwater	Afon Prysor	2[E]	<3.3	<0.23	<0.22		<0.23	<0.19	
Freshwater	Trawsfynydd Lake	2[E]	<3.3	<0.38	<0.31		<0.33	<0.25	
Freshwater	Afon Tafarn-helyg	2[E]	<3.2	<0.54	<0.26		<0.28	<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	4	0.00013	0.00076	0.0014	*	*		
Rainbow trout	Trawsfynydd Lake	6			<0.18				
Pike	Trawsfynydd Lake	1			<0.26				
Sediment	Lake shore	2[E]	<0.59	0.83	2.2				
Sediment	Bailey Bridge	2[E]	<1.0	2.9	7.8				
Sediment	Fish farm	1[E]	19	46	91				
Sediment	Footbridge	2[E]	<0.68	<0.82	2.1				
Sediment	Cae Adda	2[E]	<0.63	<0.56	1.3				
Freshwater	Public supply	2[E]						<0.023	<0.024
Freshwater	Gwylan Stream	2[E]						<0.017	0.14
Freshwater	Hot Lagoon	2[E]						<0.026	0.074
Freshwater	Afon Prysor	2[E]						<0.018	<0.056
Freshwater	Trawsfynydd Lake	2[E]						<0.019	<0.074
Freshwater	Afon Tafarn-helyg	2[E]						<0.025	<0.064

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Total ^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Terrestrial Samples										
Milk		2	<2.0	24	<0.05	<0.025	<0.06			<0.16
Milk	max		<2.1	26	<0.06	<0.030	<0.07			<0.22
Apples		1	<2.4	10	<0.08		<0.07			<0.13
Blackberries		1	<2.0	25	<0.05		0.10	<0.000040	<0.000066	0.00016
Eggs		1	<3.1	33	<0.22		<0.31	<0.000045	0.000039	0.00028
Potatoes		1	<3.1	37	<0.05		0.07	<0.00018	0.00045	0.00023
Runner beans		1	<2.4	6.4	<0.07		<0.07	<0.000062	<0.000048	<0.000082
Sheep muscle		2	<2.6	46	<0.07	<0.044	0.57	<0.000086	0.000074	0.00010
Sheep muscle	max		<2.8	55		<0.046	0.63	<0.000093	0.000087	0.00012
Sheep offal		2	<4.9	36	<0.08	<0.046	0.53	<0.000070	0.00085	<0.000061
Sheep offal	max		<6.9	42		<0.047	0.60	<0.000098	0.00011	<0.000078

* *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 29 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, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Grass and stones	1	0.11
Footbridge	Pebbles and stones	1	0.11
Lake shore	Pebbles and stones	2	0.10
Bailey Bridge	Grass	1	0.071
Bailey Bridge	Pebbles and stones	1	0.095
Fish Farm	Pebbles and stones	2	0.10
Cae Adda	Pebbles and stones	2	0.092

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2013

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	<26	32		0.70		
Bass	Outfall	1					3.6		
Crabs	Pipeline	2				0.17	0.26	0.0027	0.014
Lobsters	Pipeline	2				16	0.24		
Winkles	Cemaes Bay	2	<26	<30	32		0.58	0.033	0.23
Seaweed	Cemaes Bay	2[E]				22	<0.55		
Sediment	Cemaes Bay	2[E]					4.5		
Sediment	Cemlyn Bay West	2[E]					2.2		
Seawater	Cemaes Bay	2[E]		<3.2			<0.19		
Seawater	Cemlyn Bay West	2[E]					<0.22		

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		<0.19				
Crabs	Pipeline	2		0.058	*	*		
Lobsters	Pipeline	2		<0.18				121
Winkles	Cemaes Bay	2	1.2	0.33	*	*		
Seaweed	Cemaes Bay	2[E]		<0.60				
Sediment	Cemaes Bay	2[E]		<1.1				
Sediment	Cemlyn Bay West	2[E]		<0.70				
Seawater	Cemaes Bay	2[E]		<0.31			<2.8	10
Seawater	Cemlyn Bay West	2[E]		<0.30			<3.0	16

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		5	<2.4	26	<0.57	<0.07		
Milk	max		<2.7	29	1.1	<0.08		
Apples		1	<2.2	8.5	0.50	<0.06		
Barley		1	<5.4	110	0.50	<0.13		
Beetroot		1	<2.3	15	<0.20	<0.10		
Blackberries		1	<2.2	23	1.4	<0.06		
Broad beans		1	<2.5	29	2.0	<0.06		
Cauliflower		1	<2.0	6.9	0.80	<0.08		
Potatoes		1	<2.4	18	0.30	<0.06		
Squash		1	<2.3	10	0.60	<0.05		
Freshwater	Public supply	1[E]	<3.0		<0.19	<0.20	<0.030	0.16

* *Not detected by the method used*

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

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

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

[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, 2013

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Pebbles and sand	2	0.071
Cemlyn Bay West	Pebbles and sand	1	0.072
Cemlyn Bay West	Shingle	1	0.074

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, 2013).

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

Key points

- *Total doses* for the representative person were less than 0.5 per cent of the dose limit at all those sites assessed except at Barrow where the effects of historical discharges from Sellafield were apparent
- Discharges, environmental concentrations and dose rates in 2013 were broadly similar to those in 2012 at all establishments

Barrow, Cumbria

- *Total dose* for the representative person was 8 per cent of the dose limit but dominated by effects from Sellafield

Devonport, Devon

- Discharges varied in 2013 due to the periodic nature of routine submarine refit operations. No significant variations in food and the environment were observed

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. With effect from 1 November 2012, the Environment Agency issued a new discharge permit for AWE Aldermaston following a change in regulations in 2010. A few minor changes were made to the permit, required by a combination of a change in regulatory requirements and improvements to better reflect operations taking place at the site.

In August 2013, the Environment Agency issued a Warning Letter and Enforcement Notice to AWE following investigations relating to an increase in tritium discharges from the Aldermaston site to the Aldermaston Stream. This increased tritium release was due to a ventilation fan being switched off as a result of a facility modification in a waste store. Stopping the fan allowed tritium being discharged from the waste store to be washed into the surface water drains rather than being dispersed into the atmosphere. AWE is permitted to discharge tritium into the air from its activities as this is often the best way to dispose of this type of waste. The Environment Agency undertook its own investigation and concluded that the levels of tritium discharged were low, around 50 Bq l^{-1} (the World Health Organisation's guideline level for tritium in drinking water is 10,000 Bq l^{-1}). AWE's decision to switch off the fan did not adequately consider the impact of their facility modification work on the environment. As a result higher levels of tritium than expected entered the Aldermaston Stream instead of being rapidly dispersed through the atmosphere.

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. Data for

consumption rates, together with handling and occupancy rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

In 2013, 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 local cows' milk at high-rates were the most exposed group.

Source specific assessments for high-rate consumers of locally grown foods, for sewage workers and for anglers, give exposures that were also less than 0.005 mSv in 2013 (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.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks on the site. In November 2012, a new discharge permit was issued by the Environment Agency. The limit on krypton-85 discharges was removed, as releases of krypton-85 are now exempt from regulation (up to a limit of 1 x 10^{11} Bq per year). Additionally, the description of argon-41 discharges was changed to "Activation Products" to better reflect site operations, but the limit was unchanged.

Gaseous discharges in 2013 were generally similar to those reported in 2012. 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 2012. The tritium concentrations in milk, foodstuffs, grass and soil were below the LoD in 2013, and for grass, were less than in 2012. 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 2012. Levels of uranium isotopes also remained similar to 2011. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Liquid waste discharges and aquatic monitoring

Discharges of radioactive liquid effluent are made under permit to the sewage works at Silchester (Figure 3.1), and to the Aldermaston stream. Discharges of alpha and other beta radionuclides to Silchester in 2013 were similar to those reported in 2012; discharges of tritium to Aldermaston Stream were very low and similar to those in previous years. There are two factors behind the longer-term decline in discharges of tritium from Aldermaston (Figure 5.1): 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 the 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 continued to assess the effect of historical discharges.

Activity concentrations for freshwater, fish, crayfish and sediment 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 2012. Concentrations of tritium in samples were generally below the LoD. Activity concentrations of artificial radionuclides in River Kennet shellfish were at very low levels and similar to those reported in 2012. 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). The low concentration of iodine-131 detected in sewage sludge at Silchester treatment works is likely to have been due to local medical sources.

5.2 Barrow, Cumbria

At Barrow, BAE Systems Marine Limited (BAESM) builds, tests and commissions new nuclear powered submarines. Discharges may be made under permit but there were none in 2013. The Food Standards Agency's terrestrial monitoring is limited to grass sampling, but a larger programme operates in the marine environment in and around Barrow directed primarily at the far-field effects of Sellafield discharges. A habits survey was undertaken in 2012 (Garrod *et al*., 2013b). This has allowed a full dose assessment to be introduced, making use of the marine data. The *total dose* from all pathways and sources of radiation was 0.076 mSv (Table 5.1), which was less than 8 per cent of the dose limit. The most exposed person was an adult living on a local houseboat. Virtually all of this dose was due to the effects of Sellafield discharges. A similar dose was found in 2012 (0.057 mSv). The small increase observed was due to an increase in dose rates underlying the houseboat. Source specific assessments for

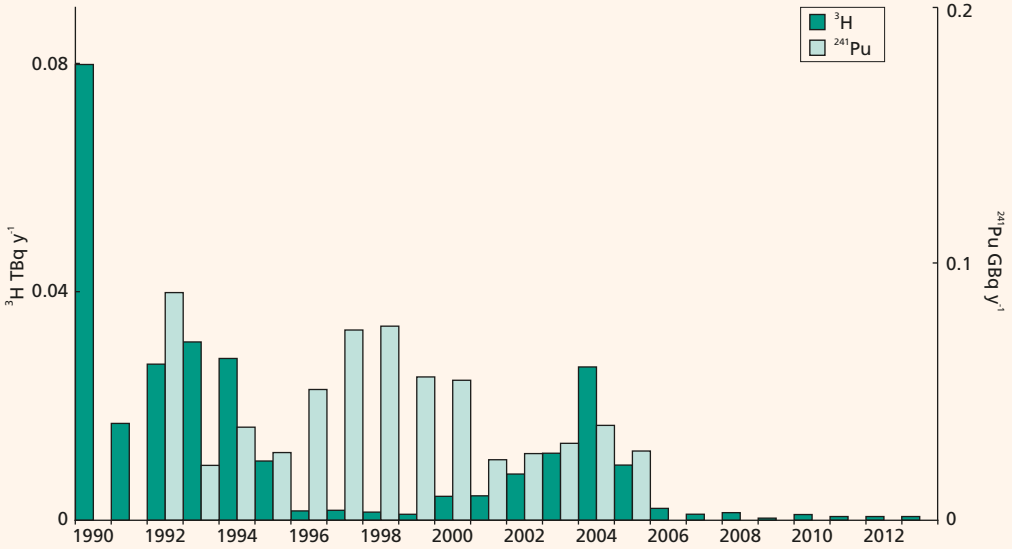


Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2013 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

a high rate fish and shellfish consumer and for a person living on a local houseboat were also carried out. The doses in 2013 for both were less than 8 per cent of the dose limit. As for *total dose* the Sellafield source dominated.

Dose rates in intertidal areas near Barrow were slightly enhanced above those expected due to natural background (Table 5.3(b)). This enhancement was due to the far-field effects of historical discharges from Sellafield. Concentrations of radionuclides in local shellfish and sediment are included for the first time in Table 5.3(a) to support the dose assessment. These samples are taken primarily to show the effects of discharges from Sellafield. In 2013 the concentrations observed are typical of those expected at this distance from Sellafield. No effects of discharges from Barrow were apparent. Tritium activity in grass samples was below the LoD (Table 5.3(a)).

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. Only one habits survey has been undertaken at Derby, in 2009 (Elliott *et al*., 2010).

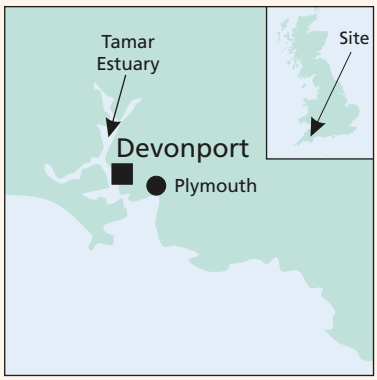
Doses to the public

In 2013, 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. Source specific assessments for consumption of vegetables, fish and drinking river water at high-rates, and for a local resident exposed to external and inhalation pathways from gaseous discharges, give exposures that were also less than 0.005 mSv in 2013 (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 2013 found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. Radionuclide concentrations in cabbage and sludge pellets were very low or below the limit of detection. 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 8.10).

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 2013 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 2013, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), which was less than 0.5 per cent of the dose limit. An adult fish consumer received the highest exposure. 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 a high-rate consumer of locally grown food and of fish and shellfish, and for an occupant of a houseboat, 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.

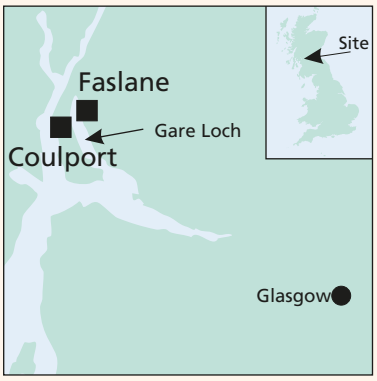
Gaseous discharges and terrestrial monitoring

Gaseous discharges of carbon-14 and argon-41 decreased in 2013 in comparison to those in 2012, due to the periodic nature of routine submarine refit operations. 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 tritium and carbon-14 to the Hamoaze were lower than those reported in 2012. Discharges of "other radionuclides", mainly iron-55, were higher than in 2012. 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 high tritium inventory 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. The effects of increased tritium discharges were not observed. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapon test fallout, were measured in fish samples. The seaweed samples contained very low concentrations of iodine-131 in 2012, 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 2012, 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 (NBC Clyde) in relation to radioactive waste disposal. Following a review by MoD of future delivery options many of the activities undertaken at Coulport have been outsourced. A contract was awarded to an industrial alliance made up of AWE plc, Babcock and Lockheed Martin UK (known as ABL). ABL will be managed by a

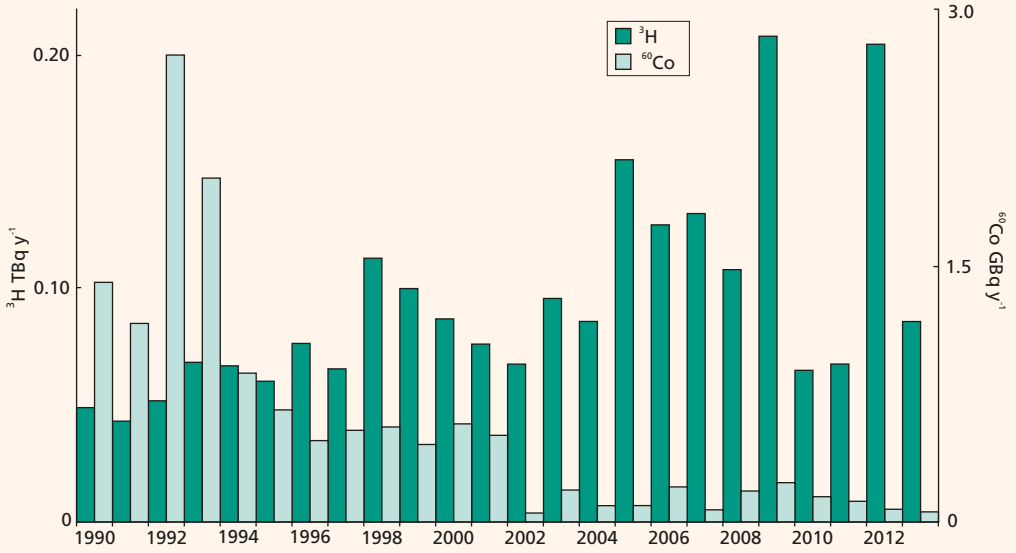


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2013

resident director but MoD will continue to remain in control of the undertaking through NBC Clyde. These arrangements formally began in January 2013.

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. SEPA reviewed these letters in 2012 and the process of updating the letters continued in 2013. The discharges released during 2013 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 2013.

During August 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Rumney *et al.*, 2013b). A slight increase in the mollusc consumption rate has been observed, together with a decrease in the occupancy rates. No crustacean consumption was reported in comparison with that of the previous survey in 2006. 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 2013 (Table 5.1). The most exposed person was an adult exposed to radioactivity in marine sediments, but as in 2012 the dose was less than 0.5 per cent of the dose limit for members of the public. Source specific assessments for a high-rate consumer of fish and shellfish and a consumer of locally grown food (based on limited data), give exposures that were also less than 0.005 mSv.

The routine marine monitoring programme consisted of the analysis of seawater, seaweed and sediment samples, and gamma dose rate measurements. Samples of fish species were not available in 2013. Mollusc samples collected included the separate radioanalysis of mussel flesh and mussel shell (to assess the impact of utilising the latter as a fertiliser). Terrestrial monitoring included beef, honey, water, grass and soil sampling. The results are given in Tables 5.3(a) and (b) and were similar to those in 2012. 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 weapon 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 2013 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 2012. The external radiation dose to a person spending time on the loch shore was less than 0.005 mSv in 2013, which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

5.7 Rosyth, Fife

The site is operated by Babcock Marine, a division of Babcock International Group 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 has mainly been completed, with the exception of some small areas of the site where facilities continue to be required to manage radioactive wastes. 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 has been disposed of under 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.

SEPA has received an application under the Radioactive Substances Act (RSA) 1993 from RRDL to dispose of solid, liquid and gaseous low level radioactive wastes arising from work to dismantle the seven redundant submarines currently berthed at Rosyth. SEPA has also received an application from the MoD to transfer solid and liquid radioactive waste from the submarines to allow RRDL to carry out the dismantling work. This application will be handled administratively in the form of letters of agreement between SEPA and the MoD rather than under RSA 1993. Currently, SEPA is determining both applications.

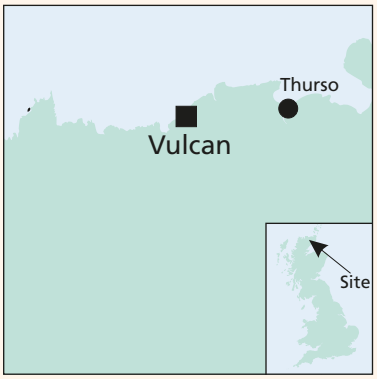
SEPA, and other stakeholders, are currently engaging with the MoD Nuclear Legacy Works Team based at Rosyth to identify the Best Practicable Environmental Option (BPEO) for managing radiologically contaminated ion-exchange resins stored securely in the Active Waste Accumulation Facility on the Rosyth site. SEPA is working closely with the Office for Nuclear Regulation and the Environment Agency on resin management as the issue is common to the Rosyth and Devonport naval sites.

The *total dose* from all pathways and sources was less than 0.005 mSv in 2013 (Table 5.1), which was less than 0.5 per cent of the dose limit. The person most exposed was an adult with exposure over marine sediments. The source specific assessments for a local fisherman (by conservatively estimating seafood concentrations from earlier data), and beach user, give an exposure that was also less than 0.005 mSv in 2013.

In 2013, authorised gaseous discharges from Rosyth were below the LoD. Liquid wastes are discharged via pipeline to the Firth of Forth. Tritium releases during 2013 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. Discharges of tritium from Rosyth decreased in 2013, due to a reduction in the numbers of samples of nuclear submarine primary coolant that were disposed of following analysis in the Rosyth Radiochemistry Laboratory.

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 2012 and in most part due to the combined effects of Sellafield, weapon 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*., 2013c).

5.8 Vulcan NRTE, Highland



The Vulcan Naval Reactor Test Establishment is operated by the Defence Equipment and Support (Submarines) and acts as the test bed for prototype submarine nuclear reactors. It 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 2013. 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 doses – defence sites, 2013

Site	Representative person[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 consumer**	**<0.005**	**–**	**<0.005**	**–**	**–**	**–**
Source specific doses	Angler[c]	<0.005	<0.005	–	<0.005	–	–
	Infant consumer of locally grown food	<0.005	–	<0.005	–	–	<0.005
	Worker at Silchester STW	<0.005	–	–	<0.005[d]	<0.005[e]	–
Barrow							
***Total dose* – all sources**	**Adult occupant on a houseboat[g]**	**0.076**	**–**	**–**	**0.076**	**–**	**–**
Source specific doses	Houseboat occupant	0.074	–	–	0.074	–	–
	Seafood consumer	0.035	0.014	–	0.021	–	–
Derby							
***Total dose* – all sources**	**Adult consumer of locally sourced water**	**<0.005**	**<0.005**	**–**	**<0.005**	**<0.005**	**–**
Source specific doses	Angler consuming fish and drinking water[f]	<0.005	<0.005	–	<0.005	<0.005	–
	Infant consumer of locally grown food	<0.005	–	<0.005	–	–	<0.005
Devonport							
***Total dose* – all sources**	**Adult fish consumer**	**<0.005**	**<0.005**	**–**	**<0.005**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupant	<0.005	–	–	<0.005	–	–
	Prenatal child of consumers of locally grown food	<0.005	–	<0.005	–	–	<0.005
Faslane							
***Total dose* – all sources**	**Adult occupant over sediment**	**<0.005**	**<0.005**	**–**	**<0.005**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Consumer of locally grown food	<0.005	–	<0.005	–	–	–
Holy Loch							
Source specific doses	Angler	<0.005	–	–	<0.005	–	–
Rosyth							
***Total dose* – all sources**	**Adult occupant over sediment**	**<0.005**	**–**	**–**	**<0.005**	**–**	**–**
Source specific doses	Fishermen and beach user	<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 people 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*

[g] *Exposures at Barrow are largely due to discharges from the Sellafield site*

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2013

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	*	0.10			
Signal crayfish	Ufton Bridge – Theale	1	<25	<25	*	<0.07	0.047	0.0015	0.039
Sediment	Pangbourne	4[E]				<0.89	14	<1.2	15
Sediment	Mapledurham	4[E]				14	7.6	<0.70	7.6
Sediment	Aldermaston	4[E]				5.2	19	<1.5	20
Sediment	Spring Lane	4[E]				<0.99	8.3	<0.94	8.7
Sediment	Stream draining south	4[E]				<0.47	26	<2.0	28
Sediment	Reading (Kennet)	4[E]				<3.1	14	<1.3	14
Gullypot sediment	Falcon Gate	1[E]		<6.2		3.7	16	<1.3	16
Gullypot sediment	Main Gate	1[E]		<4.9		2.2	15	<1.4	17
Gullypot sediment	Tadley Entrance	1[E]		<12		16	13	<1.1	13
Gullypot sediment	Burghfield Gate	1[E]		<6.6		<0.25	12	<0.88	14
Freshwater	Pangbourne	4[E]		<3.0		<0.19	0.010	<0.0012	0.0083
Freshwater	Mapledurham	4[E]		<3.5		<0.27	0.0093	<0.0018	0.0076
Freshwater	Aldermaston	4[E]		11		<0.24	0.0077	<0.0022	0.0046
Freshwater	Spring Lane	4[E]		<3.6		<0.22	<0.0036	<0.0015	<0.0028
Freshwater	Reading (Kennet)	4[E]		<3.2		<0.21	0.0060	<0.0019	<0.0046
Crude liquid effluent	Silchester treatment works	4[E]		<8.4		<0.21	<0.0043	<0.0017	<0.0032
Final Liquid effluent	Silchester treatment works	4[E]		<9.2		<0.20	<0.0030	<0.0028	<0.0032
Sewage sludge	Silchester treatment works	4[E]		<11	1.5	<0.24	<0.35	<0.030	0.32

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	0.000027	0.00017	0.00029	*	*		
Sediment	Pangbourne	4[E]	<0.46	<0.39	<0.64			250	410
Sediment	Mapledurham	4[E]	<0.57	<0.45	<0.46			<160	<190
Sediment	Aldermaston	4[E]	<0.49	1.5	<0.94			290	590
Sediment	Spring Lane	4[E]	<0.47	<0.38	0.78			<170	<280
Sediment	Stream draining south	4[E]	<0.53	<0.44	<0.73			300	940
Sediment	Reading (Kennet)	4[E]	<0.55	<0.46	<1.5			<130	280
Gullypot sediment	Falcon Gate	1[E]	<0.30	0.32	<1.5			330	880
Gullypot sediment	Main Gate	1[E]	<0.21	<0.43	<0.60			340	510
Gullypot sediment	Tadley Entrance	1[E]	<1.2	1.6	<1.2			240	920
Gullypot sediment	Burghfield Gate	1[E]	<0.26	<0.22	<0.52			<120	360
Freshwater	Pangbourne	4[E]	<0.0024	<0.0020	<0.0062			<0.062	0.23
Freshwater	Mapledurham	4[E]	<0.0022	<0.0022	<0.0054			<0.057	0.24
Freshwater	Aldermaston	4[E]	<0.0029	<0.0018	<0.0080			<0.043	0.24
Freshwater	Spring Lane	4[E]	<0.0029	<0.0023	<0.0064			<0.035	0.15
Freshwater	Reading (Kennet)	4[E]	<0.0036	<0.0032	<0.0064			<0.057	<0.14
Crude liquid effluent	Silchester treatment works	4[E]	<0.0056	<0.0020	<0.28			<0.11	0.85
Final Liquid effluent	Silchester treatment works	4[E]	<0.0055	<0.0027	<0.27			<0.12	0.66
Sewage sludge	Silchester treatment works	4[E]	<0.032	<0.031	<0.32			<7.1	9.6

Table 5.2(a). continued

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		4	<2.5		<0.07	<0.0011	<0.00079	<0.00094
Milk	max		<2.9		<0.09	<0.0016	<0.0016	<0.0016
Blackberries		1	<2.0		<0.04	0.0067	0.00068	0.0022
Carrots		1	<2.4		<0.06	0.013	0.00055	0.010
Honey		1	<3.8		<0.07	0.00066	<0.00019	<0.00019
Leaf beet		1	<2.2		<0.09	0.031	0.0011	0.032
Onions		1	<2.4		<0.03	<0.00046	<0.00046	<0.00046
Potatoes		1	<2.5		<0.05	0.018	0.0026	0.0077
Rabbit		1	<3.2		<0.11	0.013	<0.00075	0.0086
Wheat		1	<5.3		<0.11	0.00077	<0.00050	0.0013
Grass	Location 7	1[E]	<11	<1.9	<0.42	<0.25	<0.21	<0.19
Grass	Location 8	1[E]	<8.5		<0.52	0.17	<0.031	0.17
Grass	Opposite Gate 26A	1[E]		<3.1	<0.81	<0.26	<0.19	<0.29
Grass	Opposite Gate 36	1[E]	<11		<0.84	0.28	<0.072	0.24
Soil	Location 7	1[E]	<6.1		8.6	21	<1.5	21
Soil	Location 8	1[E]	<6.5		9.8	16	<0.75	15
Soil	Opposite Gate 26A	1[E]	<5.2		17	9.5	<1.2	11
Soil	Opposite Gate 36	1[E]	<7.0		16	13	<0.69	13

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples							
Milk		4	<0.000026	<0.000027	<0.00018		
Milk	max		<0.000035	<0.000040	<0.00046		
Blackberries		1	<0.00030	<0.00021	<0.00016		
Honey		1	<0.000080	<0.000062	<0.000031		
Potatoes		1	<0.000043	0.00013	0.00022		
Rabbit		1	<0.000052	0.000034	0.000071		
Grass	Location 7	1[E]	<0.041	<0.044		<2.7	290
Grass	Location 8	1[E]	<0.063	<0.050		4.1	300
Grass	Opposite Gate 26A	1[E]	<0.080	<0.052		<3.1	250
Grass	Opposite Gate 36	1[E]	<0.074	<0.053		<3.3	220
Soil	Location 7	1[E]	<0.21	0.67		220	390
Soil	Location 8	1[E]	<0.21	0.49		210	370
Soil	Opposite Gate 26A	1[E]	<0.28	1.8		<95	280
Soil	Opposite Gate 36	1[E]	<0.48	1.1		<120	260

* *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, 2013

Location	Ground type type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	3	0.065
Pangbourne, riverbank	Grass and mud	1	0.061
Mapledurham, riverbank	Grass and mud	3	0.062
Mapledurham, riverbank	Grass	1	0.061

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2013

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	^{60}Co	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs
Barrow										
Crabs[c]	Barrow	4[F]				<0.09	<0.19	*	<0.09	0.72
Lobsters[d]	Barrow	3[F]				<0.08	<0.19	*	<0.08	1.0
Grass	Barrow	2[F]		<5.0						
Sediment	Walney Channel – N of discharge point	2				<0.70	<1.7		<0.44	81
Sediment	Walney Channel – S of discharge point	2				<0.69	<1.6		<0.42	68
Derby										
Cabbage	Derby	1[F]				<0.04	<0.08	*	<0.04	<0.03
Sediment	River Derwent, upstream	1				<0.39				2.7
Sediment	Fritchley Brook	1				<0.29				0.48
Sediment	River Derwent, downstream	4				<0.81				3.3
Water	River Derwent, upstream	1				<0.37				
Water[e]	Fritchley Brook	1		<2.7		<0.21				<0.19
Water	River Derwent, downstream	4				<0.24				
Sewage pellets	Derby	1[F]				<0.19	<0.60	*	<0.30	1.4
Devonport										
Cuckoo wrasse	Plymouth Sound	1[F]			24	<0.21	<0.38	*	<0.18	<0.17
Skates/rays	Plymouth Sound	1[F]			30	<0.16	<0.33	*	<0.18	<0.15
Crabs	Plymouth Sound	2[F]			31	<0.13	<0.28	<0.24	<0.13	<0.11
Cockles	Southdown	1[F]				<0.14	<0.26	*	<0.13	<0.11
Pacific oysters	Southdown	1[F]				<0.03	<0.08	*	<0.03	<0.03
Mussels	River Lynher	2[F]	<25	<25		<0.13	<0.27	*	<0.13	<0.11
Seaweed[f]	Kinterbury	2				<0.78		<1.9		
Sediment[g]	Kinterbury	2		<4.8		<0.66				
Sediment	Torpoint South	3		<4.1		<0.58				1.2
Sediment	Lopwell	3		<5.9		<1.5				6.9
Seawater	Torpoint South	2		<3.3	<3.6	<0.23				
Seawater	Millbrook Lake	2		<3.0	<4.9	<0.36				
Beetroot		1[F]		<2.0		<0.05	<0.12		<0.05	<0.04
Blackberries		1[F]		<2.1		<0.05	<0.15		<0.05	<0.05
Courgettes		1[F]		<2.5		<0.09	<0.16		<0.09	<0.08
Lettuce		1[F]		<2.6		<0.21	<0.48	<2.2	<0.23	<0.21
Faslane										
Mussel shells	Rhu	1				<0.10	<0.10		<0.10	0.18
Mussels	Rhu	1				<0.10	<0.15		<0.10	0.41
Winkles	Garelochhead	1				<0.10	<0.18		<0.10	0.19
Winkles	Helensburgh	1				<0.10	<0.28		<0.12	0.30
Fucus vesiculosus	Rhu	1				<0.10	<0.10		<0.10	0.38
Sediment	Carnban boatyard	1				<0.10	<0.30		<0.12	1.3
Seawater	Carnban boatyard	2		1.7		<0.10	<0.16		<0.10	<0.10
Beef muscle	Faslane	1				<0.05			<0.05	<0.05
Honey	Faslane	1				<0.07			<0.08	0.13
Grass	Auchengaich	1		<5.0		<0.10			<0.11	1.2
Grass	Lochan Ghlas Laoigh	1		<5.0		<0.05			<0.05	11
Soil	Auchengaich	1				<0.05			<0.06	71
Soil	Lochan Ghlas Laoigh	1				<0.05			<0.07	16
Freshwater	Helensburgh Reservoir	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Loch Finlas	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Auchengaich	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Lochan Ghlas Laoigh	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Loch Eck	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Loch Lomond	1		<1.0		<0.01			<0.01	<0.01
Holy Loch										
Sediment	Mid-Loch	1				<0.10	<0.19		<0.10	3.5
Rosyth										
Fucus vesiculosus	East of dockyard	1				<0.10	<0.12		<0.10	0.10
Sediment	East of dockyard	1				<0.10	<0.19		<0.10	3.1
Sediment	Port Edgar	1				<0.10	<0.27		<0.12	9.2
Sediment	West of dockyard	1				<0.10	<0.13		<0.10	1.0
Sediment	East Ness Pier	1				<0.10	<0.15		<0.10	5.5
Sediment	Blackness Castle	1				<0.10	<0.18		<0.10	1.8
Sediment	Charlestown Pier	1				<0.10	<0.18		<0.10	1.6
Seawater	East of dockyard	2		<1.0		<0.10	<0.13		<0.10	<0.10
Freshwater	Castlehill	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Holl Reservoir	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Gartmorn	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Morton No. 2	1		<1.0		<0.01			<0.01	<0.01

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Barrow									
Crabs[c]	Barrow	4[F]	<0.16				0.74		
Lobsters[d]	Barrow	3[F]	<0.19				1.2		170
Sediment	Walney Channel – N of discharge point	2	<0.80				180	450	750
Sediment	Walney Channel – S of discharge point	2	<0.76				140	<150	680
Derby									
Cabbage	Derby	1[F]	<0.07				<0.04		
Sediment	River Derwent, upstream	1		24	<1.5	25		230	510
Sediment	Fritchley Brook	1		15	<1.4	13		150	750
Sediment	River Derwent, downstream	4		28	<1.8	29		310	640
Grass		4[F]		0.041	0.0018	0.043			
Grass	max			0.10	0.0041	0.11			
Soil		4[F]		19	0.75	18			
Soil	max			21	0.83	20			
Water	River Derwent, upstream	1						<0.09	0.15
Water[e]	Fritchley Brook	1		0.023	<0.0030	0.022		<0.09	0.19
Water	River Derwent, downstream	4						<0.084	0.16
Sewage pellets	Derby	1[F]	<0.74				<0.74		
Devonport									
Cuckoo wrasse	Plymouth Sound	1[F]	<0.25				<0.13		
Skates/rays	Plymouth Sound	1[F]	<0.24				<0.12		
Crabs	Plymouth Sound	2[F]	<0.20				<0.10		
Cockles	Southdown	1[F]	<0.18				<0.10		
Pacific oysters	Southdown	1[F]	<0.06				<0.03		
Mussels	River Lynher	2[F]	<0.19				<0.10		
Sediment[g]	Kinterbury	2					0.82		
Beetroot		1[F]	<0.18				<0.60		
Blackberries		1[F]	<0.22				<0.66		
Courgettes		1[F]	<0.20				<0.11		
Lettuce		1[F]	<0.44				<0.25		
Faslane									
Mussel shells	Rhu	1	<0.10				<0.10		
Mussels	Rhu	1	<0.15				<0.10		
Winkles	Garelochhead	1	<0.13				<0.10		
Winkles	Helensburgh	1	<0.24				<0.13		
Fucus vesiculosus	Rhu	1	<0.10				<0.10		
Sediment	Carnban boatyard	1	<0.33				0.50		
Seawater	Carnban boatyard	2	<0.14				<0.10		
Beef muscle	Faslane	1					<0.05		
Honey	Faslane	1					<0.11		
Grass	Auchengaich	1					<0.16		
Grass	Lochan Ghlas Laoigh	1					<0.08		
Soil	Auchengaich	1	2.8				1.3		
Soil	Lochan Ghlas Laoigh	1	0.71				<0.26		
Freshwater	Helensburgh Reservoir	1					<0.01	<0.010	0.044
Freshwater	Loch Finlas	1					<0.01	<0.010	0.021
Freshwater	Auchengaich	1					<0.01	<0.010	0.027
Freshwater	Lochan Ghlas Laoigh	1					<0.01	<0.010	0.014
Freshwater	Loch Eck	1					<0.01	<0.010	0.020
Freshwater	Loch Lomond	1					<0.01	<0.010	0.033
Holy Loch									
Sediment	Mid-Loch	1	<0.30				<0.29		
Rosyth									
Fucus vesiculosus	East of dockyard	1	<0.12				<0.10		
Sediment	East of dockyard	1	<0.25				<0.24		
Sediment	Port Edgar	1	<0.45				<0.45		
Sediment	West of dockyard	1	<0.19				<0.24		
Sediment	East Ness Pier	1	<0.26				<0.24		
Sediment	Blackness Castle	1	0.59				<0.27		
Sediment	Charlestown Pier	1	<0.25				<0.25		
Seawater	East of dockyard	2	<0.12				<0.10		
Freshwater	Castlehill	1					<0.01	<0.010	0.030
Freshwater	Holl Reservoir	1					<0.01	<0.010	0.030
Freshwater	Gartmorn	1					<0.01	<0.010	0.13
Freshwater	Morton No. 2	1					<0.01	<0.010	0.040

* *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 and sewage pellets where dry concentrations apply, and for water where units are Bq l^{-1}*

[c] *The concentrations of ^{238}Pu and $^{239+240}$Pu were 0.018 and 0.11 Bq kg^{-1} respectively*

[d] *The concentration of ^{99}Tc was 49 Bq kg^{-1}*

[e] *The concentrations of ^{228}Th, ^{230}Th and ^{232}Th were <0.0030, <0.0040 and <0.0010 Bq l^{-1} respectively*

[f] *The concentration of ^{99}Tc was <1.1 Bq kg^{-1}*

[g] *The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.66 and <0.36 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, 2013

Establishment	Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Barrow	Walney Channel, N of discharge point	Mud	1	0.088
Barrow	Walney Channel, N of discharge point	Mud and sand	1	0.091
Barrow	Walney Channel, S of discharge point	Mud and sand	2	0.093
Devonport	Torpoint South	Mud and stones	1	0.10
Devonport	Torpoint South	Rock and mud	1	0.11
Devonport	Kinterbury Access Gate	Mud and stones	1	0.10
Devonport	Kinterbury Access Gate	Sand and stones	1	0.087
Devonport	Lopwell	Mud	2	0.084
Faslane	Garelochhead	Mud, sand and stones	2	0.061
Faslane	Gulley Bridge Pier	Sand and stones	2	0.059
Faslane	Rhu	Gravel	2	0.059
Faslane	Helensburgh	Sand	2	0.059
Faslane	Carnban boatyard	Gravel	2	0.065
Holy Loch	North Sandbank	Mud and sand	1	0.062
Holy Loch	Kilmun Pier	Sand and stones	1	0.061
Holy Loch	Mid-Loch	Sand	1	0.061
Rosyth	Blackness Castle	Mud and sand	2	0.056
Rosyth	Charlestown Pier	Sand	2	0.054
Rosyth	East Ness Pier	Sand	2	0.053
Rosyth	East of Dockyard	Sand	2	0.052
Rosyth	Port Edgar	Mud	2	0.061
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 Limited. This is a health science company functioning in world-wide commercial healthcare and life science markets.

Permits have been issued by the Environment Agency and Natural Resources Wales to each of the sites respectively 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 Environment Agency has an agreement with Natural Resources Wales to carry out monitoring on its behalf in Wales. The medium-term trends in discharges, environmental concentrations and dose at Amersham and Cardiff were considered in a 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

- *Total dose* for the representative person was less than 22 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Gaseous discharges of iodine-125 reduced to nil in 2013
- Concentrations of radioactivity in terrestrial and aquatic samples, and gamma dose rates, were low and generally similar to those in 2012

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- *Total doses* for the representative person was less than 2 per cent of the dose limit. The highest dose was due to the consumption of milk
- Gaseous and liquid discharges of tritium and carbon-14 remained low in 2013; carbon-14 gaseous discharges were the lowest reported in 2013
- Tritium concentrations in fish species continued their long-term decline; levels in flounder were the lowest reported in 2013

6.1 Grove Centre, Amersham, Buckinghamshire

GE Healthcare Limited'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, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 3.4. 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 2012. This dose was primarily due to direct radiation to a local inhabitant. 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 – 2013 is given in Figure 1.1. *Total doses* remained broadly similar with time and were dominated by direct radiation.

Source specific assessments for a high-rate consumer of locally grown foods, for an angler and for a worker at Maple Lodge sewage treatment works, which serves the sewers to which permitted discharges are made, give exposures that were less than the *total dose* in 2013 (Table 6.1). The dose for a high-rate consumer of locally grown foods (which included a contribution from the gaseous plume related pathways) was 0.008 mSv, or less than 1 per cent of the dose limit to members of the public of 1 mSv. The small decrease in dose, from 0.009 mSv in 2012, was primarily due to lower atmospheric discharges of radon-222 in 2013; 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 to a local angler in 2013 was less than 0.005 mSv, as in 2012.

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 an angler.

The Grove Centre discharges liquid waste to Maple Lodge Sewage Treatment Works (STW), and the proximity to raw sewage and sludge experienced by sewage treatment workers is a likely exposure pathway (National Dose Assessment Working Group, 2004). The dose received by one of these workers in 2013 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 re-suspended 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. In 2013, discharges of iodine-125 reduced to nil in comparison to those in 2012; other gaseous discharges were generally similar. The results for the terrestrial food monitoring, including those for local milk, crops and grass samples, are given in Table 6.2. Sulphur-35 was positively detected at low concentrations (just above the LoD) in some crop samples in 2013. As in previous years, caesium-137 activities were 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 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 mostly below the LoD. 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 Grand Union Canal remained low in 2013.

6.2 Maynard Centre, Cardiff

GE Healthcare Limited operates a second establishment, on the Forest Farm industrial estate near Whitchurch, Cardiff. GE Healthcare Limited ceased manufacturing a range of radio-labelled 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 historical radioactive wastes. 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 Limited's custom radio-labelling division was acquired by Quotient Bioresearch, (a division of Quotient Bioscience) which 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 in liquid wastes. These are at much reduced levels in comparison to when the Maynard Centre was manufacturing radio-labelled products. The effluents discharged from the site are also treated to ensure that organic matter present is destroyed prior to discharge. The facility has an environmental permit issued and regulated by Natural Resources Wales.

The Food Standards Agency and the Environment Agency conduct a routine monitoring programme on behalf of Natural Resources Wales and the Welsh Government. This includes sampling of locally produced food, fish and shellfish, and external dose rate measurements over muddy, intertidal areas. 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).

Doses to the public

The *total dose* from all pathways and sources was 0.010 mSv in 2013 (Table 6.1), or 1 per cent of the dose limit, and up from 0.005 mSv in 2012. 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 increased value was due to higher carbon-14 concentrations in milk in 2013. An infant consuming milk at high-rates was the most exposed person and this is a change from that in 2012 (a prenatal child of adults who spend time over intertidal sediments). Trends in *total doses* over time (2003 – 2013) in the Severn Estuary (and areas of the south coast) are shown in Figure 6.1. 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* have generally continued to decrease over time and were consistently low.

Source specific assessments for a recreational user of the River Taff, and for a worker at Cardiff East Waste Water Treatment Works (WWTW), gave doses that were less than the *total dose* in 2013 (Table 6.1). The dose to a high-rate consumer of locally grown foods was 0.016 mSv, and the reason for the increase in dose (from 0.007 mSv in 2012) was the same as that for *total dose*. The dose to a high-rate consumer of seafood was 0.014 mSv, compared with 0.009 mSv in 2012. The higher value in 2013 was due to an increase from external exposure over intertidal areas, mostly because gamma dose rates were measured on different types of substrate (near the Cardiff pipeline) from one year to the next.

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 2013 dose assessments on the advice of PHE. For ingestion of other food, the ICRP dose coefficient for OBT is applied.

The monitoring locations for seafood, water, environmental materials and dose rates near the Cardiff site are shown in Figure 6.2.

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. As a result of reduced commercial operations, in relation to the site's planned shutdown,

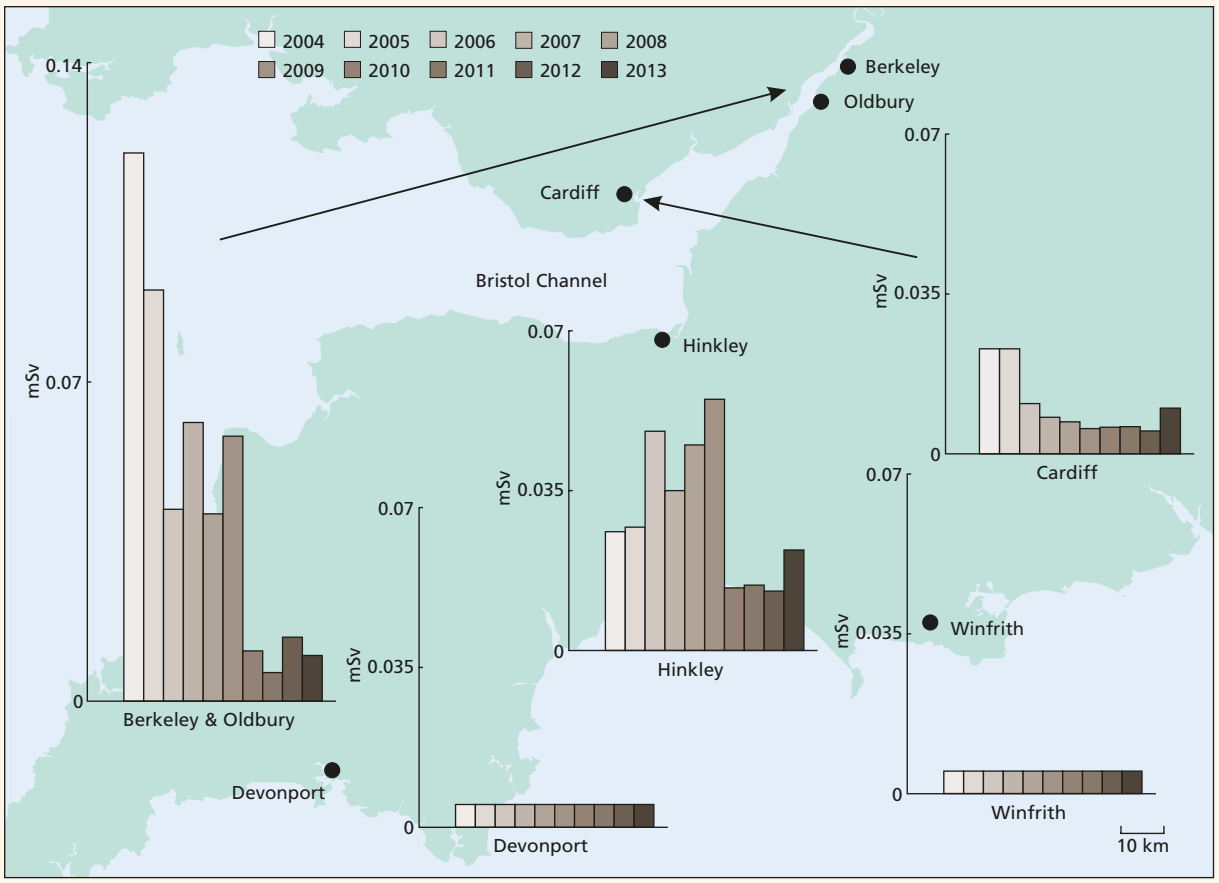


Figure 6.1. *Total dose* for major sites in the Severn Estuary and south coast, 2004-2013
(Note different scales used for Berkeley and Oldbury; small doses, less than or equal to 0.005 mSv, are recorded as being 0.005 mSv)

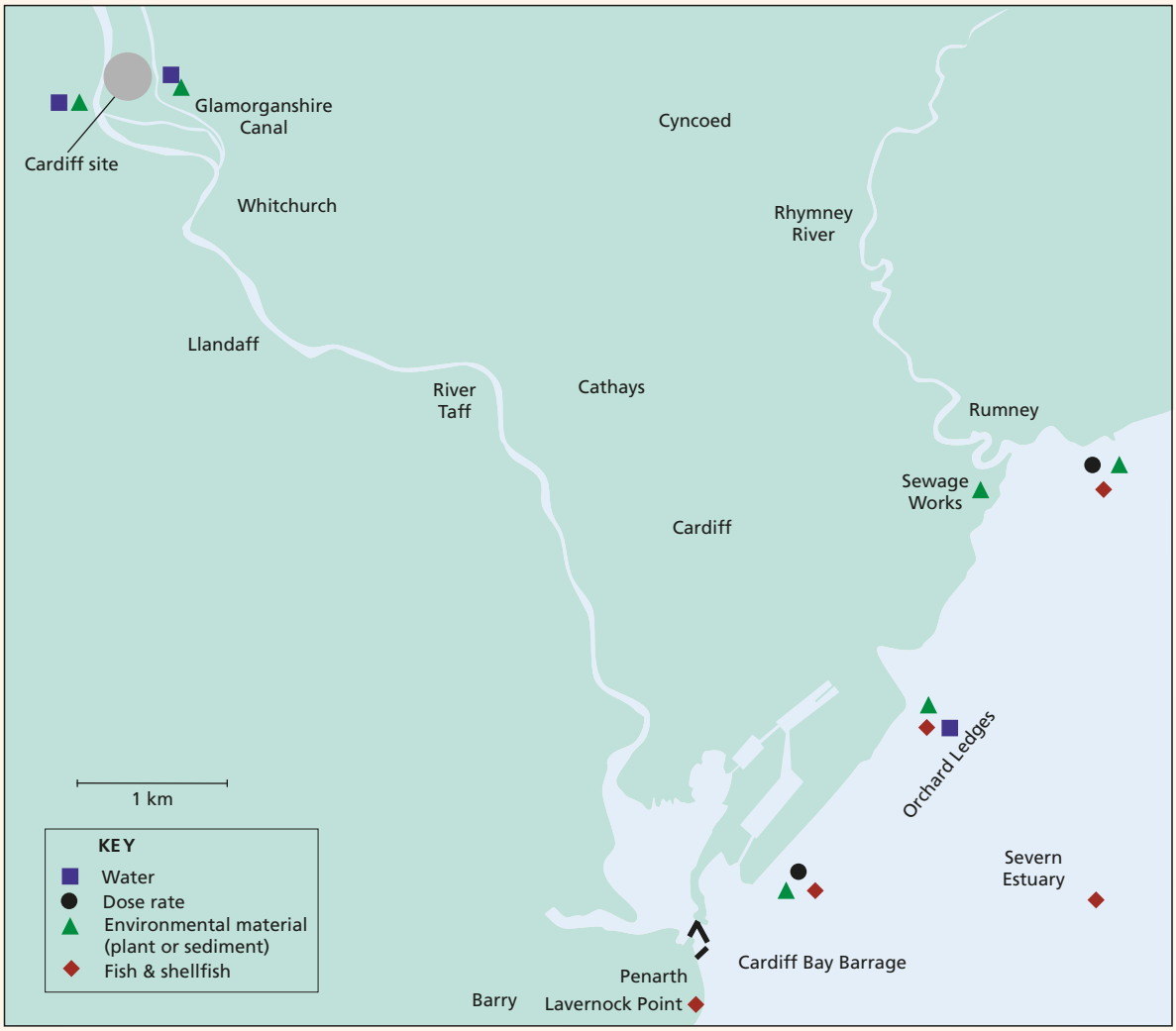


Figure 6.2. Monitoring locations at Cardiff, 2013 (not including farms)

discharges of tritium (and other discharged radionuclides) continued to be low in 2013. Carbon-14 discharges were reduced in 2013 and these were the lowest releases in recent years.

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 WWTW. 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 Food Standards Agency research project 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 (Ham *et al.*, 2007).

Tritium concentrations in terrestrial food samples were all below the LoD in 2013 (Table 6.3(a)). These values were generally lower in comparison to those in 2012 and are consistent with progressive discharge reductions in recent years. Carbon-14 concentrations in foodstuffs were generally higher in comparison to those in 2012, including an enhancement in milk in 2013. Low concentrations of sulphur-35, which is not discharged by the site, were detected in foods and were similar to those in 2012. Phosphorus-32 and iodine-125 concentrations were below the LoD in all terrestrial samples. Samples of raw and treated effluent from Cardiff East WWTW were analysed for tritium and carbon-14, caesium-137 and iodine-125 in 2013. The results (Table 6.3(a)) show that all activity concentrations in effluent were less than the LoD. Sludge pellets (analysed in previous years) were not sampled in 2013.

Relatively low levels of tritium continued 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. In 2013, tritium was detected at low concentrations from site run-off water into the River Taff. The trend of discharges, with tritium concentrations in sediment from the marine and freshwater environments, over time (2004 – 2013) are shown in Figure 6.3. The overall decline in activity concentrations generally replicates that of the tritium discharges, although the decrease in marine levels (east/west of the pipeline) is less pronounced

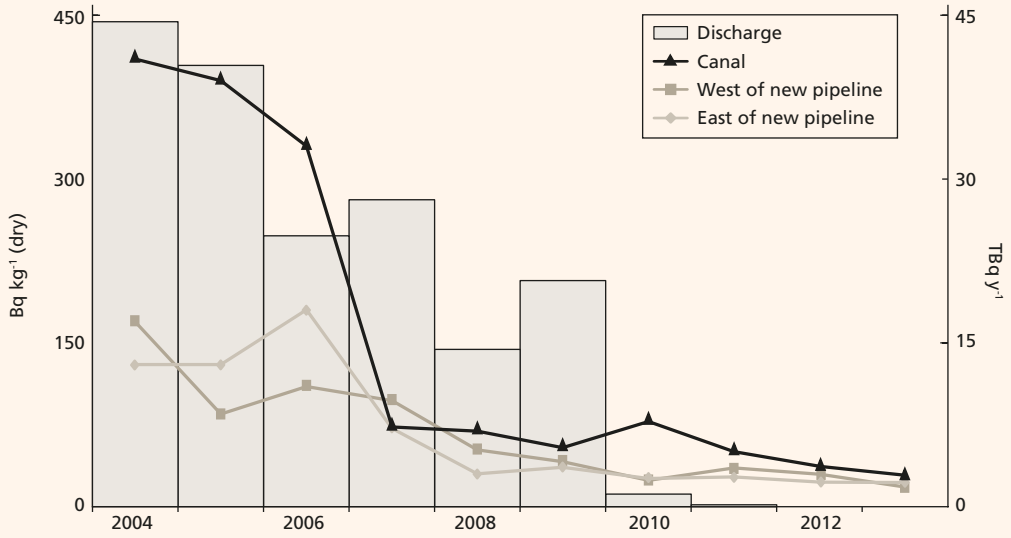


Figure 6.3. Tritium liquid discharge from Cardiff and mean concentrations in sediment near Cardiff, 2004-2013

than that in the canal sediments over the whole time period.

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 amounts of these radionuclides released to the sewer were both very low in 2013 (as in recent years). Tritium discharges were reduced and these were the lowest releases in recent years. Over the longer term both discharge rates have decreased substantially (Figures 6.4 and 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 2013 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 2013, tritium concentrations in sampled fish (flounder, sole and dogfish) decreased as compared with concentrations of their respective species in recent years. Moreover, the tritium concentrations reported in flounder were the lowest values in recent years. 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.

Figure 6.4 indicates that the overall tritium concentrations in mollusc samples have decreased significantly over a period of time. The mean concentrations for tritium in molluscs (and fish) were the lowest reported values in 2013. Tritium was also detected in marine sediment samples at similar levels to those in recent years. The mean concentrations of carbon-14 in fish and molluscs in 2013 were generally similar to those in 2012. The longer term trend in concentrations and the relationship to discharges is shown in Figure 6.5 (overall, 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 licensed sites. Gamma dose rates over sediment (Table 6.3(b)) were generally comparable to those observed in most recent years but are not (in the main) attributable to discharges from the Maynard Centre or the laboratory at Trident Park.

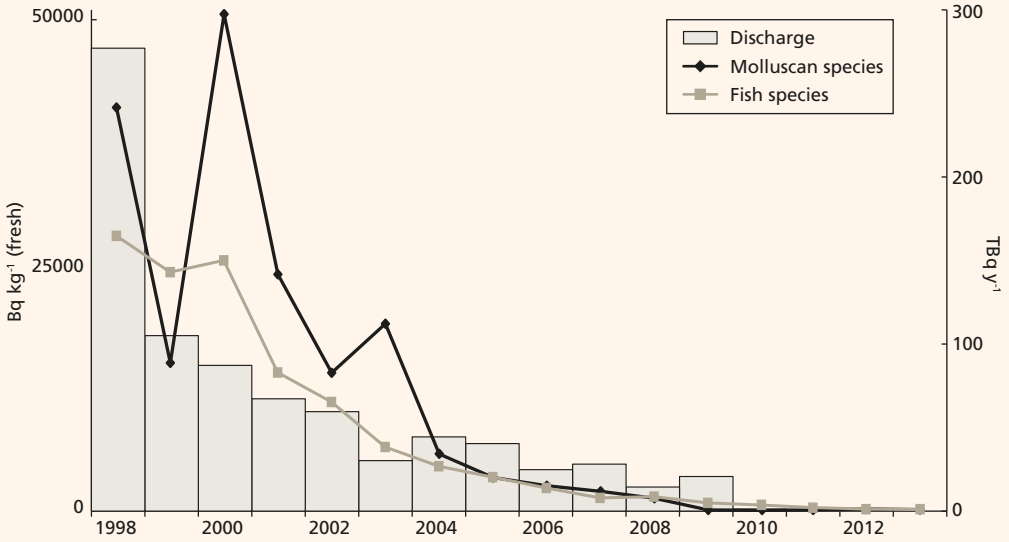


Figure 6.4. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2013 (species include all those reported in RIFE for the given year)

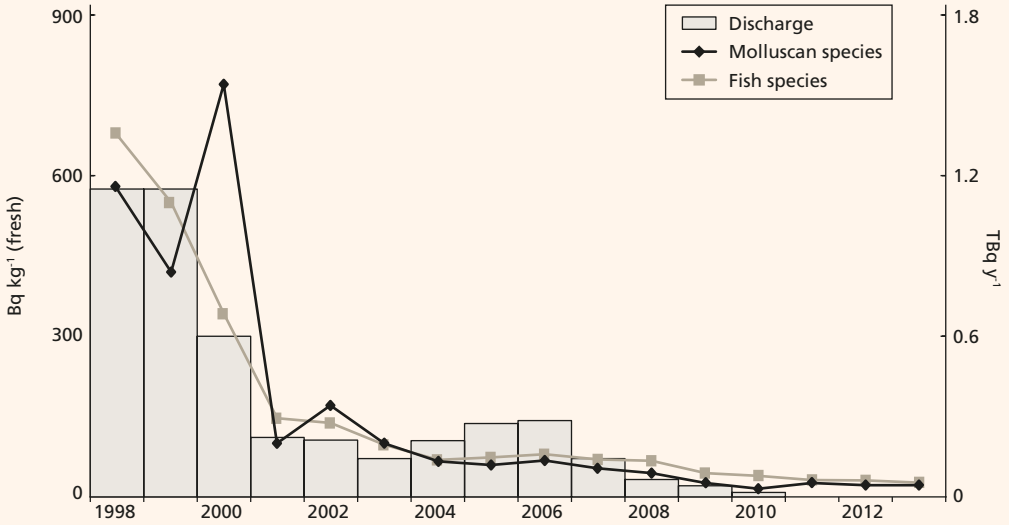


Figure 6.5. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2013 (species include all those reported in RIFE for the given year)

Table 6.1. Individual doses – radiochemical sites, 2013

Site	Representative person[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 inhabitant (0–0.25km)**	**0.22**	**–**	**<0.005**	**<0.005**	**–**	**<0.005**	**0.22**
Source specific doses	Angler	<0.005	<0.005	–	<0.005	–	–	–
	Infant consumer of locally grown food	0.008	–	<0.005	–	–	0.006	–
	Worker at Maple Lodge STW	<0.005	–	–	<0.005[b]	<0.005[c]	–	–
Cardiff								
Total dose – all sources	**Infant milk consumer**	**0.010**	**–**	**0.010**	**–**	**–**	**–**	**–**
Source specific doses	Prenatal child of seafood consumers	0.014	<0.005	–	0.013	–	–	–
	Recreational user of River Taff	<0.005	–	–	<0.005	<0.005	–	–
	Infant consumer of locally grown food	0.016	–	0.016	–	–	<0.005	–
	Worker at Cardiff East WWTW	<0.005	–	–	<0.005[b]	<0.005[c]	–	–

[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 people 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, 2013[g]

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{32}P	^{35}S	^{125}I	^{131}I	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Freshwater samples											
Flounder	Woolwich Reach	1	<25				*	0.10	<0.05		
Sediment	River Colne (Grand Union Canal)	2[E]				<1.4	<2.0	5.3		170	330
Sediment	Upstream of outfall (Grand Union Canal)	2[E]				<1.3	<2.0	5.4		210	240
Freshwater	Maple Cross	2[E]	<3.0			<0.17	<0.27	<0.19		<0.080	0.31
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<3.0			<0.17	<0.29	<0.20		<0.061	0.12
Freshwater	River Chess	1[E]	<2.8			<0.17	<0.24	<0.20		<0.060	0.11
Freshwater	River Misbourne – upstream	1[E]	<2.8			<0.17	<0.25	<0.20		<0.070	0.070
Freshwater	River Misbourne – downstream	1[E]	<2.8			<0.17	<0.26	<0.20		<0.040	<0.060
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<9.5	<2.1	<0.39	<0.17		<0.22	<0.28	<0.14	0.60
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<17	<1.3	<0.91	<0.85		<0.22	<0.30	<2.1	6.2
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<12	<1.3	<0.38	<0.18		<0.24	<0.29	<0.11	0.61

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		1	<2.2	<0.38	<0.0084	<0.0053	<0.06		
Apples		1	<2.2	<0.20	<0.087		<0.07		
Beetroot		1	<2.3	<0.20	<0.027		<0.07		
Blackberries		1	<2.1	<0.30	<0.096		<0.03		
Broad beans		1	<2.7	0.60	<0.091		<0.08		
Carrots		1	<2.7	<0.20	<0.018		<0.08		
Chard		1	<2.6	<0.20	<0.028		<0.11		
Spinach		1	<2.4	0.20	<0.053		<0.14		
Wheat		1	<6.0	0.70	<0.093		<0.06		
Grass	Next to site	1[E]		<2.0	<0.59	<1.2	<0.88	<1.9	230
Grass	Orchard next to site	1[E]		<3.0	<0.59	<1.1	<0.83	<2.1	190
Grass	Water Meadows (River Chess)	1[E]		<1.2	<0.52	<1.2	<1.1	<2.5	160
Soil	Next to site	1[E]			<0.59	<0.39	9.1	200	310
Soil	Orchard next to site	1[E]			<0.54	<0.39	2.8	310	550
Soil	Water Meadows (River Chess)	1[E]			<0.57	<0.44	12	130	310

* *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 <3.3 Bq l^{-1}*

[e] *The concentration of ^{3}H as tritiated water was <14 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <9.2 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 0.068 and 0.060 mGy 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, 2013

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	^{137}Cs
Marine samples								
Flounder	East of new pipeline	4	110	130		30		0.35
Sole	East of new pipeline	2		170		31		0.13
Mullet	East of new pipeline	1		<25		23		0.23
Lesser spotted dogfish	Off Orchard Ledges	2	310	350		30		0.38
Skates/Rays	Off Orchard Ledges	2	69	98		31		0.45
Whiting	East of new pipeline	1		<25		26		0.30
Limpets	Lavernock Point	2	<25	<29		23		0.20
Seaweed[d]	Orchard Ledges	2[E]		<14	<5.5	24	<0.56	<0.64
Sediment	East of new pipeline	2[E]		<22		<12	<0.59	17
Sediment	West of new pipeline	2[E]		<18	<5.3	<8.4	<1.3	14
Seawater	Orchard Ledges	2[E]		<10	<3.1	<12	<0.30	<0.23

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	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples											
Milk[g]		6	<2.3	<2.0		29	<0.44	<0.011	<0.07		
Milk[g]	max		<2.6			34	0.55	<0.019	<0.09		
Barley		1	<3.6	<3.6		100	1.5	<0.092	<0.05		
Blackberries		1	<4.0	<4.0		16	<0.20	<0.049	<0.24		
Cabbage		1	<2.5	<2.5		8.9	0.50	<0.037	<0.04		
Honey		1	<3.7	<3.7		66	<0.20	<0.041	<0.09		
Leeks		1	<2.3	<2.3		21	0.90	<0.055	<0.15		
Onions		1	<2.6	<2.6		16	0.70	<0.018	<0.09		
Potatoes		1	<2.8	<2.8		41	0.60	<0.062	<0.09		
Rape oil		1	<5.4	<5.4		100	3.9	<0.086	<0.08		
Strawberries		1	<2.1	<2.1		17	<0.20	<0.056	<0.06		
Swede		1	<2.2	<2.2		21	0.40	<0.078	<0.03		
Grass		5	<4.9	<4.9		40			<0.12		
Grass	max		<13	13		47			<0.15		
Silage		2	<3.1	<3.1		28					
Silage	max		<3.2	<3.2		31					
Soil		3							3.8		
Soil	max								5.0		
Sediment	Canal	2[E]		29		24		<1.4	10		
Freshwater	River Taff upstream	2[E]		<14	<3.3	<3.6		<0.18	<0.20	<0.052	0.25
Freshwater	River Taff downstream	1[E]		<7.7	<3.1	<3.4		<0.18	<0.18	<0.050	0.19
Freshwater	River Taff surface water outfall	1[E]		49	29	<8.3		<0.17	<0.25	<0.071	0.14
Freshwater	Canal	2[E]		<11	4.8	<3.8		<0.17	<0.19	<0.059	<0.092
Crude effluent	Cardiff East WWTW	1[E]	<7.5	<7.5	<3.5			<5.0	<0.18		
Final effluent	Cardiff East WWTW	1[E]	<8.1	<8.1	<3.4			<6.9	<0.33		

[a] *Except for milk, water and effluent where units are Bq l^{-1} and for sediment and sludge pellets 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 5.7 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 <0.52 (max <0.55) 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, 2013

Location	Ground type type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	2	0.081
West of Pipeline	Mud and sand	2	0.10
Peterstone Wentlooge	Mud	1	0.087
Peterstone Wentlooge	Mud and salt marsh	1	0.092

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 the LLWR near Drigg in Cumbria, as well as other landfill sites which have received small quantities of solid wastes and (ii) other sites where industries or incidents may have introduced radioactivity into the environment.

7.1 Low Level Waste Repository near Drigg, Cumbria

The Low Level Waste Repository (LLWR) is the UK's national low level waste disposal facility and is located on the west Cumbrian coast, approximately 7 km south east of Sellafield. The main function of the LLWR is to receive low-level solid radioactive wastes from all UK nuclear licensed 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 and expects to report on this in 2014. The operators have applied for a permit for disposal into vault 9 to operate in accordance with their latest ESC and to implement closure engineering. The Environment Agency has begun a consultation on their application and expects to reach a decision by the end of 2014 (Environment Agency, 2014).

Key points

LLWR, near Drigg

- Operators have applied for an extension to their permit for disposal
- Concentrations and dose rates at the LLWR were similar to those in 2012
- Doses 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
- Baseline monitoring relating to the disposal of LLW at Kings Cliffe began and showed similar results to other landfill sites
- Very small discharges from the Studsvik Metals Recycling Facility were made in 2013
- Enhancement in natural radionuclides at Whitehaven from phosphate processing is 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 6 per cent of the dose limit
- The investigation into the radium-226 contamination at Dalgety Bay, Fife continued in 2013
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in regulations. Limited monitoring of such sites was undertaken and no significant effects were found

The current 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 2013, be distinguished from those due to Sellafield. A new habits survey was published in 2013 and the results have been included in the dose assessments for the site (Clyne *et al.*, 2013c).

Small disposals of solid radioactive waste were made at the LLWR in 2013. The low volume of disposals in recent years is a consequence primarily of national efforts to divert LLW to alternative treatment or disposal routes. Waste may continue to be disposed in Vault 8 in accordance with the Environmental Permit and the National LLW-Strategy. Future waste disposals will depend on the completion of the ESC review process and the subsequent permitting of any future disposal capacity.

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 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 2012. 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 2013 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 just above the relevant WHO screening limit. Concentrations of tritium were close to the limit of detection.

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 2013 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 2013, as it was in 2012. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 2). However, elevated concentrations of plutonium-239+240, plutonium-238 and americium-241, were detected in one sheep sample (muscle and offal) in 2013. The *total dose* from all pathways and sources, including a component due to Chernobyl and weapon test fallout, was 0.061 mSv, or 6 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 most exposed person was children aged 1 year spending time near the site. Their *total dose* in 2013 was 0.037 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 0.015 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 2013 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4.

The results, in common with previous years, showed evidence for migration of tritium from some of the disposal 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.

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 DECC's website: https://www.gov.uk/government/policies/managing-the-use-and-disposal-of-radioactive-and-nuclear-substances-and-waste/supporting-pages/providing-policy-for-the-safe-and-secure-disposal-of-radioactive-waste.

In England and Wales, disposal of LLW at landfill sites requires both landfill companies and nuclear operators to hold permits to dispose of LLW. The 2007 Government policy led to applications from landfill operators for permits to dispose of LLW at their sites. The landfill sites were:

- Waste Recycling Group (WRG) Limited at the Lillyhall Landfill Site in Cumbria. Their permit, issued in 2011, allows them to dispose of VLLW
- Augean at the East Northants Resource Management Facility, near Kings Cliffe, Northamptonshire. Their

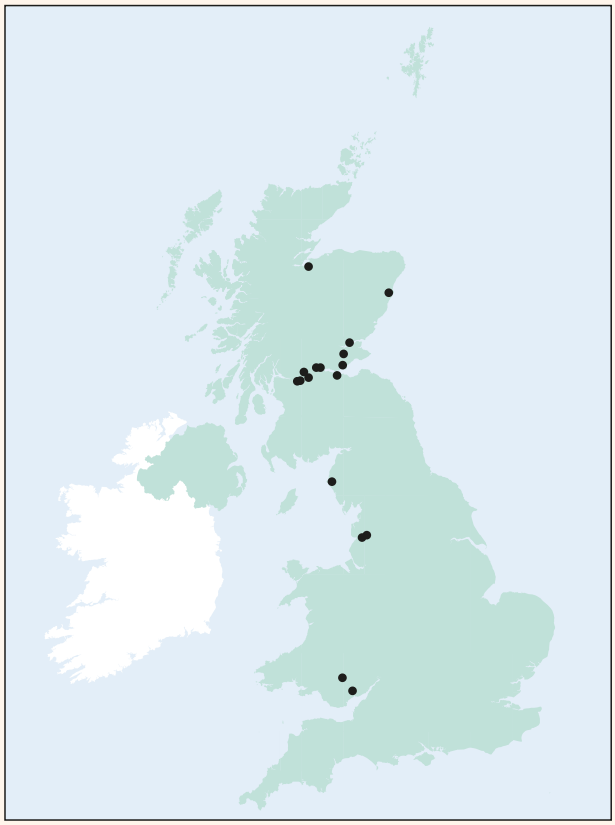


Figure 7.1. Landfill sites monitored in 2013

permit, issued in 2011, allows them to dispose of low activity LLW and VLLW.

- Sita (Lancashire) Limited at Clifton Marsh in Lancashire. They received a permit to dispose of LLW in September 2012. This permit replaced previous arrangements authorising disposals at Clifton Marsh by operators at the Springfields and Capenhurst nuclear licensed sites, whose permits used to allow disposal of solid LLW at Clifton Marsh in their own right. The varied permits now allow those operators to transfer LLW to landfill operators who hold an appropriate EPR 10 permit.

Disposals of LLW at Clifton Marsh have continued under the new permitting arrangements.

Disposals of LLW at the Augean site began in December 2011 and were from non-nuclear site remediation works. The first consignment from a nuclear licensed site was from Harwell in March 2012 this comprised soil, concrete, rubble and clay pipes from the drains on the Harwell site. In parallel, the Environment Agency began a programme of monitoring within and around the Augean landfill site in order to provide a baseline and allow any future changes to be detected. The Environment Agency carried out independent environmental monitoring at and around the East Northants Resource Management Facility (ENRMF), close to the village of King's Cliffe during 2012 and 2013. Samples were taken and analysed for radiological composition from both upstream and downstream groundwater boreholes, off-site watercourses, on-site surface water, on-site leachate and on-site soil.

The 2012 – 2013 monitoring was carried out to establish a comprehensive baseline. Tests in subsequent years will be compared to identify any noticeable radiological impact on the environment from the activities carried out at ENRMF. However the scope of future testing will be more targeted to key areas and may not include leachate testing which is replicated by the operator as part of their Environment Agency permit. The results may also serve to provide reassurance that radionuclides from LLW disposals are adequately contained within the landfill and doses to the public are insignificant and well as within the dose limits.

Samples of leachate, borehole water and surface water were taken and filtered. Both the filtrate and the particulate were analysed for their radioactivity content, along with some bulk water samples. The results for 2012 and 2013 are given in Tables 7.5 and 7.6. The results for man-made radionuclides were generally at limits of detection or at low levels expected due to UK-wide fallout from weapon testing and overseas accidents. Naturally occurring radionuclides were present at levels expected due to natural sources. Tritium was enhanced in a few samples as is found at other landfill sites. Elevated gross beta concentrations in water were observed in some samples. This is likely to be due to the presence of potassium-40 from natural sources.

In addition in 2013, the Environment Agency carried out some assurance monitoring and sampling of wastes at the Harwell site prior to dispatch to the Augean site. This work is also ongoing and will be reported in future years.

SEPA continued its programme of monitoring at the Stoneyhill Landfill Site in Aberdeenshire. The initial purpose of the programme was 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. However, the landfill has now started accepting conditioned NORM waste and the SEPA monitoring programme has been continued to gather further data. This programme is complementary to, but independent of, the operator's monitoring programme.

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 descales oil and gas industry equipment (such as pipes) using pressurised water. The solid scale removed from the equipment is then grouted into drums and can be 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 and analysing for radium-226 and radium-228, with results so far being close to or at the limit of detection (Table 7.7). The programme has also been extended to include final effluent from Nigg STW and seawater from the surrounding area since Stoneyhill landfill started to send their leachate by tanker to Nigg STW for treatment and subsequent release into the environment as part of the STW final treated effluent.

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 2013 (Appendix 2). The permit includes conditions requiring Studsvik UK Limited to monitor discharges and undertake environmental monitoring.

7.4 Phosphate processing, Whitehaven, Cumbria

An important historic 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 (Rollo *et al.*, 1992). 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 2013 are shown in Table 7.8. 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 generally decreased since 1998. Concentrations in the early 1990s were in excess of 100 Bq kg^{-1} (fresh weight). There were some variations in concentrations of polonium-210 in local samples in 2013 compared with 2012. In particular, concentrations in crab at Parton and Sellafield decreased below the expected background concentrations. Taking into account the ranges of values observed, it is now difficult to distinguish between the measured radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. The latter are shown in Figures 7.2 and 7.3 and in Appendix 1 (Annex 4). There were small enhancements for some samples at other locations 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 considered prudent to continue to estimate doses at Whitehaven based on the positive difference, if any, between observed concentrations and median levels indicative of natural background. A recent analysis has confirmed that this approach is unlikely to underestimate doses (Dewar *et al.*, 2014).

The critical radiation exposure pathway considered for the assessment at Whitehaven was internal irradiation, due to the ingestion of naturally occurring radioactivity in local fish and shellfish. The most exposed consumer was the representative person who, centred on the Sellafield site to the south of Whitehaven, obtained their sources of seafood from locations such as Whitehaven, Saltom Bay and Parton. This consumer is also considered in the assessment of the marine impacts of the Sellafield and LLWR (near Drigg) sites (Sections 2 and 7). An additional, smaller area limited to Saltom Bay is no longer assessed separately because the larger area provides adequate protection and a more robust assessment. The estimated

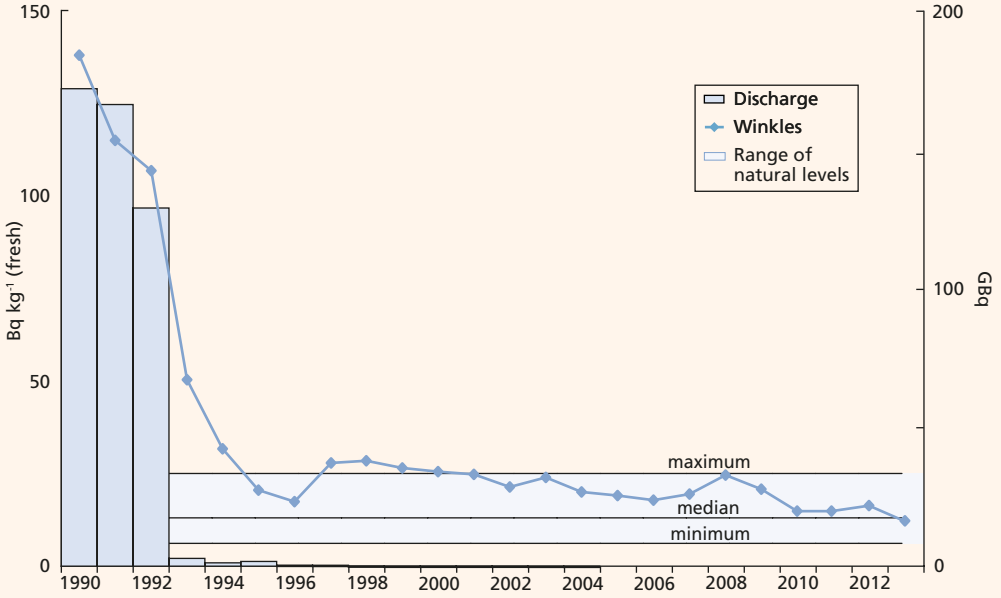


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2013

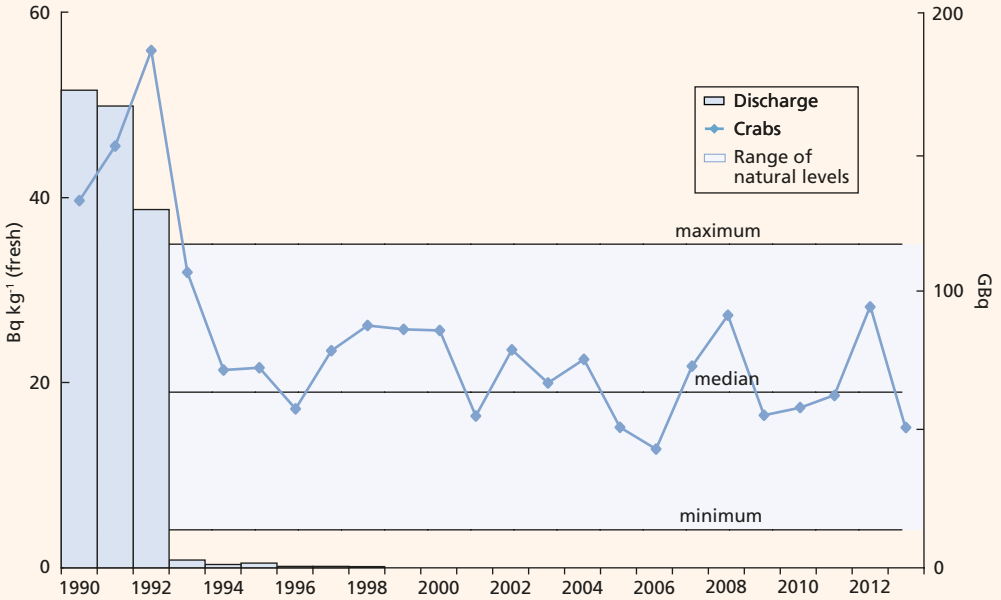


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2013

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 2013. 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 a local high rate consumer of seafood was 0.061 mSv in 2013 (Table 7.1), below the dose limit for members of the public of 1 mSv. The value for 2012 was 0.30 mSv in 2012. 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 a high-rate seafood consumer confirms the *total dose* assessment and gives a higher result in 2013, 0.18 mSv. The higher result is due to the method used to add contributions to the dose from consumption of different species of seafood. The source specific assessment conservatively assumes that high rate consumption of all seafood species can be combined additively. In reality, the consumption survey's evidence is that this does not take place to the extent assumed. The additivity found in practice is estimated more realistically in the *total dose* method.

The contribution to the *total dose* from enhanced natural radionuclides was 0.021 mSv in 2013, compared with 0.22 mSv in 2012. This large drop in dose was due to (i) reductions in concentrations of polonium-210 from

Whitehaven discharges in fish and crustaceans, and (ii) a smaller range of seafood species consumed by individuals at high rates. With these changes, the largest contribution to dose to a seafood consumer near Whitehaven is now from Sellafield discharges. The longer term trend in dose, shown in Figure 7.4, is one of a steady reduction in exposures.

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.

As reported in RIFE-17 Scotoil ceased the discharging of solid waste to sea in October 2011 upon the development of a waste treatment facility, however liquid effluent to sea continues to be discharged in accordance with their authorisation. 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.

In March 2013 Scotoil applied to SEPA to vary its authorisation to allow NORM-contaminated waste to be received from other premises for the purposes of conditioning and disposal and NORM-contaminated wastes in the form of sludges, sands and waxes to be received for the purposes of repackaging and disposal. SEPA granted the variation, subject to additional conditions, in June 2013.

Seaweed (*Fucus vesiculosus*) from Aberdeen Harbour was monitored in 2013. Technetium-99 was detected in seaweed (15 Bq kg^{-1}, fresh), in line with the expected effect from Sellafield discharges (as the releases become diluted or mixed in moving further afield). Gamma-emitting radionuclides were all below the LoD. In 2013, the dose rate on sediment was 0.093 µGy h^{-1} and similar to background. The dose rate was lower than the results in earlier years when discharges were higher.

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. The contamination is associated with historical 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.

Following the increased number of particle finds and the discovery of the high activity particles in 2011, additional public protection measures were established and these

Figure 7.4. Trend in *total dose* to seafood consumers from naturally-occurring radionuclides near Whitehaven, 2004-2013

were maintained during 2013 and into 2014. A monthly beach monitoring and particle recovery programme was adopted in 2012 by a contractor working on behalf of the MoD and this remains in place. The fence demarcating the area where the highest activity particles were discovered remains in place, as well as the information signs advising the public of the contamination and precautions to be taken. In addition, the FEPA Order issued by the Food Standards Agency in Scotland prohibiting the collection of seafood from the Dalgety Bay area remains in force. SEPA undertook a programme of shellfish monitoring between February 2012 and February 2013 during which no particles were detected in the shellfish. All shellfish samples collected were analysed for the presence of radium-226 and all were found to be less than the LoD. The continuation of these protection measures is reducing the risks to members of the public whilst further work continues to address the contamination.

Following the publication of the risk assessment together with the appropriate persons report in 2013, COMARE recommended at its meeting in July 2013 that effective remediation of the affected area is undertaken as soon as is possible. This recommendation, amongst others, was subsequently published in May 2014 in COMARE's 15th report. The MoD has progressed with addressing the contamination by initially publishing its Outline Management Options Appraisal Report in January 2014 followed by the publication in July 2014 of its broad management strategy and timescale for implementation of its preferred management option. Copies of these reports are available on the UK Government website.

In March 2014 SEPA requested advice from Public Health England (PHE) on the target levels of radioactive contamination for Dalgety Bay following any remediation of the affected area. In April 2014 PHE provided the requested advice in the form of remediation criteria which are summarised as follows:

Criterion 1

PHE advised that all efforts should be made to ensure that objects that could give rise to a committed effective dose of 100 mSv to an individual, regardless of object size, or an external dose of 1 Gy h^{-1}, averaged over an area of 1 cm^2 skin at a depth of 70 microns, are either removed or isolated so that there is no credible current or future mechanism for exposure.

In terms of activity, a criterion for the radium-226 activity content for any single object of 20 - 40 kBq detected in recovered material is recommended as a cautious indicative value corresponding to a committed effective dose of 100 mSv to an individual. Additionally, a criterion for the radium-226 activity content for any single object of 1 - 2 MBq detected in recovered material is recommended as an indicative value corresponding to the 1 Gy h^{-1} criterion.

Criterion 2

PHE advised that contaminated objects remaining after application of Criterion 1 should be either removed or isolated so that the current or future probability of an individual receiving 1 mSv committed effective dose is less than 10^{-6} per year. In addressing this criterion, optimisation should be carried out so that increasing weight is given to management options that remove or isolate objects of increasingly high activity.

In terms of activity, it is recommended that a radium-226 activity content for an object of 1 kBq is adopted as an indicative value corresponding to a committed effective dose of 1 mSv to an individual and 10 kBq for a committed effective dose of 10 mSv.

Work continues towards the implementation of the preferred management option with the convening of the Dalgety Bay Implementation Group. The Dalgety Bay Permitting Authorities Group has also been convened to ensure that any permits or licences required to proceed with the management option can be in place to allow the addressing of the contamination.

For further information on the work at Dalgety Bay please visit the Radioactive Substances pages on SEPA's website (www.sepa.org.uk).

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 7.9 and 7.10. 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)
- 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 licensed site operations detect the effects of discharges from the non-nuclear sector and, when this occurs, a comment is made in the relevant nuclear licensed 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 2013, 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 7.11 and show the expected effects of Sellafield discharges at this distance. The results were generally similar to those in 2012. An assessment of the dose to a representative high-rate mollusc consumer was undertaken. The dose was less than 0.005 mSv or less than 0.5 per cent of the dose limit.

Table 7.1. Individual doses – industrial and landfill sites, 2013

Site	Representative person[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**							
Whitehaven and LLWR near Drigg	**Adult fish consumer**	**0.061**[d]	**0.026**	**0.021**	**–**	**0.014**	**–**
Source specific doses							
LLWR near Drigg	Infant consumer of locally grown food	0.015	–	–	0.015	–	–
	Consumer of water from Drigg stream	<0.005	–	–	–	–	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumer[c]	<0.005	–	–	–	–	<0.005
Whitehaven (habits averaged 2009-13)	Seafood consumer[d]	0.18	0.085	0.060	–	0.037	–

[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 people 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, 2013

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<2.4	31	<0.07	0.028	<0.32	<0.23	<0.020	<0.61	<0.15
Blackberries		1	<3.5	24	<0.05	0.097	<0.07	<0.10		<0.37	<0.12
Cabbage		1	<2.4	11	<0.05	0.14	<0.06	<0.08	<0.11	<0.34	<0.09
Deer muscle		1	<2.9	30	<0.06	<0.042	<0.09	<0.12	<0.12	<0.43	<0.09
Eggs		1	<2.7	51	<0.06	<0.046	<0.08	<0.08		<0.33	<0.11
Potatoes		1	<3.9	27	<0.05	0.031	<0.19	<0.15	<0.35	<0.55	<0.17
Rabbit		1	<3.0	7.9	<0.06	<0.042	<0.15	<0.16	<0.11	<0.43	<0.11
Sheep muscle		1	<4.2	46	<0.09	<0.042	<0.14	<0.18	<0.12	<0.45	<0.12
Sheep offal		1	<3.3	33	<0.08	<0.041	<0.12	<0.16	<0.12	<0.43	<0.14
Swede		1	<2.7	16	<0.05	0.17	<0.07	<0.10		<0.65	<0.11
Grass		2							<0.25		
Grass	max								<0.26		
Sediment	Drigg Stream	4[E]			<0.33	<3.0	<0.25	<0.78		<2.7	<1.4
Freshwater	Drigg Stream	4[E]	<4.0		<0.24	<0.060	<0.25				
Freshwater	Railway drain	1[E]	3.7		<0.20	0.42					

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th	^{234}U
Milk		1	<0.011	<0.07	<0.13	<0.41					
Blackberries		1	<0.046	<0.06	<0.05	<0.26					
Cabbage		1	<0.034	<0.05	0.22	<0.22					
Deer muscle		1	<0.047	<0.07	0.98	<0.27					
Eggs		1	<0.017	<0.05	<0.05	<0.33					
Potatoes		1	<0.046	<0.06	0.40	<0.39					
Rabbit		1	<0.041	<0.05	3.4	<0.35					
Sheep muscle		1	<0.047	<0.07	0.63	<0.32					
Sheep offal		1	<0.052	<0.06	0.49	<0.35					
Swede		1	<0.059	<0.05	0.17	<0.26					
Grass		2									0.012
Grass	max										0.018
Soil		1									10
Sediment	Drigg Stream	4[E]		<0.31	160	<1.8	7.2	17	13	13	50
Freshwater	Drigg Stream	4[E]		<0.25	<0.20		<0.0031	<0.0046	<0.0039	<0.0023	0.010
Freshwater	Railway drain	1[E]		<0.22	<0.17						0.015

Material	Location or selection[a]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1			<0.000034	<0.000049	<0.13	<0.000057		
Blackberries		1			<0.00012	<0.00011	<0.25	0.00062		
Cabbage		1			<0.00012	<0.00019	<0.28	<0.00013		
Deer muscle		1			<0.000047	<0.000063	<0.23	0.00016		
Eggs		1			<0.000057	0.00014	<0.44	0.000088		
Potatoes		1			0.00010	0.00098	<0.19	0.0014		
Rabbit		1			<0.000049	0.000062	<0.19	0.000083		
Sheep muscle		1			0.018	0.10	<0.22	0.19		
Sheep offal		1			0.0049	0.030	<0.24	0.047		
Swede		1			<0.000099	<0.00018	<0.32	0.000043		
Grass		2	<0.00039	0.011						
Grass	max		<0.00048	0.016						
Soil		1	0.33	11						
Sediment	Drigg Stream	4[E]	<2.9	48	6.5	44	170	55	200	620
Freshwater	Drigg Stream	4[E]	<0.0024	<0.0084	<0.0039	<0.0036	<0.17	<0.0071	<0.088	0.39
Freshwater	Railway drain	1[E]	<0.0025	0.015	<0.0034	<0.0033	<0.18	<0.0065	<0.10	1.3

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

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

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

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

Table 7.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2013

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	12	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	58	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	360	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	18	<15	<0.05	<0.05
Dunbartonshire	Birdston	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	73	<15	<0.05	<0.05
Fife	Melville Wood	1	180	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	200	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	160	<15	<0.05	<0.05

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2013

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			Total ^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{137}Cs	^{228}Th
Glamorgan									
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	1000	900	<3.6				
Trecatti Landfill, Merthyr Tydfil	Treated leachate	2	1200	1000	<3.3				
Lancashire									
Clifton Marsh	Borehole 6	2		<3.5		<3.9	<0.22	<0.19	<0.0051
Clifton Marsh	Borehole 19	2		<3.6		<4.6	<0.24	<0.20	<0.0041
Clifton Marsh	Borehole 40	2		<3.5		<4.3	<0.23	<0.20	<0.0053
Clifton Marsh	Borehole 59	2		5.8		<6.5	<0.35	<0.29	<0.0053
Ulnes Walton	Pond	1		<3.2		<4.5	<0.25	<0.20	<0.0017
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2		9.0	<3.1	<6.4	<0.35	<0.28	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Lancashire									
Clifton Marsh	Borehole 6	2	<0.0047	<0.0018	<0.0048	<0.0022	<0.0045	<0.19	2.0
Clifton Marsh	Borehole 19	2	<0.0058	<0.0027	0.045	<0.0033	0.040	<1.3	6.0
Clifton Marsh	Borehole 40	2	<0.0034	<0.0019	<0.0052	<0.0014	<0.0040	<0.13	1.4
Clifton Marsh	Borehole 59	2	<0.0026	<0.0015	<0.0037	<0.0041	<0.0044	<0.24	1.7
Ulnes Walton	Pond	1	<0.0029	<0.0011	0.32	0.015	0.31	0.49	0.52
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2						<0.16	0.60

[a] *As tritiated water*

[b] *The concentrations of ^{125}I and ^{131}I were <0.21 and <0.36 Bq l^{-1} respectively*

Table 7.5. Concentrations of radionuclides in leachate and water near the East Northants Resource Management Facility landfill site, 2012

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{3}H	^{40}K	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th
A1 Leachate	100	450	<0.1	0.22	0.023	<0.01	<0.01
A2 Leachate	980	54	<0.1	0.04	0.017	<0.01	<0.01
B1 Leachate	110	300	1.4	0.39	0.036	<0.01	<0.01
05 Groundwater borehole	<4	<1	<0.1	<0.03	<0.01	<0.01	<0.01
06A Groundwater borehole	<4	2.8	<0.1	0.11	0.10	0.074	0.08
07 Groundwater borehole	<4	<1	<0.1	0.03	0.037	<0.01	<0.01
08 Groundwater borehole	<4	<2	<0.1	<0.03	<0.01	<0.01	<0.01
11 Groundwater borehole	<4	<1	<0.1	<0.03	0.01	<0.01	0.012
12 Groundwater borehole	<4	<1	<0.1	0.02	0.015	0.016	0.013
13A Groundwater borehole	<4	7.8	<0.1	0.15	0.60	0.19	0.56
15A Groundwater borehole	<4	13	<0.1	0.08	0.26	0.16	0.27
17 Groundwater borehole	<4	<1	<0.1	0.03	0.043	0.035	0.045
01 Upstream groundwater borehole	<4	<2	<0.1	<0.03	0.038	0.021	0.034
On site surface water	<4	13	<0.1	<0.03	0.011	<0.01	<0.01
On site pond Surface water	<4	2.3	<0.1	<0.03	<0.01	<0.01	<0.01
Horse Water spring	<4	<1	<0.1	<0.03	<0.01	<0.01	<0.01
Willow brook	<4	<2	<0.1	<0.03	<0.01	<0.01	<0.01
South of site Soil	<4	510	2.9	27	27	20	32
West of site soil	<4	500	4.2	34	34	31	38

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239/240}$Pu	Gross alpha	Gross beta
A1 Leachate	0.03	<0.01	0.025	<0.01	<0.01	2.4	390
A2 Leachate	0.038	<0.01	<0.01	<0.01	<0.01	0.70	41
B1 Leachate	0.011	<0.01	0.01	<0.01	<0.01	<2	228
05 Groundwater borehole	0.021	<0.01	0.021	<0.01	<0.01	0.077	0.11
06A Groundwater borehole	0.074	<0.01	0.076	<0.02	<0.01	2.8	2.2
07 Groundwater borehole	0.024	<0.01	0.021	<0.01	<0.01	0.41	0.18
08 Groundwater borehole	0.022	<0.01	0.01	<0.01	<0.01	0.095	0.085
11 Groundwater borehole	0.021	<0.01	0.021	<0.01	<0.01	0.12	0.16
12 Groundwater borehole	0.021	<0.01	0.021	<0.01	<0.01	0.20	0.17
13A Groundwater borehole	0.13	0.012	0.15	<0.01	<0.01	6.4	6.0
15A Groundwater borehole	0.055	<0.01	0.058	<0.02	<0.01	12	10
17 Groundwater borehole	0.04	<0.01	0.035	<0.01	<0.01	1.0	0.78
01 Upstream groundwater borehole	0.017	<0.01	<0.023	<0.01	<0.01	0.53	0.46
On site surface water	0.02	<0.01	0.014	<0.01	<0.01	0.35	11
On site pond Surface water	0.076	<0.01	0.06	<0.01	<0.01	0.17	1.2
Horse Water spring	0.013	<0.01	0.012	<0.01	<0.01	0.076	2.0
Willow brook	0.01	<0.01	0.01	<0.01	<0.01	<0.037	0.23
South of site Soil	25	1	27	<2	<3	590	500
West of site soil	23	1	31	<2	<3	600	580

[a] *Except for ^{3}H where units are Bq l^{-1}, and soil where dry concentrations apply*

Table 7.6. Concentrations of radionuclides in water, particulate and soil near the East Northants Resource Management Facility landfill site, 2013[a]

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{3}H	^{40}K	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th
A1 Leachate (Filtrate)	36	89	<0.1	<0.025	<0.01	<0.01	<0.01
A2 Leachate (Filtrate)	36	19	<0.1	<0.025	<0.01	<0.01	<0.01
06A Groundwater borehole (Filtrate)	<4	<1	<0.1	<0.025	<0.01	<0.01	<0.01
13A Groundwater borehole (Filtrate)	<4	<1	<0.1	<0.025	<0.01	<0.01	<0.01
15A Groundwater borehole (Filtrate)	<4	<1	<0.1	<0.025	<0.01	<0.01	<0.01
01 Upstream groundwater borehole (Filtrate)	<4	<2	<0.1	<0.025	<0.01	<0.01	<0.01
On site Surface water (Filtrate)	<4	33	<0.1	<0.025	<0.01	<0.01	<0.01
Horse Water Spring (Filtrate)	<4	<1	<0.1	<0.025	<0.01	<0.01	<0.01
Willow Brook (Filtrate)	<4	<2	<0.1	<0.025	<0.01	<0.01	<0.01
A1 Leachate (Particulate)		<500	<20	<32	<8.2	<4	<9
A2 Leachate (Particulate)		1400	<20	<120	<15	<8.1	<8.1
06A Groundwater borehole (Particulate)		<500	<50	57	15	16	29
13A Groundwater borehole (Particulate)		<500	<50	<20	42	18	39
15A Groundwater borehole (Particulate)		<500	<10	17	35	23	38
01 Upstream groundwater borehole (Particulate)		<500	<50	89	<15	9.7	15
On site Surface water (Particulate)		<2000	<60	<53	31	<10	37
Horse Water Spring (Particulate)		<5000	<200	<450	<120	<19	<19
Willow Brook (Particulate)		<10000	<500	<1100	<225	<120	<120
B1 Leachate (Bulk)	49	130	<0.1	0.12	0.013	<0.1	<0.1
05 Groundwater borehole (Bulk)	<4	<5	<0.1	<0.025	<0.1	<0.1	<0.1
07 Groundwater borehole (Bulk)	<4	<1	<0.1	<0.025	<0.1	<0.1	<0.1
08 Groundwater borehole (Bulk)	<4	<1	<0.1	<0.025	<0.1	<0.1	<0.1
11 Groundwater borehole (Bulk)	<4	<1	<0.1	<0.025	<0.1	0.01	0.01
12 Groundwater borehole (Bulk)	<4	<1	<0.1	<0.025	0.016	<0.1	0.015
17 Groundwater borehole (Bulk)	11	<1	<0.1	<0.025	0.013	0.014	0.01
On site pond Surface water (Bulk)	<4	<2	<0.1	<0.025	<0.1	<0.1	<0.01
South of site Soil	<4	550	2.9		20	6.1	17
West of site soil	<4	480	3.4		28	4.4	25

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239/240}$Pu	Gross alpha	Gross beta
A1 Leachate (Filtrate)	0.11	<0.01	0.11	<0.01	<0.01	<2.4	70
A2 Leachate (Filtrate)	0.052	<0.01	0.05	<0.01	<0.01	0.12	14
06A Groundwater borehole (Filtrate)	0.025	<0.01	0.025	<0.01	<0.01	0.099	0.22
13A Groundwater borehole (Filtrate)	0.036	<0.01	0.034	<0.01	<0.01	0.12	0.22
15A Groundwater borehole (Filtrate)	0.024	<0.01	0.017	<0.01	<0.01	0.06	0.081
01 Upstream groundwater borehole (Filtrate)	0.028	<0.01	0.021	<0.01	<0.01	<0.096	<0.21
On site Surface water (Filtrate)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.55	27
Horse Water Spring (Filtrate)	0.03	<0.01	0.013	<0.01	<0.01	0.026	0.34
Willow Brook (Filtrate)	0.018	<0.01	0.013	<0.01	<0.01	0.028	0.29
A1 Leachate (Particulate)	23	<10	25			98	170
A2 Leachate (Particulate)	23	<5	<5			150	590
06A Groundwater borehole (Particulate)	<15	<5	<5			260	88
13A Groundwater borehole (Particulate)	16	<5	12			510	310
15A Groundwater borehole (Particulate)	11	<5	14			350	240
01 Upstream groundwater borehole (Particulate)	10	<5	11			490	330
On site Surface water (Particulate)	<30	<15	25			300	350
Horse Water Spring (Particulate)	<150	<60	<190			580	530
Willow Brook (Particulate)	<280	<100	<400			1600	930
B1 Leachate (Bulk)	0.034	<0.01	0.023	<0.1	<0.1	<1.9	110
05 Groundwater borehole (Bulk)	0.025	<0.01	0.02	<0.1	<0.1	0.087	0.094
07 Groundwater borehole (Bulk)	0.018	<0.01	0.018	<0.1	<0.1	0.086	0.25
08 Groundwater borehole (Bulk)	0.017	<0.01	0.015	<0.1	<0.1	0.11	0.13
11 Groundwater borehole (Bulk)	0.017	<0.01	0.016	<0.1	<0.1	0.12	0.27
12 Groundwater borehole (Bulk)	0.023	<0.01	0.019	<0.1	<0.1	0.36	0.67
17 Groundwater borehole (Bulk)	0.079	<0.01	0.063	<0.1	<0.1	0.43	0.55
On site pond Surface water (Bulk)	0.06	<0.01	0.058	<0.1	<0.1	0.094	0.82
South of site Soil	15	<1	12	<2	<2	570	680
West of site soil	17	<1	13	<2	<2	720	600

[a] *The particulate activity results are from a surface leach not total dissolution of the sample. Typical particulate concentrations in sample leaches were between 0.007–2.066 g l^{-1}, with a small amount of particulate activity per litre of sample*

[b] *Except for ^{3}H where units are Bq l^{-1}, and particulate where dry concentrations apply*

Table 7.7. Concentrations of radionuclides in water and effluent near the Stoneyhill Landfill site and the associated Nigg Sewage Treatment Works, Aberdeenshire, 2013

Sample location and type	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}	
		^{226}Ra[a]	^{228}Ra[b]
Stoneyhill Landfill			
Borehole 50 (Groundwater)	4	0.32	0.56
Borehole 78 (Groundwater)	4	<0.06	<0.15
Laeca Burn, adjacent to site (Surface water)	4	<0.06	<0.12
Laeca Burn, downstream of site (Surface water)	4	<0.07	<0.17
Laeca Burn, upstream of site (Surface water)	4	<0.06	<0.14
Leachate collection tank (Leachate)	4	<0.07	<0.15
Nigg Bay Sewage Treatment Works			
Aberdeen beach (Seawater)	6	<0.08	<0.18
Cove Bay (Seawater)	6	<0.06	<0.12
Gregg Ness (Seawater)	6	<0.07	<0.15
Greyhope Bay (Seawater)	6	<0.07	<0.17
Nigg Bay (Seawater)	6	<0.07	<0.16
Nigg Bay Sewage Treatment Works (Final Effluent)	6	<0.06	<0.13

a *^{226}Ra activity based on ^{214}Pb activity*
b *^{228}Ra activity based on ^{228}Ac activity*

Table 7.8. Concentrations of naturally occurring radionuclides in the environment, 2013

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	16	1.6						
Winkles	Parton	4	12	1.2	0.58	0.58	0.34	1.2	0.034	1.0
Winkles	North Harrington	1	10							
Winkles	Nethertown	4	14							
Winkles	Drigg	1			0.56	0.48	0.33			
Winkles	Tarn Bay	1	14							
Mussels	Parton	4	36	1.6						
Mussels	Nethertown	2	28	2.0						
Limpets	St Bees	2	18							
Cockles	Ravenglass	2	18							
Crabs	Parton	4	15	0.080	0.14	0.011	0.0056	0.051	0.0025	0.045
Crabs	Sellafield coastal area	4	14	0.23						
Lobsters	Parton	4	12	<0.0079	0.037	0.012	0.0078	0.025	0.00052	0.020
Lobsters	Sellafield coastal area	4	11	<0.0090						
Cod	Parton	2	0.99	0.045	0.046	<0.00017	<0.000080	0.0054	0.00017	0.0048
Plaice	Whitehaven	1	1.5							
Other samples										
Winkles	South Gare (Hartlepool)	2	20	1.5						
Winkles	Kirkcudbright	1	4.3							
Mussels	Ribble Estuary	2			0.18	0.18	0.10			
Limpets	Kirkcudbright	1	2.7							
Cockles	Ribble Estuary	1			0.71	0.55	0.31			
Cockles	Southern North Sea	1			0.41	0.21	0.29			
Cockles	Flookburgh	2	18							
Crabs	Kirkcudbright	1	3.5							
Lobsters	Kirkcudbright	1	0.69							
Shrimps	Ribble Estuary	2			0.013	0.0055	0.0036			
Wildfowl	Ribble Estuary	1			0.0075	0.0091	0.0032			
Seaweed	Isle of Man	3						2.5	<0.25	2.2
Sediment	Kirkcudbright	1						14	0.42	14
Sediment	Balcary Bay	1						8.7	0.32	7.6
Sediment	Southerness	1	<0.17							

a *Except for sediment where dry concentrations apply*

Table 7.9. Discharges of gaseous radioactive wastes from non-nuclear establishments in the United Kingdom, 2013[a]

	Discharges during 2013, 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	1.6E+08						3.8E+13		1.8E+08
^{14}C	6.9E+07					4.7E+07	1.8E+13	5.0E+08	1.0E+10
^{18}F	7.3E+11						2.9E+11		
^{35}S	1.0E+03						1.0E+09		
^{41}Ar	1.7E+07								
^{85}Kr							1.2E+08		
^{99m}Tc				6.5E+08			6.2E+08		
^{106}Ru							2.6E+06		
^{125}I	2.5E+05			5.8E+07			2.8E+08		1.7E+06
^{129}I	1.0E+03								
^{131}I				7.5E+08			4.3E+08		
^{131m}Xe				1.3E+08					
^{133}Xe							6.7E+06		
^{137}Cs							1.9E+08		
^{222}Rn							8.0E+09		
Uranium Alpha							1.3E-01		
Plutonium Alpha							1.7E+02		
^{241}Am							3.1E+02		
Other Alpha particulate							1.2E+11		
Other Beta/Gamma					4.9E+11				
Other Beta/Gamma Particulate	6.9E+11		4.9E+10	3.8E+08		1.2E+09	7.9E+12		3.7E+10

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. England and Wales discharge data refers to 2012*

Table 7.10. Discharges of liquid radioactive waste from non-nuclear establishments in the United Kingdom, 2013[a]

	Discharges during 2013, Bq									
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)			Oil and gas (on-shore)
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Scotland	Northern Ireland	Scotland
^{3}H	3.4E+10	1.7E+05	6.5E+09	3.7E+08	2.7E+04	7.8E+07	9.1E+12	4.5E+09		
^{14}C	1.2E+09		2.0E+08	2.6E+07		1.2E+08	2.3E+11	2.7E+10	7.6E+05	
^{18}F	7.6E+11			2.5E+12	2.3E+08	3.6E+11	2.1E+12	8.0E+06		
^{22}Na	5.2E+06		1.0E+06					2.8E+06		
^{32}P	1.4E+10	5.0E+03	2.3E+09	7.8E+09		9.1E+08	6.3E+09	3.2E+08		
^{33}P	6.9E+08		1.1E+10				4.8E+09	2.1E+10		
^{35}S	1.2E+10		3.1E+09	3.2E+09			1.1E+10	2.5E+08		
^{51}Cr	2.1E+09		3.6E+07	4.5E+10	6.3E+05	2.2E+09	1.6E+09			
^{57}Co	9.5E+06			2.2E+04	5.0E+00		7.3E+02	1.0E+06		
^{58}Co					1.0E+01		2.7E+06			
^{60}Co	4.1E+02						1.5E+06			
^{67}Ga	6.3E+07			2.0E+10		2.0E+08	7.6E+08			
^{75}Se				2.4E+09	2.5E+04	6.1E+07	3.0E+07			
^{89}Sr	3.2E+06			1.2E+10		1.6E+08	4.3E+07			
^{90}Sr	1.4E+05						1.8E+07			
^{90}Y				3.8E+11	1.8E+04	4.9E+08		7.9E+07		
^{95}Nb	5.7E+02									
^{95}Zr	3.1E+02									
^{99}Tc	1.0E+06						3.5E+06			
^{99m}Tc	6.5E+09		4.6E+09	5.4E+13	1.9E+09	5.0E+12	8.2E+11			
^{111}In	1.3E+09		5.8E+06	3.9E+11	1.0E+07	4.0E+10	6.3E+09	3.9E+07		
^{123}I	3.5E+07		5.7E+07	1.3E+12	7.4E+07	1.2E+11	4.5E+10			
^{125}I	7.5E+09	1.3E+05	1.9E+08	1.3E+09	1.4E+04	3.3E+08	6.9E+10	1.1E+08	1.2E+03	
^{129}I							1.4E+03			
^{131}I	1.0E+06		3.2E+09	9.9E+12	5.0E+07	7.5E+11	1.0E+11			
^{134}Cs	1.9E+03						1.0E+07			
^{137}Cs	3.1E+07						2.8E+08			
^{144}Ce							2.4E+01			
^{153}Sm				5.8E+10						
^{201}Tl				7.4E+10		2.3E+10	1.9E+08			
^{210}Pb										1.7E+06
^{210}Po										1.7E+06
^{226}Ra										8.5E+08
^{228}Ra										1.3E+09
^{230}Th							1.0E+00			
^{232}Th							2.2E+09	1.2E+06		
Uranium Alpha							5.0E+09			
^{237}Np							3.5E+00			
^{241}Pu							1.6E+06			
Plutonium Alpha							1.4E+05			
^{241}Am	2.3E+03						3.0E+04			
Total Alpha	4.9E+06			8.7E+08			1.5E+10			
Total Beta/Gamma (Excl Tritium)	8.4E+11			6.4E+13			2.4E+12			
Other Alpha particulate	1.5E+02			3.0E+07			3.4E+03			
Other Beta/ Gamma[b]	4.4E+10		1.0E+11	1.6E+12	7.3E+01	9.9E+09	1.6E+09	2.7E+07		
Other Beta/Gamma particulate							5.1E+09			

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. England and Wales discharge data refers to 2012*

[b] *Excluding specific radionuclides*

Table 7.11. Monitoring in the River Clyde and near Glasgow, 2013[a]

Location	Material and selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[c], Bq kg^{-1}					
			^{3}H	^{14}C	^{32}P	^{54}Mn	^{90}Sr	^{99}Tc
Between Finlaystone and Woodhall	Mussels	1		<15	<3.0	<0.10		7.7
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1			<3.4	<0.10		31
14 km downstream of Dalmuir	Sediment	1		<17	<3.5	<0.10		
Downstream of Dalmuir	Freshwater	4			<0.062	<0.10		
River Clyde	Freshwater	4	<1.0				<0.0047	
Daldowie	Sludge pellets	4			<40	<0.10		

Location	Material and selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[c], Bq kg^{-1}					
			^{125}Sb	^{131}I	^{137}Cs	^{155}Eu	^{241}Am	Gross beta
Between Finlaystone and Woodhall	Mussels	1	<0.13	<0.62	0.68	<0.11	<0.10	
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1	<0.10	3.5	0.18	<0.10	<0.10	
14 km downstream of Dalmuir	Sediment	1	<0.24	<0.44	5.7	0.73	0.39	
Downstream of Dalmuir	Freshwater	4	<0.12	<0.60	<0.10	<0.12	<0.10	
River Clyde	Freshwater	4			<0.10			0.88
Daldowie	Sludge pellets	4	<0.28	250	3.4	<0.79	<0.37	

[a] *Results are available for other radionuclides detected by gamma spectrometry, All such results are less than the limit of detection*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima*
[c] *Except for water where units are Bq l^{-1}, and sludge pellets and sediment where dry concentrations apply*

8. Regional monitoring

Regional monitoring in areas remote from nuclear licensed sites has continued in 2013 (i) to establish long distance transport of radioactivity from UK and other nuclear licensed 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 routine component parts of this programme are:

- Channel Islands, the Isle of Man and Northern Ireland
- Overseas sources
- General diet
- Milk and crops
- Airborne particulates, rain, drinking water and groundwater
- Seawater and sediments

Key points

- Monitoring in areas remote from nuclear licensed sites continued (i) to establish the effect of long distance transport of radioactivity from UK and other nuclear licensed sites, (ii) to detect any 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 less than 2 per cent of the dose limit
- Contamination of fish in upland lakes with caesium-137 from the accident at Chernobyl in 1986 was detected but at concentrations now less than 10 per cent of those observed in the immediate aftermath of the accident. Restrictions of sheep movement on farms, due to Chernobyl caesium in sheep meat, has 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 in 2011 and no Fukushima Dai-ichi derived radioactivity was identified in the UK environment in 2013. Monitoring of imported food from Japan continued in 2013. No shipments were withdrawn because of high levels
- Monitoring at ports of entry to the UK for non-specific contamination detected no food shipments which required further investigation
- 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

8.1 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 8.1 shows analysis results for 2013. 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. It is generally difficult to attribute the results to different sources, including fallout from weapon testing, due to the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the dose to a representative person who consumes large amounts of fish and shellfish was carried out. In 2013, the representative person was estimated to receive less than 0.005 mSv, which is less than 0.5 per cent of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine

environment of the Channel Islands and the effects of discharges from local sources, therefore, continued to be of negligible radiological significance.

Milk and crop samples from the Channel Islands were also analysed. The results are included in Tables 8.2 and 8.3, respectively, and form part of the programmes considered in Sections 8.5 and 8.6.

8.2 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 8.4). The results complement the Isle of Man Government's own independent radiation monitoring programme 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 8.4).

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 licensed sites. The results demonstrate that there was no significant impact on Manx foodstuffs from the operation of mainland nuclear installations in 2013.

Table 2.18 shows radiation doses to people on the Isle of Man from different exposure pathways. The dose to a local person from consuming large amounts of food grown on the land monitored in 2013 was 0.017 mSv (0.008 mSv in 2012). This is less than 2 per cent of the dose limit for members of the public of 1 mSv. The observed increase in dose was mostly due to small increases in the increment in carbon-14 concentrations in food, and due to the inclusion of an americium-241 concentration at its limit of detection. The effects of liquid discharges from Sellafield into the Irish Sea are discussed fully in Section 2. The dose to a person consuming large quantities of Manx fish and shellfish was less than 0.005 mSv in 2013, which is unchanged from the 2012 dose. A resident that spends a typical amount of time on sandy beaches were assessed to receive 0.009 mSv from external exposure to radionuclides entrained on the sand.

8.3 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 8.1). The external exposure pathway is studied by monitoring gamma dose rates over intertidal areas. The results are presented in Tables 8.5(a) and (b).

In 2013, the main effect of discharges from Sellafield was observed in concentrations of technetium-99 in shellfish and seaweed samples. These were generally similar to those in 2012, reflecting the considerably decreased inputs to the Irish Sea in recent years (see also Section 2.3.3). Caesium-137 concentrations were low and similar to 2012 levels, and trace amounts of transuranic nuclides were detected. Observed concentrations were less than those found nearer to Sellafield and continued at the low levels seen in recent years (Figure 8.2). Further information on the trends in radioactivity in the marine environment of Northern Ireland is described in Ly *et al.,* (*in press*). 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 2013, the dose to the most exposed person was 0.010 mSv, which is 1 per cent of the dose limit for members of the public.

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

8.4 Overseas sources

Two overseas accidents have had direct implications for the UK: Chernobyl (1986) and Fukushima Dai-ichi (2011). Earlier RIFE reports have provided detailed results of monitoring by the environment agencies and the Food Standards Agency (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2013).

For Chernobyl, the main sustained impact on the UK environment has been in upland areas where heavy rain fell in the days following the accident. In particular, restrictions were put in place on moving, selling and slaughtering sheep from the affected areas to prevent

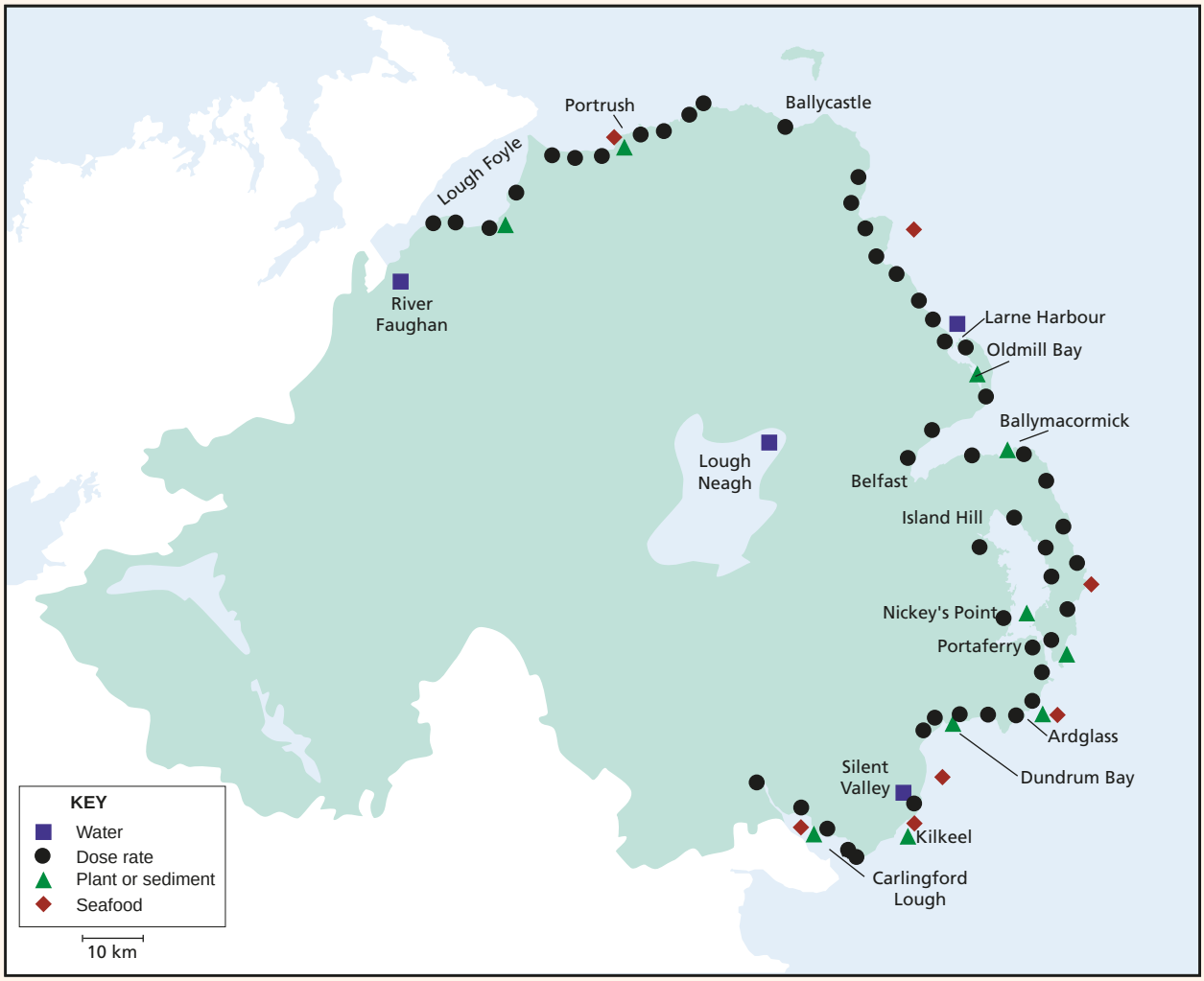


Figure 8.1. Monitoring locations in Northern Ireland, 2013

meat from 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.

All remaining restrictions in Northern Ireland were lifted in 2000 and the final controls were removed in Scotland in 2010. Following a review, including an assessment of the potential dose to people eating sheep meat, a public consultation and further consideration from the consultation (Food Standards Agency, 2012b), all remaining 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 are also obtained for comparison. Table 8.6 shows concentrations of caesium-134 and caesium-137 in fish in 2013. Other artificial radionuclides from the Chernobyl accident are no longer detectable. In 2013, the highest concentration of caesium-137 was 120 Bq kg^{-1} in perch from Devoke Water, similar to the value for 2012. 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 – 2013, are shown in Figure 8.3.

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 an adult subject to the highest exposure. In 2013, estimated doses were less than 0.1 mSv. 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.

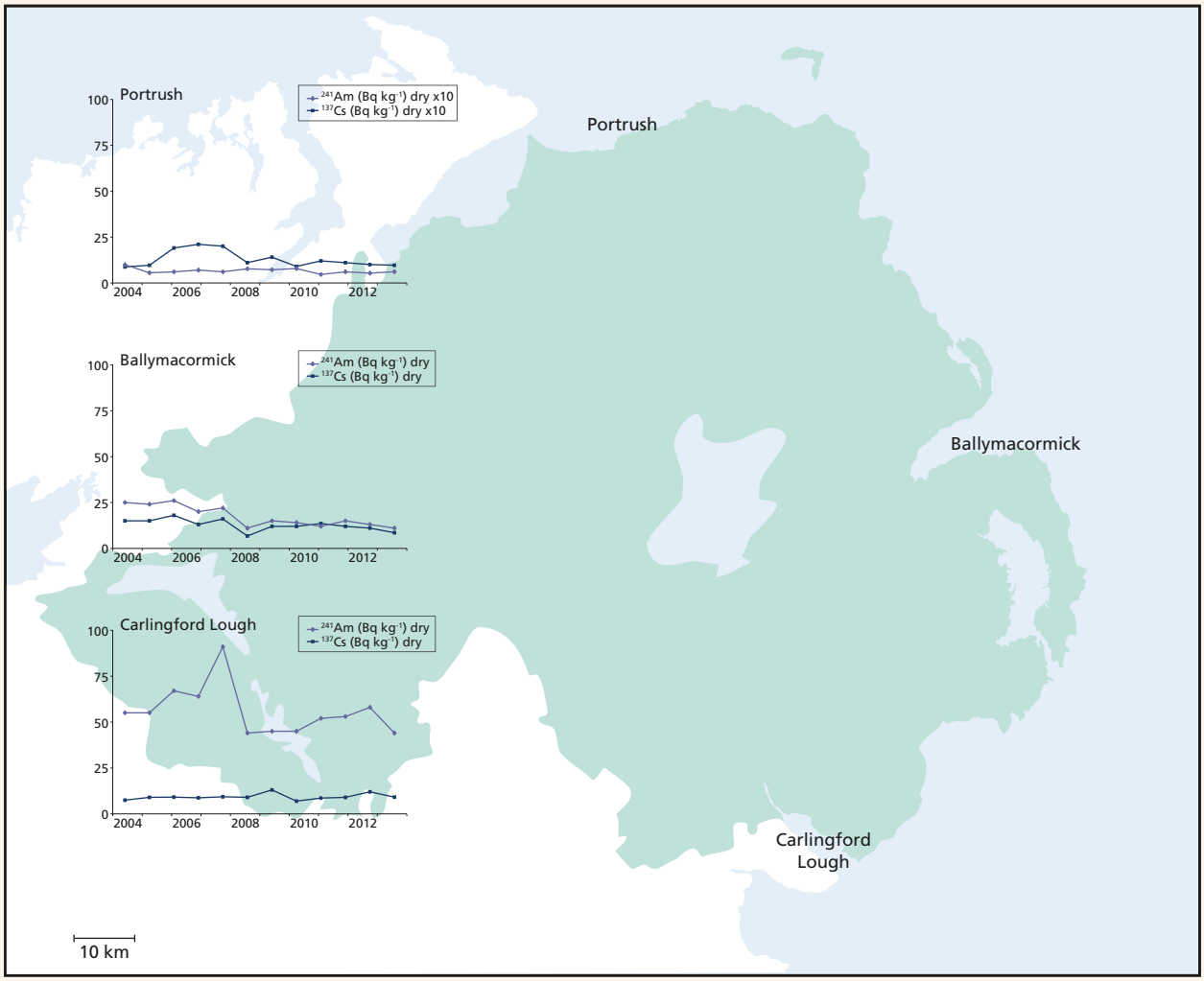


Figure 8.2. Concentrations of americium-241 and caesium-137 in coastal sediments in Northern Ireland, 2004-2013

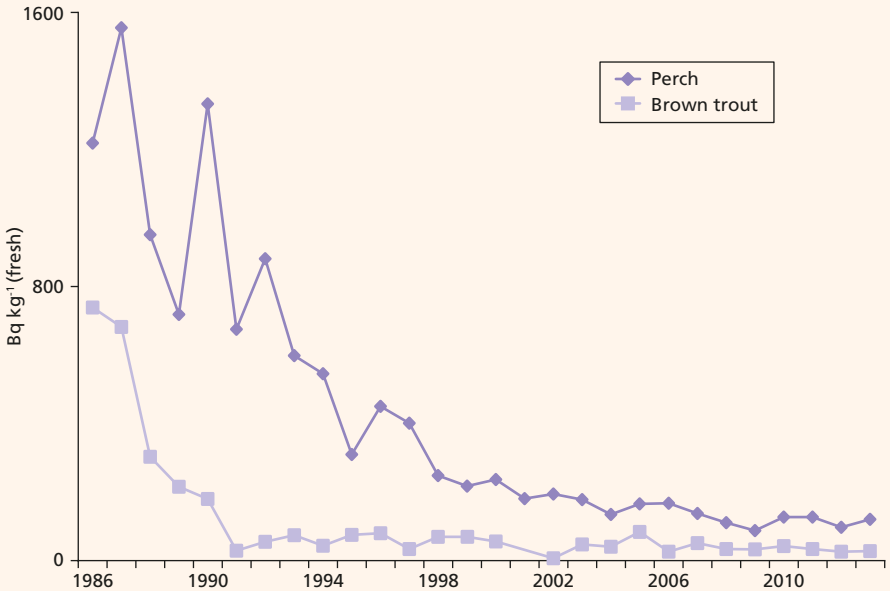


Figure 8.3. Caesium-137 concentrations in freshwater fish from Devoke Water, Cumbria 1986-2013

For the Fukushima Dai-ichi accident, the UK response in 2011 included:

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

After the initial detection of iodine-131 by the routine monitoring programmes, the environment agencies and the Food Standards Agency undertook additional monitoring but concentrations of iodine-131 were very low, as expected, and of minimal risk to public health. The additional monitoring ceased in July 2011 and monitoring returned to normal frequencies. Further information is available in RIFE 17 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2012).

On 25 March 2011, the European Commission (EC) implemented controls (Regulation EU/297/2011) on the import of food and feed originating in or consigned from Japan (European Commission, 2011). Various amendments have been made to legislative controls since that time. The legislation in place during 2013 was Regulation EU/996/2012, issued in October 2012 (European Commission, 2012b) and amended by Regulation EU/495/2013 in May 2013 (European Commission, 2013). This has subsequently been replaced in March 2014 by Regulation EU/322/2014 (European Commission, 2014b). All food and feed imported from Japan (with the exception of certain alcoholic beverages and, since March 2014, tea) has to be certified by the Japanese authorities. As part of this certification, certain food and feed types from specified prefectures (regions) of Japan known to have been affected by radioactive contamination have to be tested to confirm contamination is below the maximum permissible levels for caesium-134 and caesium-137. Further information is available on the Food Standards Agency's website: http://food.gov.uk/business-industry/imports/banned_restricted/japan.

A percentage of Japanese imports into the EU are monitored at ports of entry and this work continued in 2013. 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 the highest recorded result being 34 Bq kg^{-1}. The doses received due to the imports were of negligible radiological significance.

Screening instruments are used at importation points of entry to the UK as a general check on possible contamination from unknown sources. In 2013, unlike in previous years, the instruments were not triggered at any points of entry by the presence of caesium-137 or other radionuclides in consignments of food being brought into the UK.

8.5 General diet

As part of the UK governments' general responsibility for food safety, concentrations of radioactivity are determined in regional diets. These data (and data on other dietary components in Sections 8.6 and 8.7) form the basis of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with 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 2013, the concentrations found in a survey of radioactivity in diet, as represented by canteen meals collected across the UK (Table 8.7), were very low or typical of natural sources. Similar values were observed in 2012.

8.6 Milk

The programme of milk sampling across dairies in the UK continued in 2013. 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 8.7, provides useful information with which to compare data from farms close to nuclear licensed 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 8.2. 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 2013, the maximum dose was to a one-year-old infant. For the range of radionuclides analysed, the dose was 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.

8.7 Crops

The nationwide programme of monitoring naturally occurring and man-made radionuclides in crops continued in 2013 as a check on general food contamination (Table 8.3). Tritium concentrations were 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 2012.

8.8 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. These data are reported on behalf of the Department of Energy and Climate Change (DECC), NIEA and the Scottish and Welsh Governments, 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 8.8. The routine programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an *ad hoc* basis by gamma-ray spectrometry. Caesium-137 concentrations were all below the limits of detection. These levels in air, typical of recent years, remain less than 0.01 per cent of those observed in 1986, the year of the Chernobyl reactor accident.

Concentrations of beryllium-7, a naturally occurring radionuclide formed by cosmic ray reactions in the upper atmosphere, were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2012. 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 2013 (Figure 8.4). These water data are reported by the Environment Agency (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (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

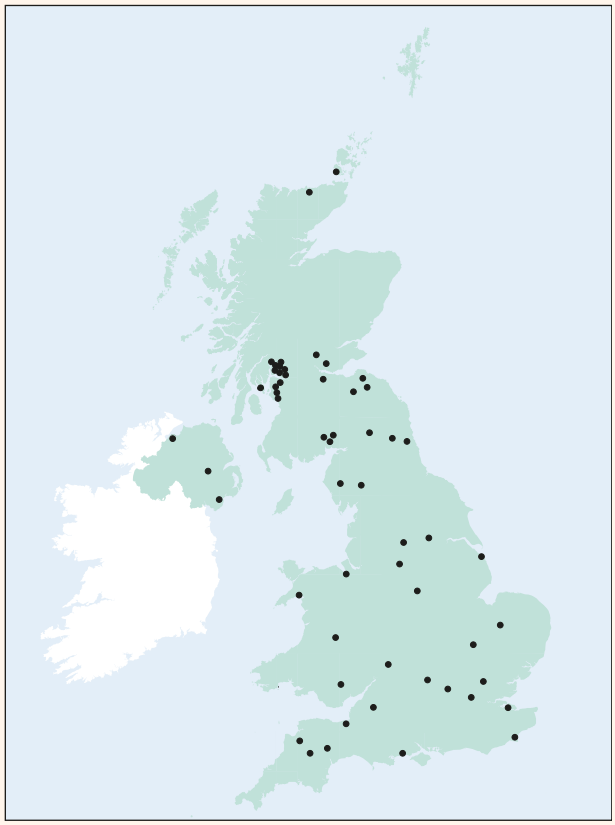


Figure 8.4. Drinking water sampling locations, 2013

waters before treatment and supply to the public water system. The results in Tables 8.9, 8.10 and 8.11 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 licensed site. 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 2013 (Table 8.12). 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 0.028 mSv due to radionuclides in a source of drinking water from Matlock in Derbyshire.

Separately, in 2013, SEPA took a series of groundwater samples from across Scotland and the results are displayed in Table 8.13. All samples contained levels below or near the limit of detection and are generally consistent with those in recent years. A single positive measurement of tritium in groundwater from Annan could conceivably be due to the operation of the nearby Chapelcross nuclear site. Regardless of the source, at the levels detected there are no radiological protection implications.

8.9 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). A third periodic evaluation of progress towards internationally agreed objectives have been published by OSPAR (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 objectives for 2020 (now part of the North-east Atlantic Environment Strategy adopted by OSPAR for the period 2010-2020). The surveys also provide information that can be used to distinguish different sources of man-made radioactivity (for example, Kershaw and Baxter, 1995) and to derive dispersion factors for nuclear licensed 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 report (Department for Environment, Food and Rural Affairs, 2010).

The research vessel programme on radionuclide distribution currently comprises annual surveys of the Bristol Channel/ western English Channel and biennial surveys of the Irish Sea and the North Sea. The results obtained in 2013 are given in Figures 8.5 – 8.9.

A seawater survey of the Irish Sea was carried out in 2013. Caesium-137 data (given in Figure 8.5) show a band of higher concentrations along the coast to the north and south of Sellafield, with levels generally decreasing with distance from the coast. Caesium-137 concentrations were reasonably uniform in a large part of the Irish Sea. The 2013 survey recorded concentrations of up to 0.09 Bq l^{-1} in the eastern Irish Sea; elsewhere concentrations were generally below 0.03 Bq l^{-1}. Overall, concentrations were similar to those reported in the previous Irish Sea survey in 2011 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2012). 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.

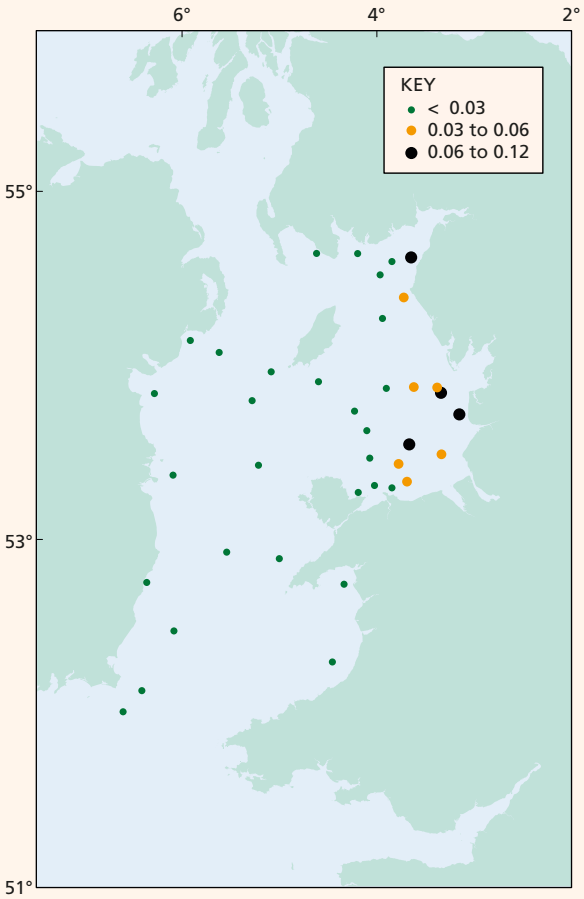


Figure 8.5. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water fom the Irish Sea, September 2013

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. This was re-confirmed in a recent study (Hunt *et al.*, 2013). Discharges from Sellafield have decreased substantially since the commissioning of the SIXEP waste treatment process in the mid 1980s, and this has been reflected in a near exponential decrease in shoreline seawater concentrations at St Bees (Figure 8.10). In more recent years, the rate of decline of caesium-137 concentrations with time has been decreasing at St Bees. Longer time series showing peak concentrations in the Irish Sea and, with an associated time-lag, the North Sea are also shown in Figure 8.10.

In 2012, very low concentrations of caesium-137 (up to 0.005 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, 2013), 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).

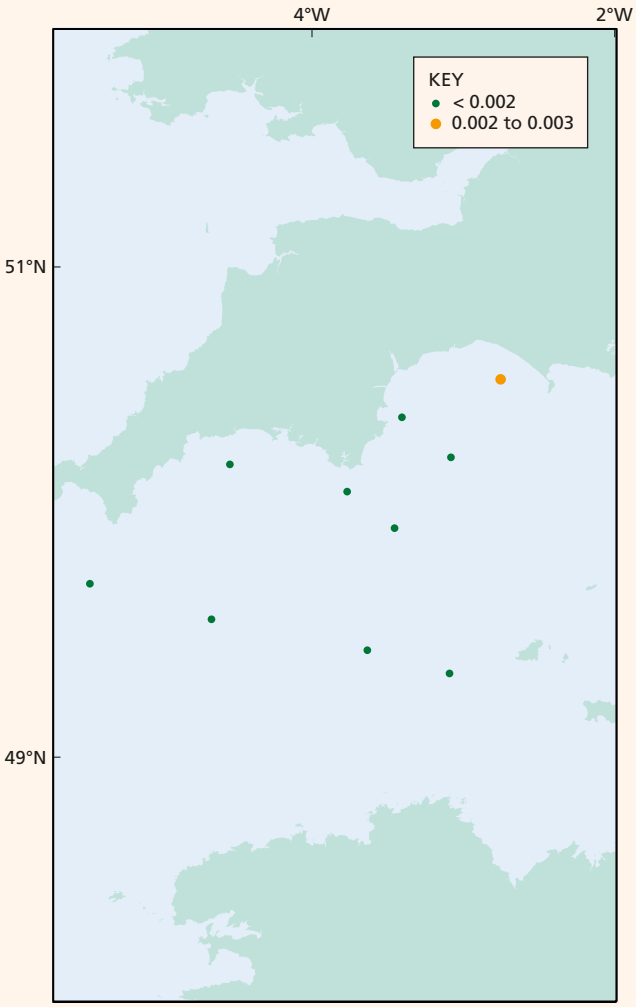


Figure 8.6. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the English Channel, February-March 2013

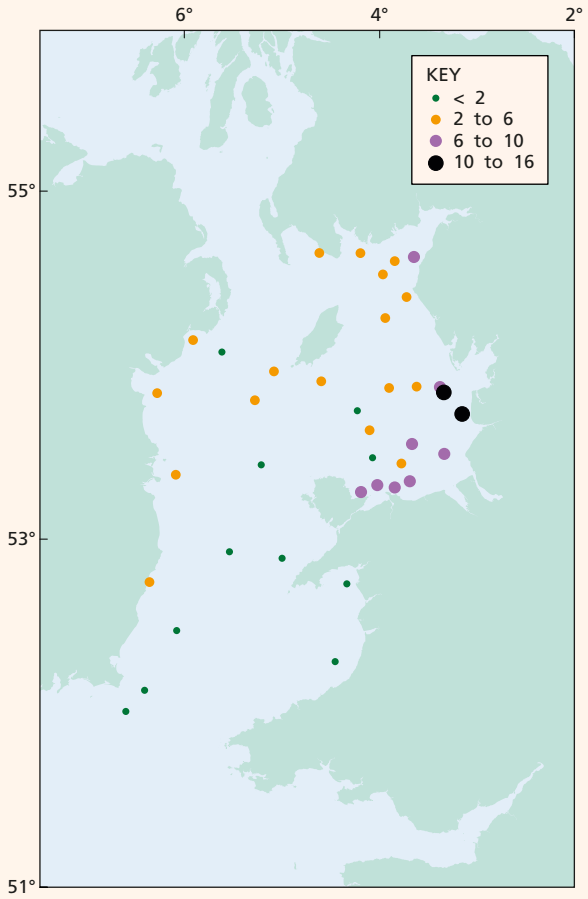


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water fom the Irish Sea, September 2013

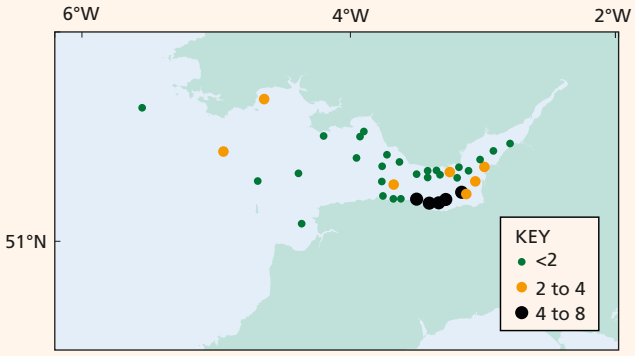


Figure 8.8. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September 2013

Concentrations of caesium-137 (< 0.003 Bq l^{-1}) in the western English Channel (Figure 8.6) were not distinguishable from the background levels of global fallout (within experimental error) in 2013. Activity concentrations near the Channel Islands were similar in 2013 (compared to those in 2012), and lower than concentrations in both the Irish and North Seas.

A full assessment of long-term trends of caesium-137 in surface waters of Northern European seas is provided elsewhere (Povinec *et al.*, 2003).

Tritium concentrations in Irish Sea seawater (in 2013) are shown in Figure 8.7. As expected, these are higher than those observed in the North Sea in 2012 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2013) due to the influence of discharges from Sellafield and other nuclear licensed sites. Some samples, to the south of the Isle of Man and along the coastline of Ireland, contained small enhancements of tritium concentrations (but still very low), in comparison to those at equivalent sites in the previous survey in 2011 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2012). The variation in levels in 2013 was most likely the result of authorised discharges of tritium being distributed by complex hydrographic transport patterns in the Irish Sea (Leonard *et al.*, 2004).

In the Bristol Channel, the combined effect of tritium discharges from Cardiff, Berkeley, Oldbury and Hinkley Point is shown in Figure 8.8. Overall, the general level of tritium concentrations in the Bristol Channel was very low in 2013. Tritium concentrations in samples taken close to these installations were generally similar to those in the 2012 survey, but were lower than levels in the North-east

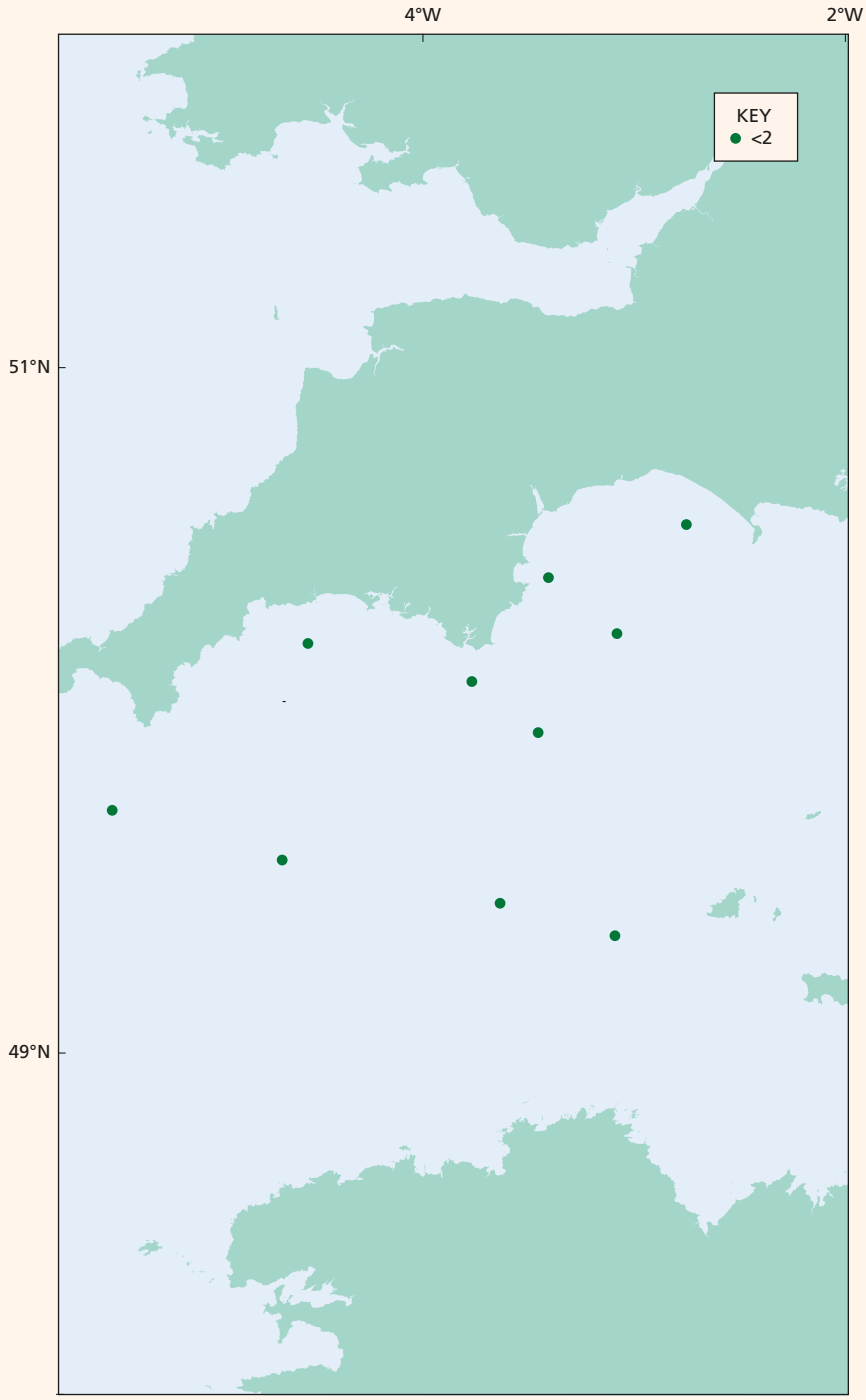


Figure 8.9. Concentrations (Bq l^{-1}) of tritium in surface water from the English Channel, February-March 2013

Irish Sea (Figure 8.7). Tritium concentrations in the western English Channel were also very low (Figure 8.9).

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-east Atlantic and a periodic evaluation of progress towards internationally agreed objectives have been published by OSPAR (2000b; 2009b; 2010b). A research study, commissioned by the Food Standards Agency, determined the depth distributions of technetium-99 concentrations in sea-bed cores to produce an estimate of the total inventory residing in the sub-tidal sediments of the Irish Sea (Jenkinson *et al.*, 2013). The study concluded that the inventory of technetium-99 was estimated to have been of the order of 30 TBq (or approximately 2 per cent of the total cumulative Sellafield discharge), with approximately 8 TBq present in surface material and thereby potentially most susceptible to re-dissolution or re-suspension.

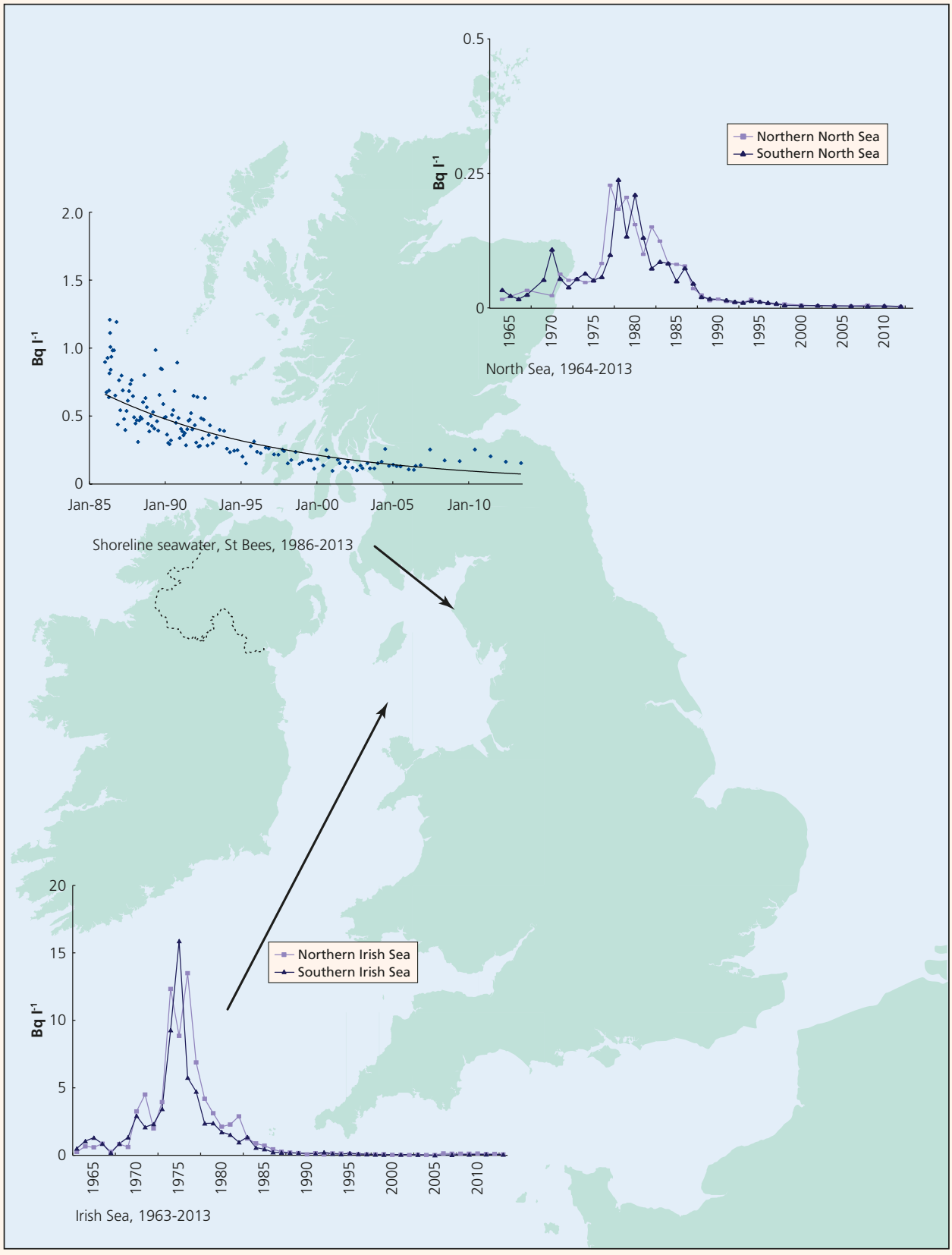


Figure 8.10. Concentration of caesium-137 in the Irish Sea, North Sea and in shoreline seawater close to Sellafield at St. Bees
(Note different scales used for activity concentrations)

Shoreline sampling was also carried out around the UK, as part of routine site and regional monitoring programmes. Much of the shoreline sampling was directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, these are reported in the relevant sections of this report, and the analysis results are collated in Table 8.14. Most radionuclides are below limits of detection, and tritium and caesium-137 levels remote from site discharge points are consistent with those in Figures 8.5 – 8.9.

In 2013, SEPA took a series of marine sediment samples from across Scotland and the results are displayed in Table 8.15. Various radionuclides were detected. The results are consistent with those to be expected from measurements at nuclear licensed sites in this report (see, for example, section 2). They exhibit a reducing trend in concentration with distance from the Sellafield site, albeit confounded by natural variability due to sediment type.

8.10 Bottled water

The European Commission published Council Directive 2013/51/EURATOM on 22 October 2013, laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption. This legislation requires the testing, by drinking water companies, of drinking water and bottled water for certain radionuclides and will be implemented into UK law during 2015.

Legally, bottled water is considered a food and hence is within the remit of the Food Standards Agency, whilst drinking water is the responsibility of the Drinking Water Inspectorate in England, Wales and Northern Ireland and the Drinking Water Quality Regulator in Scotland. As food regulations are a devolved responsibility, the regulation covering composition and standards of bottled drinking water are the responsibility of Defra in England and the Food Standards Agency in the rest of the UK with the Food Standards Agency in Scotland (FSAS) handling food safety and standards in Scotland.

In autumn 2013, the Food Standards Agency commissioned a survey of bottled water. Samples were collected between January and February 2014. Public Health England was commissioned to analyse the samples for levels of radionuclides.

Naturally occurring radionuclides uranium-234 and uranium-238 were detected in 9 of the 28 samples. From these results the subsequent doses were calculated. The calculated doses are very low, less than 0.005 mSv, and can be attributed to low activity concentrations in water of naturally occurring radionuclides.

Full results of this survey have been published as a Food Information Sheet on the Food Standards Agency website:

http://www.food.gov.uk/science/research/surveillance/food-surveys/food-survey-information-sheets-2014/radioactivity

Table 8.1. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2013

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I
Guernsey										
	Mackerel	1				<0.09			<0.87	
	Bass	1				<0.05			<0.44	
	Crabs	1				<0.08			<0.73	
	Lobsters	1				<0.07			<0.62	
	Limpets	1				<0.11			<1.2	
	Scallops	1				<0.17			<1.8	
	Ormers	1				<0.20			<2.1	
Fermain Bay	*Porphyra*	2				<0.11			<1.1	
Fermain Bay	*Fucus serratus*	2				<0.07	<0.040	4.6	<0.64	
St. Sampson's Harbour	Mud and sand	1				<0.21			<2.2	
Jersey										
	Pollack	2				<0.04			<0.32	
	Bass	1				<0.09			<0.74	
	Crabs	1				<0.08			<0.71	
	Spiny spider crabs	1				<0.04			<0.30	
	Lobsters	1				<0.05		0.78	<0.53	
	Scallops[b]	2				<0.05			<0.37	
La Rocque	Oysters	1				<0.05			<0.43	
La Rozel	Limpets	1				<0.06			<0.54	
Plemont Bay	*Porphyra*	2				<0.04			<0.38	
La Rozel	*Fucus vesiculosus*	4				<0.07	0.076	3.5	<0.53	
Gorey	*Fucus vesiculosus*	1				<0.05			<0.40	
Gorey	*Ascophyllum nodosum*	2				<0.07			<0.54	
Gorey	*Fucus serratus*	1				<0.07			<0.58	
St Helier	Mud	1				2.3			<3.6	
Alderney										
	Crabs	1	<25	<25	31	<0.04		<0.35	<0.29	
	Lobsters	1				<0.08			<0.68	
	Toothed winkles	1	<25	<25	33	<0.23	0.60		<1.9	
	Fucus vesiculosus	2								0.78
Quenard Point	*Fucus serratus*	4				<0.10	0.10	2.5	<0.81	
Quenard Point	*Laminaria digitata*	4				<0.08			<0.69	
Little Crabbe Harbour	Sand	1				0.48			<1.7	
	Seawater	4		<5.4						

Table 8.1. 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	<0.09	<0.22	<0.000039	0.000062	0.000054	*	*	120
	Bass	1	0.89	<0.08	<0.000024	0.000029	0.00018	*	*	160
	Crabs	1	<0.07	<0.19	0.00025	0.00089	0.0019	*	0.00014	96
	Lobsters	1	<0.06	<0.13			<0.07			120
	Limpets	1	<0.11	<0.25			<0.23			58
	Scallops	1	<0.14	<0.23	0.0010	0.0035	0.0022	*	0.00016	97
	Ormers	1	<0.16	<0.27			<0.14			110
Fermain Bay	*Porphyra*	2	<0.09	<0.17	0.0036	0.014	0.015	*	0.0010	240
Fermain Bay	*Fucus serratus*	2	<0.06	<0.16	0.0035	0.019	0.0057	*	0.00033	170
St. Sampson's Harbour	Mud and sand	1	0.43	<0.59	0.027	0.12	0.16	*	0.011	520
	Seawater	4	0.002							
Jersey										
	Pollack	2	0.16	<0.06			<0.03			170
	Bass	1	0.15	<0.13			<0.07			150
	Crabs	1	<0.07	<0.19	0.00033	0.00086	0.0022	*	0.00012	120
	Spiny spider crabs	1	<0.03	<0.06			<0.04			99
	Lobsters	1	<0.05	<0.15	0.00024	0.00073	0.0060	0.000055	0.00044	96
	Scallops[b]	2	<0.06	<0.09	0.0085	0.028	0.037	*	0.0025	130
La Rocque	Oysters	1	<0.04	<0.11	0.0014	0.0037	0.0055	*	0.00044	83
La Rozel	Limpets	1	<0.05	<0.10	0.0014	0.0048	0.0076	*	0.00054	230
Plemont Bay	*Porphyra*	2	<0.04	<0.08			<0.08			130
La Rozel	*Fucus vesiculosus*	4	<0.06	<0.15	0.0054	0.017	0.0089	*	0.00076	230
Gorey	*Fucus vesiculosus*	1	<0.04	<0.11			<0.13			130
Gorey	*Ascophyllum nodosum*	2	<0.05	<0.12			<0.13			260
Gorey	*Fucus serratus*	1	<0.06	<0.15			<0.19			210
St Helier	Mud	1	2.2	<1.0	0.43	1.2	2.4	*	0.14	740
St Catherine's Bay	Seawater	1	0.001							
Alderney										
	Crabs	1	<0.03	<0.05	0.00033	0.00089	0.0028	*	0.00024	87
	Lobsters	1	<0.07	<0.19	<0.00024	0.00012	0.0031	*	0.00028	110
	Toothed winkles	1	<0.16	<0.27	0.011	0.037	0.059	*	0.0063	380
	Fucus vesiculosus	2								
Quenard Point	*Fucus serratus*	4	<0.07	<0.17	0.0043	0.016	0.0059	0.00022	0.00061	250
Quenard Point	*Laminaria digitata*	4	<0.06	<0.13			<0.11			340
Little Crabbe Harbour	Sand	1	1.7	<0.49			0.93			800
	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*

[b] *The concentration of ^{108m}Ag was 0.05 Bq kg^{-1}*

Table 8.2. Concentrations of radionuclides in milk remote from nuclear sites, 2013

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	<2.2	24	<0.024	0.16
Co. Armagh		1	<2.2	33	<0.023	0.14
Ceredigion		1	<2.3	18	<0.024	0.11
Cheshire		1	<2.2	22	<0.026	0.22
Clwyd		1	<2.3	24	<0.026	<0.06[c]
Cornwall		1	<2.1	21	<0.034	0.12
Devon		1	<2.2	25	<0.033	0.11
Dorset		1	<2.2	15	<0.025	0.12
Co. Down		1	<10	22	<0.030	0.16
Dumfriesshire		1	<5.0	<15	<0.10	<0.05[c]
Essex		1	<2.3	18	<0.026	0.11
Co. Fermanagh		1	<2.1	26	<0.024	0.12
Gloucestershire		1	<2.1	18	<0.027	0.099
Guernsey		1	<2.2	16	<0.029	<0.05[c]
Gwynedd		1	<2.3	25	<0.027	0.11
Hampshire		1	<2.1	23	<0.034	0.11
Humberside		1	<2.4	21	<0.030	0.11
Kent		1	<2.3	19	<0.027	0.14
Lanarkshire		1			0.024	<0.03[c]
Lancashire		1	<2.2	23	<0.024	0.15
Leicestershire		1	<2.2	22	<0.026	0.12
Middlesex		1	<2.1	25	<0.024	0.11
Midlothian		1	<5.0	<15	<0.10	<0.05[c]
Nairnshire		1	<5.0	<15	<0.10	<0.05[c]
Norfolk		1	<2.2	23	<0.025	<0.06[c]
North Yorkshire		2	<2.2	17	<0.025	0.14
North Yorkshire	max				<0.030	0.16
Renfrewshire		1	<5.0	<16	<0.10	<0.05[c]
Co. Tyrone		2	<2.2	26	<0.024	0.10[c]
Co. Tyrone	max		<2.3		<0.025	<0.15
Mean Values						
Channel Islands			<2.2	16	<0.029	<0.053[c]
England			<2.2	21	<0.028	<0.12[c]
Northern Ireland			<3.7	26	<0.025	0.14[c]
Wales			<2.3	22	<0.026	<0.092[c]
Scotland			<5.0	<15	<0.085	<0.05[c]
United Kingdom			<2.9	<21	<0.037	<0.11[c]

[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] *Wholly or partly ^{137}Cs by gamma spectrometry*

Table 8.3. Concentrations of radionuclides in animals and crops remote from nuclear sites, 2013[a]

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{3}H	^{14}C	^{90}Sr	^{137}Cs	^{210}Pb	^{210}Po
Berkshire								
Wokingham	Cabbage	1	<2.7	7.7	0.079	<0.05	0.010	0.039
	Carrots	1	<2.0	31	0.12	<0.07	0.13	0.079
Channel Islands								
Guernsey	Lettuce	1	<2.6	11	0.022	0.05	<0.0072	0.024
	Potatoes	1	<2.5	30	<0.038	<0.06	0.074	0.041
Jersey	Potatoes	1	<2.6	18	0.040	<0.06		
	Strawberries	1	<2.0	20	<0.044	<0.06		
Cornwall								
Port Isaac	Cabbage	1	<2.4	13	0.27	<0.06	0.048	0.044
	Gooseberries	1	<2.5	18	0.19	<0.05	0.18	0.079
Cumbria								
Cockermouth	Cabbage	1	<2.3	7.6	0.23	<0.06	<0.0055	0.024
Penrith	Swede	1	<2.4	6.1	0.16	<0.05	0.030	<0.0020
Devon								
Ottery St Mary	Beetroot	1	<2.2	15	0.14	<0.07	0.25	0.025
	Chard	1	<2.5	19	0.75	0.12	0.39	0.17
Dumfriesshire								
Dumfries	Mixed diet[d]	4			<0.10	<0.05		
East Lothian								
North Berwick	Mixed diet[d]	4			<0.10	<0.05		
Flintshire								
Hawarden	Kale	1			1.5	<0.27	0.20	0.13
	Strawberries	1	<2.5	8.8	0.18	<0.04	0.087	0.042
Gloucestershire								
Chipping Camden	Cabbage	1	<2.7	10	0.13	<0.07	<0.011	0.054
	Potatoes	1	<2.9	22	0.088	<0.05	0.18	0.058
Hampshire								
Southampton	Leek	1	<2.1	7.6	0.057	<0.06	0.12	0.043
	Lettuce	1	<2.5	9.6	0.066	<0.08	0.21	0.10
Herefordshire								
Hereford	Cabbage	1	<2.5	16	0.28	<0.08	0.059	0.050
	Strawberries	1	<2.0	24	<0.11	<0.06	0.027	0.022
Lancashire								
Ormskirk	Kale	1	<2.9	12	0.57	<0.07	0.15	0.078
	Potatoes	1	<2.5	16	0.12	<0.05	<0.013	0.074
Lincolnshire								
Lincoln	Spinach	1	<3.1	6.2	0.13	<0.16	0.60	0.24
Norfolk								
Norwich	Potatoes	1	<2.8	32	0.054	<0.05	0.19	0.081
	Rabbit	1	9.4	56	<0.043	0.07		
	Sheep liver/kidney	1	<2.8	37	<0.086	0.09		
	Sheep Muscle	1	<4.4	34	<0.047	<0.13		
North Walsham	Spinach	1	<2.8	8.6	0.21	<0.140	0.45	0.23
Northumberland								
Ashington	Kale	1	<2.3	7.1	0.66	<0.07	0.59	0.28
	Potatoes	1	<2.7	26	0.061	<0.05	0.064	0.017
North Yorkshire								
Northallerton	Spinach	1	<2.7	13	0.19	<0.08	0.35	0.19
	Strawberries	1	<2.1	31	0.088	<0.07	0.050	0.048
Kirkbymoorside	Cabbage	1	<2.6	14	0.32	0.09	0.19	0.10
	Carrots	1	<2.1	7.4	0.30	<0.06	0.051	0.057
Nottinghamshire								
Nottingham	Carrots	1	<2.4	17	0.16	<0.06	0.024	0.067
Powys								
Montgomery	Blackcurrants	1	<2.5	23	0.17	<0.06	0.082	0.12
Glynneath	Leafy green vegetables	1	<2.3	18	1.0	<0.05	0.43	0.15
Renfrewshire								
Paisley	Mixed diet[d]	4			<0.10	<0.05		
Ross-shire								
Dingwall	Mixed diet[d]	4			<0.11	<0.05		
Shropshire								
Market Drayton	Spinach	1	<2.7	12	0.26	<0.05	0.45	0.25
	Gooseberries	1	<2.5	7.8	0.074	<0.07	0.10	0.048
Somerset								
Farrington Gurney	Lettuce	1	<2.3	11	<0.076	<0.03	0.029	0.018
	Potatoes	1	<2.6	14	0.060	<0.05	<0.031	0.090
Suffolk								
Bungay	Duck	1	<3.1	37	<0.030	<0.08		
	Pheasant[c]	1	<3.4	43	<0.042	<0.07		
Mean Values[b]								
Channel Islands			<2.4	20	<0.036	<0.06	<0.041	0.033
England			<2.8	19	<0.18	<0.07	<0.17	0.089
Wales			<1.8	12	0.57	<0.08	0.16	0.088
Scotland					<0.10	<0.05		
Great Britain			<2.3	15	<0.28	<0.07	<0.16	0.088

Table 8.3. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{226}Ra	^{232}Th	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Berkshire							
Wokingham	Cabbage	1	0.045	0.012			<0.48
	Carrots	1	0.048	0.0011			<0.36
Channel Islands							
Guernsey	Lettuce	1	<0.0030	<0.00038	<0.000053	0.000072	0.00018
	Potatoes	1	<0.0080	0.018	0.000025	0.00019	0.00026
Jersey	Potatoes	1			<0.000073	0.00012	0.000074
	Strawberries	1			<0.00019	<0.00012	<0.000027
Cornwall							
Port Isaac	Cabbage	1	0.019	0.00095			<0.09
	Gooseberries	1	0.018	0.00095			<0.13
Cumbria							
Cockermouth	Cabbage	1	0.068	0.0056			<0.11
Penrith	Swede	1	0.082	0.0018			<0.13
Devon							
Ottery St Mary	Beetroot	1	0.072	0.010			<0.16
	Chard	1	0.21	0.011			<0.20
Flintshire							
Hawarden	Kale	1	<0.0080	0.0026			<0.61
	Strawberries	1	0.064	<0.00028			<0.60
Gloucestershire							
Chipping Camden	Cabbage	1	0.015	<0.00048			<0.10
	Potatoes	1	0.032	0.020			<0.54
Hampshire							
Southampton	Leek	1	0.011	0.0031			<0.13
	Lettuce	1	<0.0040	0.0021			<0.17
Herefordshire							
Hereford	Cabbage	1	0.044	<0.00060			<0.13
	Strawberries	1	0.010	0.0027			<0.13
Lancashire							
Ormskirk	Kale	1	0.067	0.0079			<0.12
	Potatoes	1	0.023	0.0051			<0.10
Lincolnshire							
Lincoln	Spinach	1	0.015	0.0081			<0.58
Norfolk							
Norwich	Potatoes	1	0.0030	0.027			<0.11
	Rabbit	1			<0.000067	0.000052	0.000081
	Sheep liver/kidney	1			0.00022	0.0011	0.0024
	Sheep Muscle	1			<0.000094	<0.000083	<0.000047
North Walsham	Spinach	1	0.037	0.0080			<0.52
Northumberland							
Ashington	Kale	1	<0.034	0.032			<0.16
	Potatoes	1	0.031	0.013			<0.44
North Yorkshire							
Northallerton	Spinach	1	0.10	0.046			<0.16
	Strawberries	1	0.025	0.0021			<0.07
Kirkbymoorside	Cabbage	1	<0.044	<0.00045			<0.12
	Carrots	1	0.028	0.0079			<0.11
Nottinghamshire							
Nottingham	Carrots	1	0.016	0.025			<0.10
Powys							
Montgomery	Blackcurrants	1	0.037	<0.00050			<0.29
Glynneath	Leafy green vegetables	1	0.033	0.0082			<0.63
Shropshire							
Market Drayton	Spinach	1	0.082	0.0083			<6.9
	Gooseberries	1	0.16	0.0030			<0.16
Somerset							
Farrington Gurney	Lettuce	1	0.027	0.020			<0.49
	Potatoes	1	0.034	0.036			<0.14
Suffolk							
Bungay	Duck	1			<0.000074	0.000085	0.00021
	Pheasant[c]	1			0.000032	0.00012	0.00023
Mean Values[b]							
Channel Islands			0.0055	0.0092	<0.000085	<0.00013	<0.00014
England			<0.047	<0.011	<0.00010	<0.00029	<0.38
Wales			<0.028	<0.0023			<0.43
Great Britain			<0.038	<0.0065	<0.00010	<0.00029	<0.40

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

[b] *Great Britain mean excludes Channel Islands. Mean values include crops and animals*

[c] *The concentrations of $^{234, 235, 238}$U were 0.011, <0.00021 and 0.00070 Bq kg^{-1} respectively*

[d] *Mixed diet samples comprise food from the following food groups in the ratios specified in brackets: domestic fruit (1), green vegetables (1), pig meat (1), cattle meat (1), potatoes (2) and cereals (3)*

Table 8.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2013[a]

Material	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{60}Co	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Cod	4	<0.07	<0.15	<0.17		<0.61	<0.16	<0.07	1.2
Herring	3	<0.11	<0.57	<0.40		<1.0	<0.23	<0.11	0.48
Mackerel	1	<0.11	<0.18	<0.24		<1.1	<0.29	<0.12	1.1
Lobsters	4	<0.09	<0.30	<0.26	14	<0.83	<0.19	<0.09	0.23
Scallops	4	<0.06	<0.13	<0.14		<0.54	<0.14	<0.06	0.18
Seaweed[c]	3[E]	<0.78	<0.52	<0.97	81	<4.7	<2.7	<0.69	<0.61
Sediment	1[E]	<0.32	<0.28	<0.70		<2.0	<0.99	<0.31	6.7

Material	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Aquatic samples									
Cod	4	<0.30	0.00039	0.0023	0.0046	*	0.00011		
Herring	3	<0.43	0.000045	0.00025	0.00032	*	*		
Mackerel	1	<0.56			<0.35				
Lobsters	4	<0.34			<0.14				120
Scallops	4	<0.28	0.016	0.095	0.030	*	*		
Seaweed[c]	3[E]	<2.1			<0.71				
Sediment	1[E]	<1.4			1.6			<130	680

Material or selection[d]	No. of sampling observations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb
Terrestrial samples									
Milk	2	<2.1	27	<0.34	<0.07	<0.027	<0.025	<0.62	<0.16
Milk max				<0.37		0.030		<0.70	<0.20
Broccoli	1	<2.0	21	0.80	<0.10	<0.043	<0.11	<0.67	<0.15
Cabbage	1	<2.1	8.7	<0.40	<0.07	0.18	<0.11	<0.42	<0.19
Gooseberries	1	<2.1	14	0.20	<0.04	0.15		<0.22	<0.07

Material or selection[d]	No. of sampling observations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{129}I	^{134}Cs	^{137}Cs	^{238}Pu	^{240}Pu	^{239}Pu + ^{241}Pu	^{241}Am
Terrestrial samples								
Milk	2	<0.0050	<0.08	<0.05	<0.000021	<0.000031	<0.12	<0.000035
Milk max			<0.09					
Broccoli	1	<0.041	<0.10	<0.08	<0.00011	<0.00018	<0.21	0.000042
Cabbage	1	<0.042	<0.07	<0.07	<0.00011	0.00012	<0.36	0.00027
Gooseberries	1		<0.04	<0.04				<0.54

* *Not detected by the method used*

a *The gamma dose rate in air at 1m over sand and stones at Ramsey[E] was 0.087 mGy h^{-1}*

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

c *The concentrations of ^{234}U, ^{235}U and ^{238}U were 2.5, <0.25 and 2.2 Bq kg^{-1} respectively*

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

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

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

Table 8.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2013[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	28	<0.08		<0.17	<0.08	1.3
Plaice	Kilkeel	4		<0.06		<0.14	<0.06	1.1
Haddock	Kilkeel	4		<0.06		<0.14	<0.06	0.40
Herring	Ardglass	2		<0.15		<0.29	<0.14	0.57
Lesser spotted dogfish	North coast	2		<0.17		<0.36	<0.18	1.0
Skates / rays	Kilkeel	3		<0.12		<0.27	<0.12	2.2
Thornback ray	Kilkeel	1		<0.14		<0.31	<0.14	2.8
Spurdog	North coast	2		<0.14		<0.34	<0.15	1.3
Crabs	Kilkeel	4		<0.06		<0.14	<0.06	0.15
Lobsters	Ballycastle	2		<0.15	5.1	<0.34	<0.15	<0.14
Lobsters	Kilkeel	4		<0.06	7.5	<0.14	<0.06	0.15
Nephrops	Kilkeel	4		<0.07	2.3	<0.17	<0.07	0.39
Winkles	Minerstown	3		<0.08		<0.18	<0.08	0.22
Toothed winkles	Minerstown	1		<0.14		<0.35	<0.14	0.25
Mussels	Carlingford Lough	2		<0.09	1.7	<0.19	<0.09	0.25
Scallops	Co. Down	2		<0.06		<0.14	<0.06	0.30
Ascophyllum nodosum	Ardglass	3		<0.07	170	<0.17	<0.08	0.37
Fucus spp.	Carlingford Lough	4		<0.06	28	<0.13	<0.07	0.33
Fucus spp.	Portrush	4		<0.04		<0.08	<0.04	<0.09
Fucus vesiculosus	Ardglass	1		<0.12		<0.23	<0.12	0.29
Rhodymenia spp.	Portaferry	4		<0.06	0.14	<0.12	<0.05	0.48
Mud	Carlingford Lough	2		<0.45		<1.2	<0.61	44
Mud	Carrichue	1						
Mud	Dundrum Bay	2		<0.55		<1.3	<0.73	17
Mud	Oldmill Bay	2		<0.30		<0.96	<0.42	18
Mud	Strangford Lough-Nicky's point	2		<0.30		<0.90	<0.42	18
Mud and sand	Carrichue	2		<0.27		<0.80	<0.37	4.0
Mud and sand	Ballymacormick	4		<0.27		<0.82	<0.35	11
Mud and shell	Carrichue	1		<0.32		<0.75	<0.37	1.7
Sand	Portrush	2		<0.20		<0.56	<0.25	0.61
Seawater	North of Larne	12			0.0012		*	0.01

Table 8.5(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	<0.14			<0.12		
Plaice	Kilkeel	4	<0.14			<0.11		
Haddock	Kilkeel	4	<0.13			<0.14		
Herring	Ardglass	2	<0.25			<0.14		
Lesser spotted dogfish	North coast	2	<0.24			<0.12		
Skates / rays	Kilkeel	3	<0.21			<0.19		
Thornback ray	Kilkeel	1	<0.19			<0.09		
Spurdog	North coast	2	<0.26			<0.19		
Crabs	Kilkeel	4	<0.12			<0.10		
Lobsters	Ballycastle	2	<0.26			0.20		
Lobsters	Kilkeel	4	<0.12			<0.09		
Nephrops	Kilkeel	4	<0.17	0.0013	0.0083	0.025	*	*
Winkles	Minerstown	3	<0.15	0.029	0.18	0.14	*	*
Toothed winkles	Minerstown	1	<0.32			0.25		
Mussels	Carlingford Lough	2	<0.14			<0.08		
Scallops	Co. Down	2	<0.15			<0.18		
Ascophyllum nodosum	Ardglass	3	<0.18			<0.21		
Fucus spp.	Carlingford Lough	4	<0.14			<0.16		
Fucus spp.	Portrush	4	<0.07			<0.08		
Fucus vesiculosus	Ardglass	1	<0.19			<0.13		
Rhodymenia spp.	Portaferry	4	<0.10	0.060	0.34	0.66	*	*
Mud	Carlingford Lough	2	<1.2	1.7	11	9.1	*	*
Mud	Carrichue	1		0.13	0.89	1.6	*	*
Mud	Dundrum Bay	2	<1.3			5.7		
Mud	Oldmill Bay	2	<1.2			5.6		
Mud	Strangford Lough-Nicky's point	2	<1.0			6.4		
Mud and sand	Carrichue	2	<1.0			1.3		
Mud and sand	Ballymacormick	4	<1.1			8.5		
Mud and shell	Carrichue	1	<0.71			0.73		
Sand	Portrush	2	<0.77			<0.96		

* *Not detected by the method used*

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

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

Table 8.5(b). Monitoring of radiation dose rates in Northern Ireland, 2013[a]

Location	Ground type	No. of sampling observ-ations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lisahally	Mud	1	0.068
Donnybrewer	Shingle	1	0.054
Carrichue	Mud	1	0.074
Bellerena	Mud	1	0.064
Benone	Sand	1	0.060
Castlerock	Sand	1	0.058
Portstewart	Sand	1	0.062
Portrush, Blue Pool	Sand	1	0.061
Portrush, White Rocks	Sand	1	0.063
Portballintrae	Sand	1	0.060
Giant's Causeway	Sand	1	0.056
Ballycastle	Sand	1	0.061
Cushendun	Sand	1	0.061
Cushendall	Sand and stones	1	0.069
Red Bay	Sand	1	0.066
Carnlough	Sand	1	0.059
Glenarm	Sand	1	0.054
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.054
Drains Bay	Sand	1	0.057
Larne	Sand	1	0.066
Whitehead	Sand	1	0.064
Carrickfergus	Sand	1	0.058
Jordanstown	Sand	1	0.057
Helen's Bay	Sand	1	0.062
Groomsport	Sand	1	0.063
Millisle	Sand	1	0.066
Ballywalter	Sand	1	0.069
Ballyhalbert	Sand	1	0.068
Cloghy	Sand	1	0.073
Portaferry	Shingle and stones	1	0.084
Kircubbin	Sand	1	0.088
Greyabbey	Sand	1	0.089
Ards Maltings	Mud	1	0.083
Island Hill	Mud	1	0.074
Nicky's Point	Mud	1	0.076
Strangford	Shingle and stones	1	0.10
Kilclief	Sand	1	0.074
Ardglass	Mud	1	0.082
Killough	Mud	1	0.078
Ringmore Point	Sand	1	0.071
Tyrella	Sand	1	0.076
Dundrum	Sand	1	0.089
Newcastle	Sand	1	0.086
Annalong	Sand	1	0.12
Cranfield Bay	Sand	1	0.088
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.078
Rostrevor	Sand	1	0.11
Narrow Water	Mud	1	0.092

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

Table 8.6. Concentrations of radiocaesium in the freshwater environment, 2013

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Cogra Moss	Rainbow trout	2	<0.13	0.18
Narborough[a]	Rainbow trout	1	<0.06	0.15
Devoke Water	Brown trout	1	<0.13	26
Devoke Water	Perch	1	0.19	120
Gilcrux	Rainbow trout	1	<0.08	<0.08
New Mills	Rainbow trout	1	<0.07	0.13

[a] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}$Pu and ^{241}Am were 44, <0.000016, 0.000066 and 0.000072 Bq kg^{-1} respectively*

Table 8.7. Concentrations of radionuclides in canteen meals, 2013[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	8	36	98	<0.088	<0.05
Northern Ireland	5	44	100	<0.088	<0.04
Scotland	12[S]	37		0.040	<0.02
Scotland	2	35	90	0.060	0.10
Wales	5	32	92	0.10	<0.07

[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 8.8. Concentrations of radionuclides in rainwater and air 2013

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]					
				^{3}H	^{7}Be	^{7}Be[d]	^{90}Sr[b]	^{137}Cs	^{137}Cs[d]
Ceredigion									
	Aberporth	Rainwater	4	<0.93	<1.3			<0.014	
		Air	4		0.0021			$<7.2\ 10^{-7}$	
Co. Down									
	Conlig	Rainwater	4		<0.71			<0.013	
		Air	4		0.0017			$<7.8\ 10^{-7}$	
Dumfries and Galloway									
	Eskdalemuir	Rainwater	4	<0.93	<0.81			<0.010	
		Air	4		0.0016			$<7.8\ 10^{-7}$	
Glasgow									
	Glasgow	Air	12		0.0029			<0.010	
North Yorkshire									
	Dishforth	Rainwater	4		<0.83			<0.011	
		Air	4		0.0021			$<6.5\ 10^{-7}$	
Oxfordshire									
	Chilton	Rainwater	4		<1.1	1.4	<0.00028	<0.014	<0.0020
		Air	12		0.0013			$<4.7\ 10^{-7}$	
Shetland									
	Lerwick	Rainwater	4		<0.91			<0.010	
		Air	4		0.0018			$<7.0\ 10^{-7}$	
Suffolk									
	Orfordness	Rainwater	4	<1.1	<0.71			<0.013	
		Air	4		0.0017			$<6.7\ 10^{-7}$	

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]				
				^{238}Pu[c]	$^{239}Pu+$ ^{240}Pu[c]	^{241}Am[c]	Gross alpha[d]	Gross beta[d]
Ceredigion								
	Aberporth	Rainwater	4	$<2.0\ 10^{-5}$	$<2.0\ 10^{-5}$	$<2.0\ 10^{-5}$		
		Air	4	$<3.0\ 10^{-9}$	$<3.0\ 10^{-9}$	$<3.0\ 10^{-9}$		
Glasgow								
	Glasgow	Air	12					<0.0020
Oxfordshire								
	Chilton	Rainwater	4				<0.028	<0.020

[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 8.9. Concentrations of radionuclides in sources of drinking water in Scotland, 2013

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	<0.0053	<0.01	<0.015	0.040
Argyll and Bute	Auchengaich	1	<1.0		<0.01	<0.010	0.027
Argyll and Bute	Helensburgh Reservoir	1	<1.0		<0.01	<0.010	0.044
Argyll and Bute	Loch Ascog	1	<1.0		<0.01	<0.010	0.086
Argyll and Bute	Loch Eck	1	<1.0		<0.01	<0.010	0.020
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.0		<0.01	<0.010	0.014
Argyll and Bute	Loch Finlas	1	<1.0		<0.01	<0.010	0.021
Clackmannanshire	Gartmorn Dam	1	<1.0		<0.01	<0.010	0.13
Dumfries and Galloway	Black Esk	1	1.0		<0.01	<0.011	0.042
Dumfries and Galloway	Gullielands Burn	1	32		<0.01	<0.017	0.24
Dumfries and Galloway	Purdomstone	1	1.9		<0.01	0.022	0.090
Dumfries and Galloway	Winterhope	1	1.4		<0.01	0.015	0.079
East Lothian	Hopes Reservoir	1	<1.0		<0.01	0.013	0.035
East Lothian	Thorters Reservoir	1	<1.0		<0.01	0.022	0.067
East Lothian	Whiteadder	1	<1.0		<0.01	0.012	0.056
East Lothian	Thornton Loch Burn	1	<1.0		<0.01	<0.013	0.10
Fife	Holl Reservoir	1	<1.0		<0.01	<0.010	0.030
Highland	Loch Baligill	1	<1.0		<0.01	<0.010	0.023
Highland	Loch Calder	1	<1.0		<0.01	<0.011	0.041
Highland	Loch Glass	4	<1.0	<0.0048	<0.01	<0.0094	<0.052
Highland	Loch Shurrerey	1	<1.0		<0.01	<0.010	0.029
North Ayrshire	Camphill	1	<1.0		<0.01	<0.010	0.023
North Ayrshire	Knockendon Reservoir	1	<1.0		<0.01	<0.010	0.036
North Ayrshire	Munnoch Reservoir	1	<1.0		<0.01	<0.010	0.037
North Ayrshire	Outerwards	1	<1.0		<0.01	<0.010	0.061
Orkney Islands	Heldale Water	1	<1.0		<0.01	<0.010	0.058
Perth and Kinross	Castlehill Reservoir	1	<1.0		<0.01	<0.010	0.030
Scottish Borders	Knowesdean	4	<1.1	<0.0050	<0.01	<0.010	<0.047
Stirling	Loch Katrine	12	<1.0	0.0034	<0.001	<0.0080	0.044
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0		<0.01	<0.010	0.033
West Lothian	Morton No 2 Reservoir	1	<1.0		<0.01	<0.010	0.040

Table 8.10. Concentrations of radionuclides in sources of drinking water in England and Wales, 2013

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}							
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England										
Buckinghamshire	Bourne End, Groundwater	4	<4.0	<0.030	<0.0010		<0.0013	<0.022	0.058	<0.048
Cambridgeshire	Grafham Water	4	<4.0	0.29	0.0026		<0.0010	0.029	0.43	0.27
Cheshire	River Dee, Chester	4	<4.0	0.15	0.0031	0.0042	<0.0013	0.024	0.15	0.093
Cornwall	River Fowey	4	<4.0	0.054	0.0019	<0.0032	<0.0010	0.027	0.10	0.067
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.038	0.0038		0.0025	0.042	0.12	0.077
County Durham	River Tees, Darlington	4	<4.0	0.035	0.0034	<0.0026	<0.0010	<0.020	0.065	<0.051
Cumbria	Ennerdale Lake	4	<4.0	0.010	0.0029		<0.0010	<0.020	<0.050	<0.050
Cumbria	Haweswater Reservoir	4	<4.0	<0.014	0.0022		<0.0010	<0.020	<0.050	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.024	0.0015		<0.0010	<0.020	0.052	<0.050
Derbyshire	Matlock, Groundwater[a]	4	<4.0	<0.025	0.0014		<0.0010	0.11	0.11	0.074
Devon	River Exe, Exeter	4	<4.0	0.069	<0.0030	<0.0097	<0.0021	0.063	0.17	0.11
Devon	Roadford Reservoir, Broadwoodwidger	4	<4.0	0.064	0.0026		<0.0010	<0.020	0.093	0.063
Gloucestershire	River Severn, Tewkesbury	2	<4.0	0.10	0.0021	<0.0030	<0.0015	0.078	0.26	0.16
Greater London	River Lee, Chingford	4	<4.0	0.26	<0.0013	<0.0090	<0.0010	<0.042	0.38	0.25
Hampshire	River Avon, Christchurch	4	<4.0	0.088	<0.0010	<0.0025	<0.0010	<0.021	0.096	0.069
Humberside	Littlecoates, Groundwater	4	<4.0	0.066	<0.0012		<0.0019	0.024	0.14	0.088
Kent	Chatham, Deep Groundwater	4	<4.0	0.036	<0.0010		<0.0010	0.018	0.065	0.049
Kent	Denge, Shallow Groundwater	4	<4.0	0.11	0.0040		<0.0010	<0.020	0.12	0.081
Lancashire	Corn Close, Groundwater	4	<4.0	0.076	<0.0010		<0.0010	0.021	0.15	0.097
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.085	0.0018	<0.0030	<0.0010	0.026	0.15	0.0099
Northumberland	Kielder Reservoir	4	<4.0	0.087	0.0036		<0.0022	0.022	0.11	0.080
Oxfordshire	River Thames, Oxford	4	<4.0	0.17	0.0017	<0.0033	<0.0010	0.029	0.22	0.15
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.075	<0.0012		<0.0010	0.018	0.11	0.072
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.11	0.0023		<0.0010	0.024	0.19	0.13
Surrey	River Thames, Chertsey	4	<4.0	0.16	0.0018	<0.0030	<0.0010	0.026	0.20	0.13
Surrey	River Thames, Walton	4	<4.0	0.17	0.0018	<0.0031	<0.0010	<0.023	0.28	0.19
Yorkshire	Chellow Heights, Bradford	2	<4.0	<0.018	0.0037		<0.0010	<0.020	0.050	<0.050
Wales										
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.015	0.0032		<0.0010	<0.020	<0.050	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.014	0.0026		<0.0010	0.019	<0.050	<0.050
Powys	Elan Valley Reservoir	4	<4.0	<0.014	0.0027		<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 0.0099, 0.010, 0.043, <0.010 and 0.022 Bq l^{-1} respectively*

Table 8.11. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2013

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	0.0031	<0.05	<0.010	<0.01	<0.010	<0.010	<0.010	<0.020	0.055
Co. Antrim	Lough Neagh	4	<1.0	0.0022	<0.05	<0.010	<0.01	<0.010	<0.010	<0.010	<0.020	0.11
Co. Down	Silent Valley	4	<1.0	0.0035	<0.05	<0.010	<0.01	<0.010	<0.010	<0.010	<0.020	<0.16

Table 8.12. Doses from radionuclides in drinking water, 2013[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	0.028	0.028	Matlock, Groundwater, Derbyshire	0.028
Wales[d]	<0.001			Cwm Ystradllyn Treatment Works, Gwynedd	<0.001[d]
Northern Ireland	<0.001	0.026	0.027	Silent Valley, Co. Down	0.028
Scotland[d]	<0.001			Gullielands Burn, Dumfries and Galloway	0.001[d]
UK	<0.001	0.027	0.027	Matlock, Groundwater, Derbyshire	0.028

[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 8.13. Analysis of groundwater – background survey in Scotland, 2013

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Aberdeenshire	Peterhead	1	<1.0	<0.10	<0.010	0.10
Aberdeenshire	Turriff	1	<1.0	<0.10	<0.012	<0.10
Angus	Brechin	1	<1.0	<0.10	<0.010	<0.10
Angus	Montrose	1	<1.0	<0.10	<0.014	<0.10
Ayrshire	Girvan	1	<1.0	<0.10	<0.016	<0.10
Dumfries and Galloway	Annan	1	3.0	<0.10	<0.10	<0.10
Dumfries and Galloway	Dumfries	1	<1.0	<0.10	<0.010	<0.10
Dumfries and Galloway	Stranraer	1	<1.0	<0.10	<0.10	<0.10
Fife	Kingsbarns	1	<1.0	<0.10	<0.10	0.25
Highlands	Cromarty	1	<1.0	<0.10	<0.010	<0.10
Highlands	Torridon	1	<1.0	<0.10	<0.010	<0.10
Moray	Elgin	1	<1.0	<0.10	0.026	0.25
Scottish Borders	Selkirk	1	<1.0	<0.10	<0.010	<0.10

Table 8.14. Concentrations of radionuclides in seawater, 2013

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}						
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag
Dounreay (Sandside Bay)	4[S]	<1.0		<0.10			<0.51	<0.08
Dounreay (Brims Ness)	4[S]	<1.0		<0.10			<0.53	<0.10
Rosyth	2[S]	<1.0		<0.10			<0.50	<0.10
Torness[a]	2[S]	<15		<0.10			<0.48	<0.10
Hartlepool (North Gare)	2	<3.6		<0.27			<2.1	<0.35
Sizewell	2	<6.4		<0.34			<2.5	<0.44
Bradwell	2			<0.30			<2.1	<0.39
Dungeness south	2	<3.3		<0.28			<2.0	<0.31
Winfrith (Lulworth Cove)	1			<0.40			<2.8	<0.50
Alderney	4[F]	<5.4						
Devonport (Millbrook Lake)	2	<3.0	<4.9	<0.36				
Devonport (Tor Point South)	2	<3.3	<3.6	<0.23				
Hinkley	2			<0.31	<0.050		<2.1	<0.40
Berkeley and Oldbury	2			<0.27			<1.9	<0.31
Cardiff (Orchard Ledges)[b]	2	<10	<12	<0.27				
Holyhead	4[D]	<1.8						
Wylfa (Cemaes Bay)	2	<3.2		<0.23			<1.8	<0.29
Wylfa (Cemlyn Bay West)	2			<0.26			<1.9	<0.33
Heysham (inlet)	2	15		<0.28			<1.9	<0.32
Seascale (Particulate)	2			<0.04	<0.022		<0.35	<0.06
Seascale (Filtrate)	2			<0.22	<0.035	<0.17	<1.9	<0.27
St. Bees (Particulate)	2			<0.04	<0.015		<0.34	<0.05
St. Bees (Filtrate)	2	6.2		<0.17	<0.060	<0.08	<1.3	<0.23
Seafield	4[S]	<2.0		<0.10			<0.51	<0.10
Southerness[c]	4[S]	<2.3		<0.10			<0.45	<0.10
Auchencairn	4[S]	<2.3		<0.10			<0.53	<0.10
Knock Bay	4[S]	<1.1		<0.10			<0.37	<0.10
Knock Bay	4[D]	<1.8						
Hunterston[d]	2[S]	5.9		<0.10			<0.82	<0.11
Hunterston (South of pipeline)[e]	2[S]	2.7		<0.10			<0.70	<0.11
North of Larne	12[N]					0.0012		
Faslane (Carnban)	2[S]	1.7		<0.10			<0.54	<0.10

Table 8.14. continued

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}					
		^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	4[S]	<0.10	<0.10	<0.32	<0.11		
Dounreay (Brims Ness)	4[S]	<0.10	<0.10	<0.31	<0.10		
Rosyth	2[S]	<0.10	<0.10	<0.28	<0.10		
Torness[a]	2[S]	<0.10	<0.10	<0.31	<0.10		
Hartlepool (North Gare)	2	<0.28	<0.22	<1.1	<0.30	<3.2	13
Sizewell	2	<0.34	<0.27	<1.0	<0.28	<4.2	13
Bradwell	2	<0.29	<0.24	<0.93	<0.26	<3.5	15
Dungeness south	2	<0.28	<0.20	<0.89	<0.27	<3.3	16
Winfrith (Lulworth Cove)	1	<0.38	<0.32	<1.1	<0.31	<1.9	4.6
Alderney	4[F]	*	0.002				
Jersey	1[F]	*	0.001				
Guernsey	4[F]	*	0.002				
Hinkley	2	<0.31	<0.26	<1.0	<0.30	<1.9	8.5
Berkeley and Oldbury	2	<0.27	<0.21	<0.88	<0.27	<1.6	7.0
Cardiff (Orchard Ledges)[b]	2	<0.23					
Holyhead	4[D]	*	0.01				
Wylfa (Cemaes Bay)	2	<0.24	<0.19	<0.91	<0.31	<2.8	10
Wylfa (Cemlyn Bay West)	2	<0.27	<0.22	<1.0	<0.30	<3.0	16
Llandudno	1[D]	*	0.02				
Prestatyn	1[D]	*	0.03				
New Brighton	1[D]	*	0.03				
Ainsdale	1[D]	*	0.04				
Rossall	1[D]	*	0.07				
Heysham (inlet)	2	<0.28	<0.24	<0.89	<0.29	<3.0	14
Half Moon Bay	1[D]	*	0.04				
Silecroft	1[D]	*	0.07				
Seascale (Particulate)	2	<0.04	<0.04	<0.16	0.15	<0.25	<0.10
Seascale (Filtrate)	2	<0.23	<0.20	<1.0	<0.31	<2.6	12
St. Bees (Particulate)	2	<0.04	<0.04	<0.16	0.15	0.37	0.13
St. Bees (Filtrate)	2	<0.18	<0.15	<0.71	<0.21	<3.0	<11
Whitehaven	1[D]	*	0.04				
Maryport	1[D]	*	0.04				
Silloth	1[D]	*	0.06				
Seafield	4[S]	<0.10	<0.10	<0.29	<0.10		
Southerness[c]	4[S]	<0.10	<0.12	<0.29	0.00084		
Auchencairn	4[S]	<0.10	<0.10	<0.34	<0.11		
Ross Bay	1[D]	*	0.05				
Isle of Whithorn	1[D]	*	0.004				
Drummore	1[D]	*	0.02				
Knock Bay	4[S]	<0.10	<0.10	<0.24	<0.10		
Knock Bay	4[D]	*	0.01				
Hunterston[d]	2[S]	<0.10	<0.10	<0.48	<0.12		
Hunterston (South of pipeline)[e]	2[S]	<0.10	<0.10	<0.40	<0.11		
North of Larne	12[N]	*	0.01				
Faslane (Carnban)	2[S]	<0.10	<0.10	<0.32	<0.10		

* *Not detected by the method used*

[a] *The concentration of ^{35}S was <0.85 Bq l^{-1}*

[b] *The concentrations of ^{3}H as tritiated water and ^{125}I were <3.1 Bq l^{-1} and <0.30 Bq l^{-1} respectively*

[c] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were 0.00019 and 0.0015 Bq l^{-1} respectively*

[d] *The concentration of ^{35}S was <0.50 Bq l^{-1}*

[e] *The concentration of ^{35}S was <0.65 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*

Table 8.15. Concentrations of radionuclides in marine sediments – background survey in Scotland, 2013[a]

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1} (dry)							
			^{3}H	^{60}Co	^{125}Sb	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Firth of Clyde	East of Gull Point	1	<5.0	<0.10	0.17	19	<0.21	4.6	84	1300
Firth of Clyde	SW of Lady Isle	1	<5.0	<0.11	<0.35	48	<0.36	20	140	2100
Firth of Clyde	East of Johnston's Point	1	<5.0	<0.10	<0.22	16	<0.22	18	120	1500
Firth of Clyde	East of Brodick	1	<5.0	<0.10	<0.37	99	<0.39	24	150	2000
Clyde Estuary	The Hole	1	<5.0	<0.12	0.77	61	<0.50	8.2	170	1700
Clyde Estuary	Kempoch Point	1	<5.0	0.23	0.83	79	<0.43	13	240	1800

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

9. References

(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, 2013

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (CNS Ltd)[1]	Alpha	BAT	1.90E+06	NA
Other authorised outlets	Beta	BAT	1.19E+06	NA
Capenhurst	Uranium	7.50E+06	2.90E+05	3.9
(Urenco UK Ltd)	Other alpha	2.40E+06	Nil	Nil
	Technetium-99	1.00E+08	Nil	Nil
	Others	2.25E+09	Nil	Nil
	Alpha (Incinerator)	2.00E+08	Nil	Nil
	Beta (Incinerator)	2.50E+08	Nil	Nil
Sellafield[c]	Alpha	8.80E+08	7.44E+07	8.5
	Beta	4.20E+10	7.15E+08	1.7
	Tritium	1.10E+15	1.76E+14	16
	Carbon-14	3.30E+12	5.18E+11	16
	Krypton-85	4.40E+17	5.03E+16	11
	Strontium-90	7.10E+08	3.53E+07	5.0
	Ruthenium-106[2]	2.30E+10	7.04E+08	3.1
	Antimony-125	3.00E+10	9.26E+09	31
	Iodine-129	7.00E+10	9.00E+09	13
	Iodine-131[2]	3.70E+10	4.04E+08	1.1
	Caesium-137	5.80E+09	1.94E+08	3.3
	Radon-222[2]	5.00E+11	4.26E+10	8.5
	Plutonium alpha	1.90E+08	1.57E+07	8.3
	Plutonium-241	3.00E+09	1.43E+08	4.8
	Americium-241 and curium-242	1.20E+08	1.24E+07	10
Springfields	Uranium	5.30E+09	5.63E+08	11
Springfields	Tritium	1.00E+08	3.60E+06	3.6
(National Nuclear Laboratory)	Carbon-14	1.00E+07	4.99E+05	5.0
	Other alpha radionuclides	1.00E+06	Nil	Nil
	Other beta radionuclides	1.00E+07	6.93E+04	<1
Research establishments				
Dounreay	Alpha[e,f]	9.80E+08	9.18E+06	<1
(Fuel Cycle Area)[d]	Beta[f,h]	4.50E+10	1.16E+08	<1
	Tritium	2.00E+12	8.39E+10	4.2
	Krypton-85[i,3]	4.36E+13	Nil	Nil
	Strontium-90	4.20E+09	1.42E+07	<1
	Ruthenium-106	3.90E+09	2.04E+06	<1
	Iodine-129	1.10E+09	3.21E+07	2.9
	Iodine-131	1.50E+08	4.55E+06	3.0
	Caesium-134	8.40E+08	2.55E+05	<1
	Caesium-137	7.00E+09	2.46E+05	<1
	Cerium-144	7.00E+09	1.70E+06	<1
	Plutonium-241	3.30E+09	8.84E+05	<1
	Curium-242	2.70E+08	1.05E+04	<1
	Curium-244[j]	5.40E+07	4.12E+02	<1
Dounreay	Alpha[f,k]	1.00E+07	6.23E+03	<1
(Fast Reactor)[d]	Beta[f,g,h]	1.50E+09	2.32E+04	<1
	Tritium	4.50E+12	1.11E+09	<1
	Krypton-85[i]	4.00E+08	4.66E+08	120

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Dounreay	Alpha[f,k]	6.00E+06	2.57E+04	<1
(Prototype Fast Reactor)[d]	Beta[f,g,h]	5.10E+07	2.19E+05	<1
	Tritium	1.05E+13	5.67E+09	<1
	Krypton-85[i,3]	5.25E+14	1.08E+13	2.1
Dounreay	Alpha[f,k]	6.00E+04	2.65E+02	<1
(PFR minor sources)[d]	Beta[f,g,h]	5.00E+05	9.97E+02	<1
	Tritium	2.00E+11	8.42E+09	4.2
Dounreay	Alpha[f,k]	1.37E+07	8.83E+04	<1
(East minor sources)[d]	Beta[f,g,h]	3.71E+08	3.79E+05	<1
	Krypton-85[i]	1.00E+12	Nil	Nil
Dounreay	Alpha[f,g,k]	3.00E+05	2.35E+03	<1
(West minor sources)[d]	Beta[g,h]	7.50E+07	9.82E+03	<1
	Tritium	1.00E+10	1.40E+08	1.4
Harwell	Alpha	8.00E+05	6.40E+04	8.0
Research Sites Restoration Ltd	Beta	2.00E+07	9.10E+05	4.6
	Tritium	1.50E+13	3.90E+11	2.6
	Krypton-85	2.00E+12	Nil	Nil
	Radon-220	1.00E+14	4.90E+12	4.9
	Radon-222	3.00E+12	2.60E+11	8.7
	Iodines	1.00E+10	Nil	Nil
	Other radionuclides	1.00E+11	Nil	Nil
Winfrith	Alpha	1.00E+05	Nil	Nil
Inutec	Tritium	1.95E+13	1.41E+12	7.2
	Carbon-14	3.00E+10	1.25E+06	<1
	Other	1.00E+05	Nil	Nil
Winfrith	Alpha	2.00E+06	8.00E+02	<1
Research Sites Restoration Ltd	Tritium	5.00E+13	5.19E+10	<1
	Carbon-14	6.00E+09	1.86E+08	3.1
	Other	5.00E+06	1.60E+04	<1
Minor sites				
Imperial College Reactor Centre	Tritium	3.00E+08	1.08E+07	3.6
Ascot	Argon-41	1.70E+12	Nil	Nil
Nuclear power stations				
Berkeley[l]	Beta	2.00E+07	9.26E+04	<1
	Tritium	2.00E+10	9.67E+09	48
	Carbon-14	5.00E+09	5.03E+08	10
Bradwell	Beta	6.00E+08	5.16E+05	<1
	Tritium[4]	6.00E+12	1.27E+10	<1
	Carbon-144	9.00E+11	4.20E+08	<1
Chapelcross[5]	Tritium	2.30E+14	4.58E+13	20
	All other nuclides	7.50E+09	1.07E+08	1.4
Dungeness	Beta[f]	5.00E+08	3.84E+06	<1
A Station[6]	Tritium	2.60E+12	1.07E+10	<1
	Carbon-14	5.00E+12	4.52E+08	<1
Dungeness	Tritium	1.20E+13	9.65E+11	8.0
B Station	Carbon-14	3.70E+12	5.57E+11	15
	Sulphur-35	3.00E+11	1.15E+10	3.8
	Argon-41	7.50E+13	7.42E+12	9.9
	Cobalt-60[f]	1.00E+08	5.36E+06	5.4
	Iodine-131	1.50E+09	2.30E+07	1.5

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Hartlepool	Tritium	1.00E+13	5.37E+11	5.4
	Carbon-14	4.50E+12	2.25E+12	50
	Sulphur-35	2.30E+11	2.15E+10	9.4
	Argon-41	1.50E+14	5.88E+12	3.9
	Cobalt-60[f]	1.00E+08	2.28E+07	23
	Iodine-131	1.50E+09	1.69E+08	11
Heysham Station 1	Tritium	1.00E+13	1.01E+12	10
	Carbon-14	4.50E+12	1.66E+12	37
	Sulphur-35	2.00E+11	3.28E+10	16
	Argon-41	1.50E+14	4.85E+12	3.2
	Cobalt-60[f]	1.00E+08	6.77E+06	6.8
	Iodine-131	1.50E+09	7.07E+07	4.7
Heysham Station 2	Tritium	1.00E+13	1.42E+12	14
	Carbon-14	3.70E+12	1.56E+12	42
	Sulphur-35	2.30E+11	1.02E+10	4.4
	Argon-41	7.50E+13	7.78E+12	10
	Cobalt-60[f]	1.00E+08	1.05E+07	11
	Iodine-131	1.50E+09	7.56E+07	5.0
Hinkley Point A Station	Beta	5.00E+07	1.95E+05	<1
	Tritium	7.50E+11	3.00E+10	4.0
	Carbon-14	5.00E+10	5.10E+08	1.0
Hinkley Point B Station	Tritium	1.20E+13	1.22E+12	10
	Carbon-14	3.70E+12	1.21E+12	33
	Sulphur-35	3.50E+11	6.20E+10	18
	Argon-41	1.00E+14	1.26E+13	13
	Cobalt-60[f]	1.00E+08	8.78E+06	8.8
	Iodine-131	1.50E+09	7.43E+06	<1
Hunterston A Station	Beta[f]	6.00E+07	7.29E+05	1.2
	Tritium	2.00E+10	8.40E+08	4.2
	Carbon-14	2.00E+09	8.30E+07	4.2
Hunterston B Station[d]	Particulate beta	5.00E+08	5.76E+07	12
	Tritium	1.50E+13	1.78E+12	12
	Carbon-14	4.50E+12	1.22E+12	27
	Sulphur-35	5.00E+11	9.17E+10	18
	Argon-41	1.50E+14	7.77E+12	5.2
	Iodine-131	2.00E+09	2.11E+06	<1
Oldbury	Beta	1.00E+08	1.79E+06	1.8
	Tritium	9.00E+12	2.95E+11	3.3
	Carbon-14	4.00E+12	1.41E+10	<1
	Sulphur-35	4.50E+11	4.80E+08	<1
	Argon-41	5.00E+14	Nil	Nil
Sizewell A Station	Beta	8.50E+08	Nil	Nil
	Tritium	3.50E+12	5.16E+10	1.5
	Carbon-14	1.00E+11	7.69E+09	7.7
Sizewell B Station	Noble gases	3.00E+13	3.12E+12	10
	Particulate Beta	1.00E+08	2.40E+06	2.4
	Tritium	3.00E+12	8.50E+11	28
	Carbon-14	5.00E+11	2.20E+11	44
	Iodine-131	5.00E+08	1.80E+07	3.6
Torness	Particulate beta	4.00E+08	6.58E+06	1.6
	Tritium	1.10E+13	1.33E+12	12
	Carbon-14	4.50E+12	9.74E+11	22
	Sulphur-35	3.00E+11	4.63E+10	15
	Argon-41	7.50E+13	3.98E+12	5.3
	Iodine-131	2.00E+09	4.16E+06	<1
Trawsfynydd	Particulate Beta	5.00E+07	1.40E+06	2.8
	Tritium[7]	3.75E+11	5.40E+10	14
	Carbon-14	1.00E+10	7.00E+08	7.0

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Wylfa	Particulate Beta	7.00E+08	1.23E+07	1.8
	Tritium	1.80E+13	1.02E+12	5.7
	Carbon-14	2.30E+12	8.71E+11	38
	Sulphur-35	4.50E+11	1.31E+11	29
	Argon-41	1.00E+14	8.57E+12	8.6
Defence establishments				
Aldermaston[m,8]	Alpha	1.65E+05	1.82E+04	11
	Particulate Beta	6.00E+05	4.74E+03	<1
	Tritium	3.90E+13	6.90E+11	1.8
	Carbon-14	6.00E+06	3.50E+05	5.8
	Acitvation products	NA	4.40E+05	NA
	Volatile beta	4.40E+06	Nil	Nil
Barrow[n]	Tritium	3.20E+06	Nil	Nil
	Argon-41	4.80E+10	Nil	Nil
Burghfield[m]	Tritium	1.00E+10	Nil	Nil
	Alpha	5.00E+03	1.07E+03	21
Coulport	Tritium	5.00E+10	2.81E+09	5.6
Derby[o,p]	Uranium	4.00E+06	5.96E+05	15
	Alpha[f]	2.40E+04	4.40E+01	<1
	Beta[f]	1.80E+06	3.78E+04	2.1
Devonport[q]	Beta/gamma[f]	3.00E+05	4.14E+04	14
	Tritium	4.00E+09	6.30E+08	16
	Carbon-14	4.30E+10	4.10E+08	<1
	Argon-41	1.50E+10	4.00E+06	<1
Dounreay[d] (Vulcan)	Beta[f]	5.10E+06	1.20E+06	24
	Noble gases	5.00E+09	1.68E+08	3.4
Rosyth[r]	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)[9]	Alpha	2.25E+06	2.68E+05	12
	Radionuclides T1/2<2hr	7.50E+11	4.72E+10	6.3
	Tritium	2.00E+12	1.08E+06	<1
	Radon-222	1.00E+13	1.73E+12	17
	Other including selenium-75 and iodine-131	1.60E+10	4.52E+06	<1
Cardiff (GE Healthcare)	Soluble tritium	1.56E+14	4.80E+11	<1
	Insoluble tritium	6.00E+14	6.10E+11	<1
	Carbon-14	2.38E+12	1.67E+11	7.0
	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	Alpha	BAT	2.12E+04	NA
	Beta	BAT	1.15E+05	NA
Lillyhall (Studsvik)	Alpha (particulate)	5.00E+05	4.64E+03	<1
	Beta (particulate)	5.00E+05	1.47E+04	2.9

Table A2.1. continued

* *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 discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection*
[e] *Excluding curium-242 and 244*
[f] *Particulate activity*
[g] *Excluding tritium*
[h] *Excluding krypton-85*
[i] *Krypton-85 discharges are calculated monthly*
[j] *Data excludes any curium-243 present*
[k] *Excluding radon and daughter products*
[l] *Combined data for Berkeley Power Station and Berkeley Centre*
[m] *Discharges were made by AWE plc*
[n] *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
[o] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[p] *Annual limits on beta and alpha derived from monthly and weekly notification levels*
[q] *Discharges were made by Devonport Royal Dockyard Ltd*
[r] *Discharges were made by Rosyth Royal Dockyard Ltd*
[1] *Permit formerly held by Sellafield Limited prior to 30 November 2012*
[2] *Discharge permit revised with effect from 1 June 2012*
[3] *Discharge permit revised with effect from 22 August 2012*
[4] *Discharge permit revised with effect from 1 October 2012*
[5] *Discharge permit revised with effect from 28 May 2013, sulphur-35 and argon-41 are no longer within the authorisation*
[6] *Discharge permit revised with effect from 1 September 2011, sulphur-35 and argon-41 are no longer within the permit*
[7] *Discharge limit revised with effect from 1 November 2011*
[8] *Discharge permit revised with effect 1 November 2012, krypton-85 is now exempt from regulation (up to 1.00E+11 Bq per year), the description of argon-41 was changed to Activation products and the limit is no longer applicable*
[9] *Discharge permit revised with effect from September 2013, sulphur-35, iodine-125 and noble gases are no longer with the permit*
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, 2013

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Urenco UK Ltd)[1]	Uranium	7.50E+08	2.92E+06	<1
(Rivacre Brook)	Uranium daughters	1.36E+09	4.82E+06	<1
	Non-uranic alpha	2.20E+08	1.06E+07	4.8
	Technetium-99	1.00E+09	1.18E+06	<1
Sellafield (sea pipelines)[c]	Alpha	1.00E+12	1.57E+11	16
	Beta	2.20E+14	8.98E+12	4.1
	Tritium	2.00E+16	1.37E+15	6.9
	Carbon-14	2.10E+13	5.53E+12	26
	Cobalt-60	3.60E+12	5.07E+10	1.4
	Strontium-90[2]	4.50E+13	1.06E+12	2.4
	Zirconium-95 + Niobium-95[2]	2.80E+12	9.43E+10	3.4
	Technetium-99	1.00E+13	1.10E+12	11
	Ruthenium-106[2]	5.10E+13	5.83E+11	1.1
	Iodine-129	2.00E+12	2.93E+11	15
	Caesium-134	1.60E+12	8.37E+10	5.2
	Caesium-137	3.40E+13	3.24E+12	9.5
	Cerium-144	4.00E+12	1.92E+11	4.8
	Neptunium-237[2]	7.30E+11	3.45E+10	4.7
	Plutonium alpha	7.00E+11	1.53E+11	22
	Plutonium-241	2.50E+13	3.20E+12	13
	Americium-241	3.00E+11	1.94E+10	6.5
	Curium-243+244[2]	5.00E+10	1.76E+09	3.5
	Uranium[d]	2.00E+03	3.47E+02	17
Sellafield (factory sewer)	Alpha	3.00E+08	4.79E+07	16
	Beta	6.10E+09	1.94E+09	32
	Tritium	6.80E+10	6.58E+09	9.7
Springfields	Alpha	1.00E+11	1.60E+10	16
	Beta	2.00E+13	2.71E+12	14
	Technetium-99	6.00E+11	5.61E+10	9.4
	Thorium-230	2.00E+10	1.90E+09	9.5
	Thorium-232	1.50E+10	1.60E+08	1.1
	Neptunium-237	4.00E+10	3.11E+09	7.8
	Other transuranic radionuclides	2.00E+10	1.97E+09	9.9
	Uranium	4.00E+10	1.00E+10	25
Research establishments				
Dounreay	Alpha[f]	2.00E+10	Nil	Nil
PFR liquid metal disposal plant[e]	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
Dounreay	Alpha[f]	9.00E+10	3.81E+08	<1
Other facilities[e]	Beta[h]	6.20E+11	1.68E+08	<1
	Tritium	5.50E+12	8.88E+10	1.6
	Strontium-90	7.70E+11	3.00E+10	3.9
	Caesium-137	1.00E+12	3.03E+09	<1
Harwell (River Thames)[3]				
	Alpha	1.00E+07	1.27E+05	1.3
	Beta	6.00E+08	4.86E+06	<1
	Tritium	1.00E+11	1.07E+08	<1
	Cobalt-60	5.00E+06	8.90E+04	1.8
	Caesium-137	2.00E+08	1.84E+06	<1
Harwell (Lydebank Brook)[3]	Alpha	3.00E+07	5.03E+06	17
	Beta	3.00E+08	4.55E+07	15
	Tritium	2.00E+10	2.43E+09	12

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Harwell (sewer)[3]	Alpha	1.00E+07	3.53E+05	3.5
	Beta	6.00E+08	9.74E+07	16
	Tritium	1.00E+11	4.68E+08	<1
	Cobalt-60	5.00E+06	9.46E+05	19
	Caesium-137	2.00E+08	6.72E+07	34
Winfrith (inner pipeline)[i]	Alpha	2.00E+10	9.78E+08	4.9
	Tritium	2.20E+14	9.75E+12	4.4
	Caesium-137	2.00E+12	2.58E+09	<1
	Other radionuclides	1.00E+12	1.38E+10	1.4
Winfrith (outer pipeline)	Alpha	2.00E+09	4.96E+06	<1
	Tritium	1.50E+11	1.22E+09	<1
	Other radionuclides	1.00E+09	3.60E+07	3.6
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	1.59E+08	<1
	Caesium-137	2.00E+11	7.26E+07	<1
	Other radionuclides	2.00E+11	3.44E+07	<1
Bradwell	Tritium	7.00E+12	8.30E+09	<1
	Caesium-137	7.00E+11	8.00E+08	<1
	Other radionuclides	7.00E+11	5.00E+08	<1
Chapelcross[4]	Alpha	1.00E+09	1.37E+06	<1
	Non-alpha[j]	1.00E+12	1.52E+09	<1
	Tritium	6.50E+12	1.61E+09	<1
Dungeness A Station	Tritium	8.00E+12	6.67E+10	<1
	Caesium-137	1.10E+12	3.98E+09	<1
	Other radionuclides	8.00E+11	5.43E+09	<1
Dungeness B Station	Tritium	6.50E+14	2.10E+14	32
	Sulphur-35	2.00E+12	1.78E+11	8.9
	Cobalt-60	1.00E+10	4.93E+08	4.9
	Caesium-137	1.00E+11	3.32E+09	3.3
	Other radionuclides	8.00E+10	3.99E+09	5.0
Hartlepool	Tritium	6.50E+14	3.22E+14	50
	Sulphur-35	3.00E+12	1.49E+12	50
	Cobalt-60	1.00E+10	1.61E+08	1.6
	Caesium-137	1.00E+11	1.52E+09	1.5
	Other radionuclides	8.00E+10	6.71E+08	<1
Heysham Station 1	Tritium	6.50E+14	3.33E+14	51
	Sulphur-35	2.00E+12	4.34E+11	22
	Cobalt-60	1.00E+10	2.33E+08	2.3
	Caesium-137	1.00E+11	4.49E+09	4.5
	Other radionuclides	8.00E+10	6.17E+09	7.7
Heysham Station 2	Tritium	6.50E+14	3.63E+14	56
	Sulphur-35	2.00E+12	3.34E+10	1.7
	Cobalt-60	1.00E+10	9.81E+07	<1
	Caesium-137	1.00E+11	2.70E+09	2.7
	Other radionuclides	8.00E+10	1.19E+10	15
Hinkley Point A Station	Tritium	1.00E+12	1.67E+11	17
	Caesium-137	1.00E+12	5.01E+10	5.0
	Other radionuclides	7.00E+11	2.55E+11	36

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Hinkley Point B Station	Tritium	6.50E+14	2.51E+14	39
	Sulphur-35	2.00E+12	4.24E+11	21
	Cobalt-60	1.00E+10	1.17E+08	1.2
	Caesium-137	1.00E+11	1.32E+09	1.3
	Other radionuclides	8.00E+10	3.40E+09	4.3
Hunterston A Station	Alpha	4.00E+10	1.07E+08	<1
	Beta	6.00E+11	1.90E+09	<1
	Tritium	7.00E+11	2.91E+09	<1
	Plutonium-241	1.00E+12	4.50E+07	<1
Hunterston B Station	Alpha	1.00E+09	2.88E+07	2.9
	All other non-alpha	1.50E+11	8.78E+09	5.9
	Tritium	7.00E+14	3.15E+14	45
	Sulphur-35	6.00E+12	9.20E+11	15
	Cobalt-60	1.00E+10	4.60E+08	4.6
Oldbury	Tritium	1.00E+12	1.23E+11	12
	Caesium-137	7.00E+11	1.11E+11	16
	Other radionuclides	7.00E+11	8.04E+10	11
Sizewell A Station	Tritium	5.00E+12	1.05E+11	2.1
	Caesium-137	1.00E+12	1.24E+11	12
	Other radionuclides	7.00E+11	4.53E+10	6.5
Sizewell B Station	Tritium	8.00E+13	4.11E+13	51
	Caesium-137	2.00E+10	1.00E+09	5.0
	Other radionuclides	1.30E+11	1.20E+10	9.2
Torness	Alpha	5.00E+08	3.51E+06	<1
	All other non-alpha	1.50E+11	2.56E+09	1.7
	Tritium	7.00E+14	3.61E+14	52
	Sulphur-35	3.00E+12	8.72E+11	29
	Cobalt-60	1.00E+10	1.14E+08	1.1
Trawsfynydd[5]	Tritium	3.00E+11	4.51E+09	1.5
	Caesium-137	1.50E+10	1.14E+09	7.6
	Other radionuclides[k]	3.00E+10	1.73E+09	5.8
Wylfa	Tritium	1.50E+13	2.11E+12	14
	Other radionuclides	1.10E+11	3.59E+09	3.3
Defence establishments				
Aldermaston (Silchester)[l]	Alpha	1.00E+07	1.60E+06	16
	Other beta emitting radionuclides	2.00E+07	2.10E+06	11
	Tritium	2.50E+10	1.10E+08	<1
Aldermaston (to Stream)[m,l]	Tritium	NA	5.20E+08	NA
Barrow[n,6]	Tritium	1.20E+10	Nil	Nil
	Carbon-14	2.70E+07	Nil	Nil
	Other gamma emitting radionuclides	3.50E+06	Nil	Nil
Derby[o]	Alpha[p]	2.00E+09	4.71E+07	2.4
	Alpha[q]	3.00E+05	7.89E+03	2.6
	Beta[q]	3.00E+08	2.00E+05	<1
Devonport (sewer)[r]	Tritium	2.00E+09	7.79E+07	3.9
	Cobalt-60	3.50E+08	4.70E+06	1.3
	Other radionuclides	6.50E+08	1.62E+08	25
Devonport (estuary)[r]	Tritium	7.00E+11	8.60E+10	12
	Carbon-14	1.70E+09	1.73E+08	10
	Cobalt-60	8.00E+08	5.48E+07	6.9
	Other radionuclides	3.00E+08	1.56E+08	52

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2013	
			Bq	% of annual limit[b]
Faslane	Alpha	2.00E+08	8.00E+04	<1
	Beta[s,j]	5.00E+08	8.50E+05	<1
	Tritium	1.00E+12	8.52E+09	<1
	Cobalt-60	5.00E+08	4.20E+05	<1
Rosyth[t]	Tritium	3.00E+09	5.91E+07	2.0
	Cobalt-60	3.00E+08	1.48E+06	<1
	Other radionuclides	3.00E+08	1.17E+06	<1
Radiochemical production				
Amersham (GE Healthcare)[q,7]	Alpha	3.00E+08	4.80E+06	1.6
	Tritium	1.41E+11	1.50E+06	<1
	Other radionuclides	6.50E+10	4.17E+08	<1
Cardiff (GE Healthcare)	Tritium	1.30E+14	4.49E+09	<1
	Carbon-14	9.10E+11	1.12E+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	Alpha	BAT	5.42E+07	NA
	Beta	BAT	8.57E+08	NA
	Tritium	BAT	6.54E+10	NA
Lillyhall (Studsvik)	Alpha	5.00E+05	8.77E+02	<1
	Beta	5.00E+05	1.32E+04	2.6

[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 when values are less than 1%*
[c] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[d] *The limit and discharge data are expressed in kg*
[e] *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*
[f] *All alpha emitting radionuclides taken together*
[g] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[h] *All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together*
[i] *Discharges reported include those from INUTEC*
[j] *Excluding tritium*
[k] *Including strontium*
[l] *Discharges were made by AWE plc*
[m] *The discharge permit has been replaced by a activity notification level of 30 Bq l^{-1}*
[n] *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*
[o] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[p] *Discharge limit is for Nuclear Fuel Production Plant*
[q] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[r] *Discharges were made by Devonport Royal Dockyard Ltd*
[s] *Excluding cobalt-60*
[t] *Discharges were made by Rosyth Royal Dockyard Ltd*
[1] *Permit formerly held by Sellafield Limited prior to 30 November 2012*
[2] *Discharge permit revised with effect from 1 June 2012*
[3] *Discharge permit revised with effect from 7 November 2011*
[4] *Discharge authorisation revised with effect from 28 May 2013*
[5] *Discharge permit revised with effect from 1 November 2011*
[6] *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 2.70E+07 Bq, to the sewer*
[7] *Discharge permit revised with effect from September 2013, iodine-125 and caesium-137 are not longer within the permit*

NA Not applicable under permit
BAT Best available technology

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2013

Establishment	Radioactivity	Disposal limit	Disposals during 2013	
		Bq	Bq	% of limit[a]
LLWR[b]	Tritium	1.00E+13	2.18E+10	<1
	Carbon-14	5.00E+10	1.05E+09	2.1
	Cobalt-60	2.00E+12	3.17E+09	<1
	Iodine-129	5.00E+10	1.98E+05	<1
	Radium-226 plus thorium-232	3.00E+10	3.47E+07	<1
	Uranium	3.00E+11	2.88E+09	<1
	Other alpha[c]	3.00E+11	3.39E+09	1.1
	Others[c,d]	1.50E+13	2.73E+10	<1
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*

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 2013

Site	Month	Summary of incident	Consequences and action taken
Aldermaston	November 2012 – March 2013	The operator reported increases in tritium discharges from the site to the Aldermaston stream. Whilst these levels were very low and not an environmental hazard, an investigation was undertaken.	Investigations identified the source as out-gassing of tritium waste drums in one of the storage buildings. The Environment Agency undertook its own investigation. It concluded that, whilst the tritium discharged did not represent an environmental hazard, environmental protection factors were not adequately taken in to account when a facility modification was made. A Warning Letter and Enforcement Notice were issued to the operator to bring back compliance with their permit and has now been closed out.
Dounreay	October 2013	Samples taken from the Fast Reactor indicated that the krypton-85 activity present in the reactor cover gas was higher than that present in an historical sample. This historical sample had been used as the basis for the calculation of the krypton-85 content of discharges arising from reactor blow-down operations.	DSRL's discharge estimation for the 12 month rolling total of krypton-85 from the facility was likely to have exceeded the annual authorised limit for this facility. Although the impact on the environment and public health due to the increased krypton-85 discharge was very low, the discharges and the associated sampling arrangements constituted contraventions of the limitations and conditions of the RSA authorisation held by the operator. This resulted in SEPA issuing a Final Warning Letter to DSRL in relation to the operator's management system and procedures.
GE Healthcare Maynard Centre, Cardiff	January 2012 – March 2013	A number of transfers of waste to two incinerators were identified to have had the incorrect activity assigned to them. This caused one of the incinerators to breach discharge limits.	The impact of the incinerator breaching its limits was insignificant in terms of radiological dose. The Environment Agency, on behalf of Natural Resources Wales (NRW), and the site conducted investigations and a number of actions were identified and progressed to help prevent future errors occurring. An inspection was then carried out to confirm that these improvements had been implemented. A Warning Letter was issued to GE Healthcare by NRW in September 2013.
Hartlepool	December 2013	The quarterly notification level was breached for sulphur-35 in liquid discharges.	A BAT justification was provided and levels have subsequently reduced.
Metal Recycling Facility, Lillyhall	June 2013	Low Level Waste (LLW) metal was inadvertently transferred to the Sellafield site. There was no harm to people or the environment as a result of this transfer.	The operator immediately put in place measures to prevent a recurrence, along with a comprehensive improvement programme to address the wider findings. The waste was returned to the Metal Recycling Facility for its correct disposal to be arranged. The Environment Agency's formal investigation of the event resulted in a caution being accepted by the operator in February 2014 for three offences under the Environmental Permitting Regulations 2010.
Oldbury	N/A	Levels of tritium had increased in a small number of boreholes on the site.	The site operator is investigating the source of the tritium which is thought to originate from the site's fuel pond.
Sellafield	March 2013	A hole was found in the analytical services vent duct which resulted from an inadequate maintenance and inspection regime. This had no discernible environmental impact.	Advice and guidance was provided to the operator to improve inspection and maintenance regime for the affected ductwork.
Sellafield	June 2013	A break in the trace active drain resulted in minor loss of liquor.	Advice and guidance was provided to the operator. The event had negligible impact on people or the environment, nor the realistic potential for greater harm to occur.
Sellafield	November 2013	A partial loss of power affected the Waste Vitrification Plant Line 3, resulting in a release of contamination within the facility. There was a small increase in discharges to air compared with normal releases but discharge levels remained within the permit limits.	A Warning Letter was issued to the operator. The Office for Nuclear Regulation served an Improvement Notice for the operator to improve arrangements with respect to the physical containment barriers and resilience of the facility's ventilation systems, with a deadline of end of October 2014.

APPENDIX 3. Abbreviations and glossary

ABL	AWE plc, Babcock and Lockheed Martin UK
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
CNS	Capenhurst Nuclear Services Limited
COS	Carbonyl Sulphide
CoRWM	Committee on Radioactive Waste Management
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DH	Department of Health
DPAG	Dounreay Particles Advisory Group
DSRL	Dounreay Site Restoration Limited
DSTL	Defence Science and Technology Laboratory
Euratom	European Atomic Energy Community
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EDF	Electricité de France
EPR 10	Environment Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
ESC	Environmental Safety Case
ESG	Environmental Scientifics Group
EU	European Union
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GDL	Generalised Derived Limit
GE	General Electric
GES	Good Environmental Status
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
ICRP	International Commission on Radiological Protection
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
MCAA	Marine and Coastal Act 2009
MMO	Marine Management Organisation
MoD	Ministry of Defence
MODP	Magnox Optimised Decommissioning Programme
MRF	Metals Recycling Facility
MRL	Minimum Reporting Level
MRWS	Managing Radioactive Waste Safely
ND	Not Detected
NDA	Nuclear Decommissioning Authority
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NMP	Nuclear Management Partners Limited
NORM	Naturally Occurring Radioactive Material
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
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)
PHE	Public Health England
PWR	Pressurised Water Reactor
RAPs	Reference Animals and Plants
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 Ion Exchange Plant
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
VLLW	Very Low Level Waste
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.
Radiationweighting	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 person	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 (for example, 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 their websites (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*

APPENDIX 5. Disposal of dredge material

In England, the Marine Management Organisation (MMO) administers a range of statutory controls that apply to marine works on behalf of the Secretary of State for Environment, Food and Rural Affairs, this includes issuing licences under the Marine and Coastal Access Act (MCAA), 2009 (United Kingdom - Parliament, 2009) for the disposal of dredged material at sea. Licences for disposals made in Scottish waters and around the coast of Northern Ireland are the responsibility of the Scottish Government (Marine Scotland) and the Department of Environment (NIEA), respectively and licences for Welsh waters are the responsibility of the Welsh Government.

The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003). This has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006).

In 2013, Magnox Limited lodged a licensing application for the removal of silt from the inlet and outlet of Bradwell Nuclear Power Station in Essex, involving the dredging and disposal at sea of approximately 915 m^3 (1,400 tonnes) of silt. EDF Energy Nuclear Generation Limited lodged two separate licensing applications in 2012 and 2013. In 2012, the application included a variety of dredging scenarios for Hinkley Point C Power Station in Somerset, within which dredging and disposal could occur from 1 November 2013 to 31 October 2015. The volume of material to be dredged and disposed of at sea involved up to 200,000 m^3 for the intakes and outfalls and 24,885 m^3 for the temporary jetty. In 2013, the application involved a dredging program to dispose at sea of 198,000 tonnes of material (sand and silt), over the licence lifetime, from the cooling water intake area of Heysham 1 and 2 Power Station in Lancashire. Specific assessments were conducted for the disposal of the dredge material for each of the three locations (Dewar *et al.*, 2013; Leonard *et al.*, 2013; Leonard and Smedley, 2013).

At Bradwell, the silt contained artificial radionuclides typical of sediments resulting from discharges from the Bradwell Nuclear Power Station and the long distant effects (due to the long distance transfer of Sellafield derived activity and fallout from weapon testing). Similarly at Hinkley, sediments contained artificial radionuclides typical of sediments resulting from the combined effects of discharges from the Hinkley Point Power station, other nuclear establishments discharging into the Bristol Channel and weapon testing (and possibly a small Sellafield derived component). Sand and silt samples taken from the cooling water intake area for Heysham Power Stations contained artificial radionuclides typical of sediments along the Cumbrian coastline, being significantly enhanced above background levels outside the Irish Sea. The contamination is a legacy of large discharges from the Sellafield Limited reprocessing plant (formally British Nuclear Fuels) at Sellafield in the 1970's.

Samples of the material were taken and analysed, and the results are given in Tables A5.1 (Bradwell Nuclear Power Station), A5.2 (Hinkley Point Power Station) and A5.3 (Heysham Power Station). The contributions from individual radionuclides to the doses for individual crew members and individual members of the public are given in Figures A5.1-2 (Bradwell Nuclear Power Station), A5.3-4 (Hinkley Point Power Station) and A5.5-6 (Heysham Power Station). Under the London Convention, only materials with *de minimis* levels of radioactivity may be considered for dumping. Using the conservative generic radiological assessment procedure developed by the IAEA (International Atomic Energy Agency, 2003) to convert radionuclide concentrations in dumped material into radiation doses due to dumping, the *total dose* (from artificial and naturally occurring radionuclides) to an individual member of the crew and to a member of the public were within the IAEA *de minimis* criteria of 0.010 mSv per year, for each of the three locations.

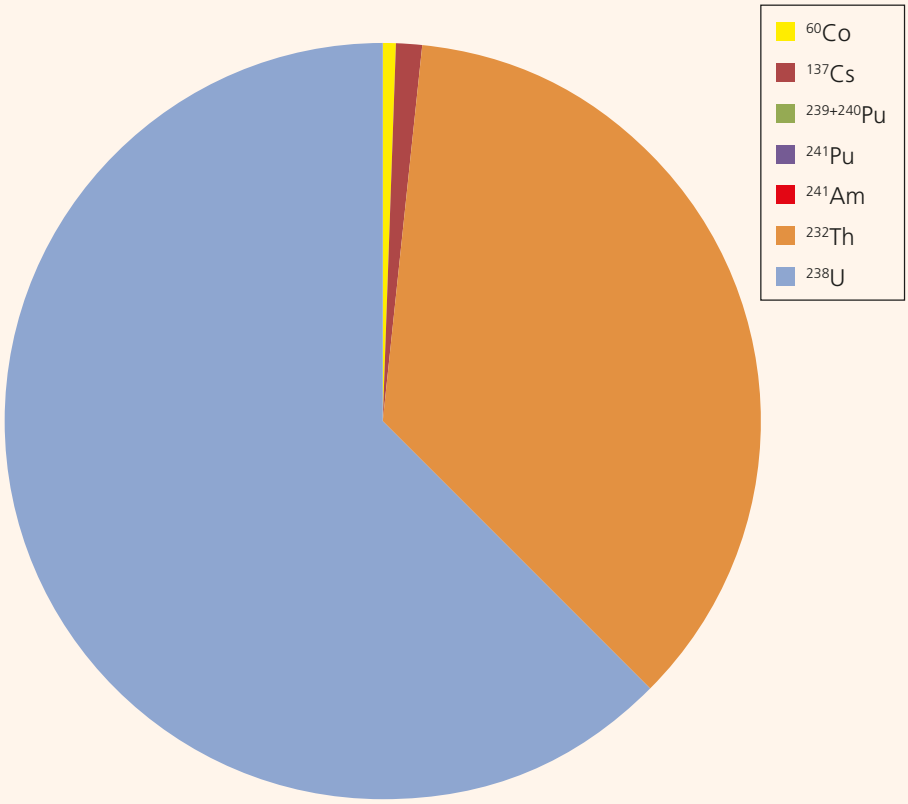

Figure A5.1. Radionuclide contribution to dose to individual crew members due to dredging at Bradwell nuclear power station, 2013

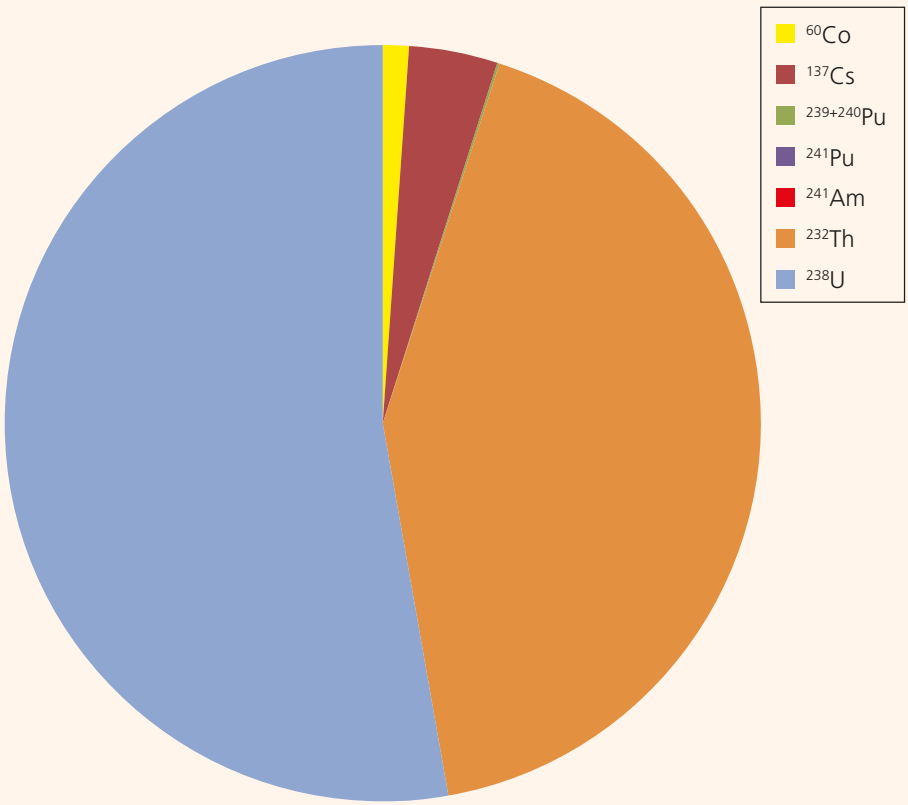

Figure A5.3. Radionuclide contribution to dose to individual crew members due to dredging at Hinkley Point nuclear power stations, 2013

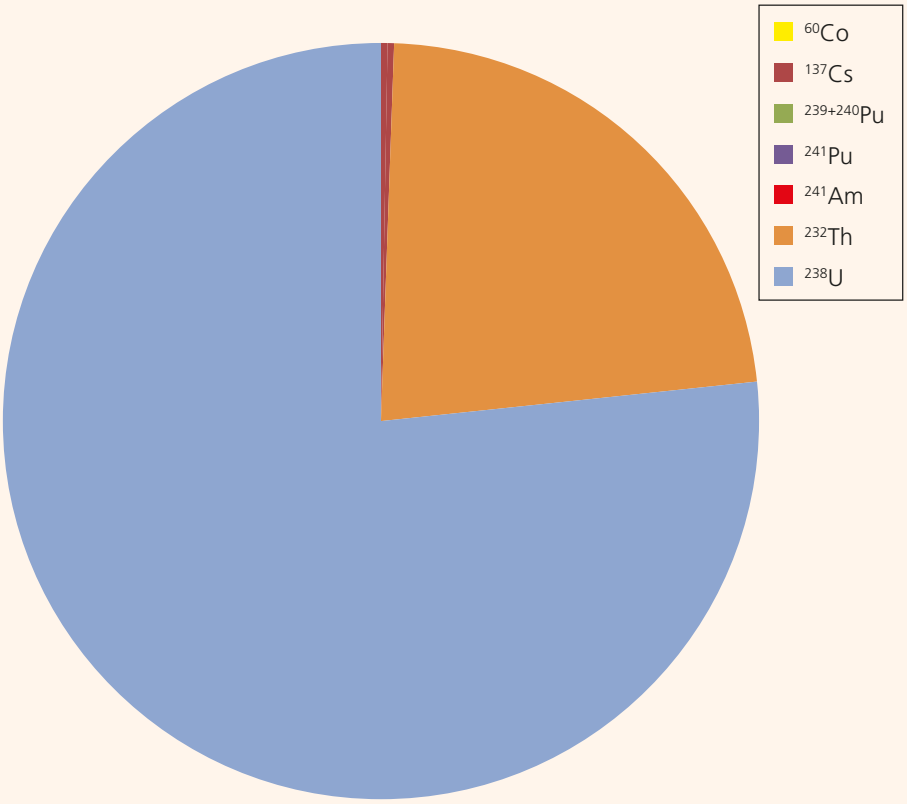

Figure A5.2. Radionuclide contribution to dose to individual members of the public due to dredging at Bradwell nuclear power station, 2013

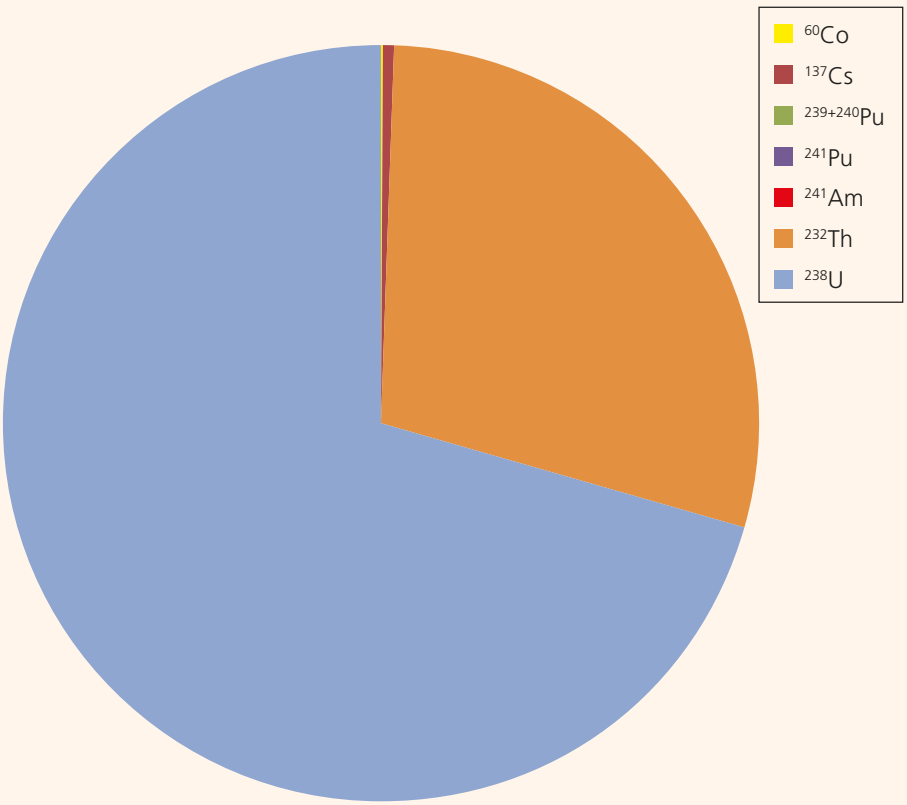

Figure A5.4. Radionuclide contribution to dose to individual members of the public due to dredging at Hinkley Point nuclear power stations, 2013

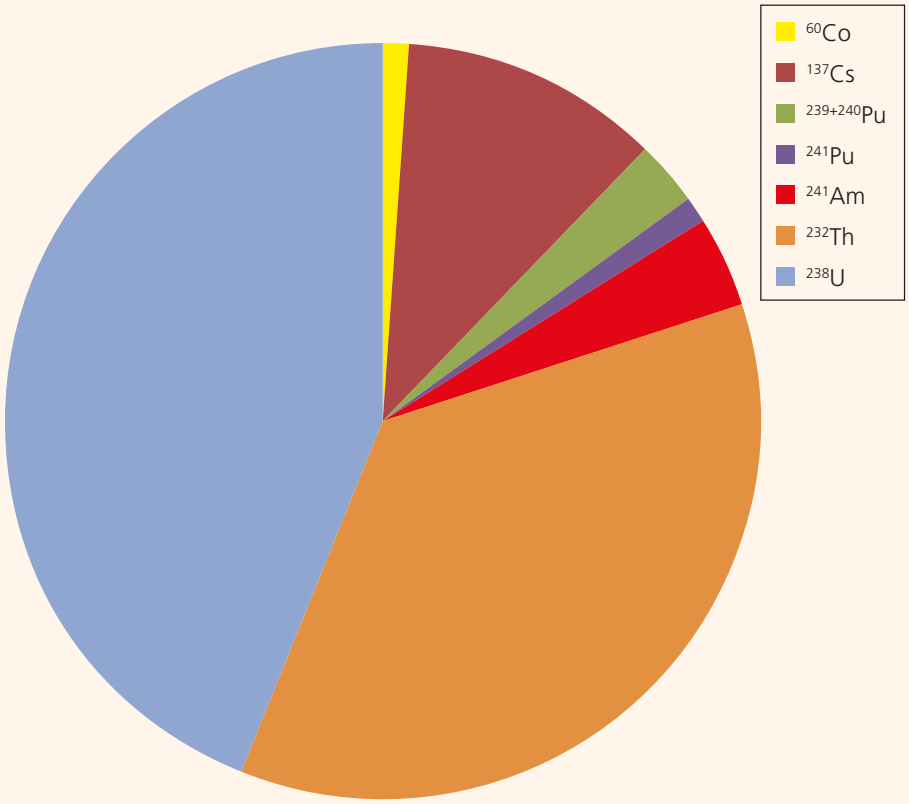

Figure A5.5. Radionuclide contribution to dose to individual crew members due to dredging at Heysham nuclear power stations, 2013

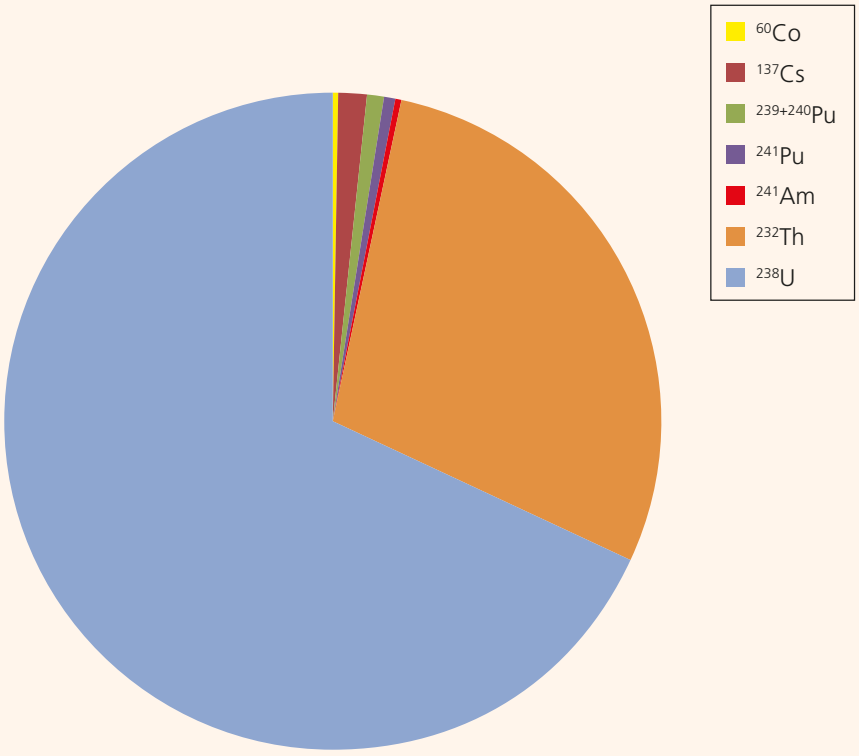

Figure A5.6. Radionuclide contribution to dose to individual members of the public due to dredging at Heysham nuclear power stations, 2013

Table A5.1. Concentrations of radionuclides in sediment dredged from Bradwell nuclear power station, 2013

Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb)[1]	^{232}Th (via ^{228}Ac)[1]	^{238}U (via ^{234}Th)[1]	^{241}Am
1 (East Outlet Culvert)	0.52	8.0	22	25	48	0.39
2 (West Inlet Culvert)	<0.24	8.0	22	25	54	<0.71
Mean*	0.4	8.0	22	25	51	0.55

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

Table A5.2. Concentrations of radionuclides in sediment dredged from Hinkley Point nuclear power stations, 2013

Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb)[1]	^{232}Th (via ^{228}Ac)[1]	^{238}U (via ^{234}Th)[1]	^{241}Am
1 – In/Out (MCU 12/45)	<0.43	22	23	28	45	<1.5
2 – In/Out (MCU 12/45)	<0.40	27	22	27	43	<1.6
3 – In/Out (MCU 12/45)	<0.44	17	21	25	41	0.63
4 – In/Out (MCU 12/58)	<0.25	7.0	11	14	19	<0.96
5 – In/Out (MCU 12/45)	<0.44	32	26	34	42	<1.6
6 – In/Out (MCU 12/45)	<0.42	23	24	31	43	<1.5
7 – In/Out (MCU 12/45)	<0.45	21	24	28	33	<1.6
8 – In/Out (MCU 12/45)	<0.41	19	23	26	46	<1.5
9 – In/Out (MCU 12/45)	<0.45	21	24	26	44	<1.6
10 – In/Out (MCU 12/45)	<0.46	22	22	26	39	<1.7
11 – In/Out (MCU 12/45)	<0.44	23	24	26	42	<1.6
12 – In/Out (MCU 12/45)	<0.41	19	22	27	42	<1.5
1 – NNB (MCU 12/58)	<0.43	20	24	27	40	<0.71
2 – NNB (MCU 12/58)	<0.43	21	23	26	43	<1.6
3 – NNB (MCU 12/58)	<0.49	19	24	26	41	0.97
4 – NNB (MCU 12/48)	<0.45	21	24	28	39	3.2
5 – NNB (MCU 12/58)	<0.45	22	25	27	44	<0.66
Mean*	0.4	21	23	27	40	1.6

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

Table A5.3. Concentrations of radionuclides in sediment dredged from Heysham nuclear power stations, 2013

Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb)[1]	^{232}Th (via ^{228}Ac)[1]	^{238}U (via ^{234}Th)[1]	^{241}Am
A – Surface	<0.28	35	16	14	16	48
B – Surface	<0.31	38	16	15	25	49
C – Surface	<0.30	42	14	14	18	44
A – Sub-surface	<0.30	45	16	16	24	56
B – Sub-surface	<0.32	52	16	16	32	69
C – Sub-surface	<0.29	36	13	15	17	44
Mean*	0.30	41	15	15	22	52

[1] *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

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ISSN 1365-6414