RIFE - 19

Radioactivity in Food and the Environment, 2013

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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.

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* *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.

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

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

* *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

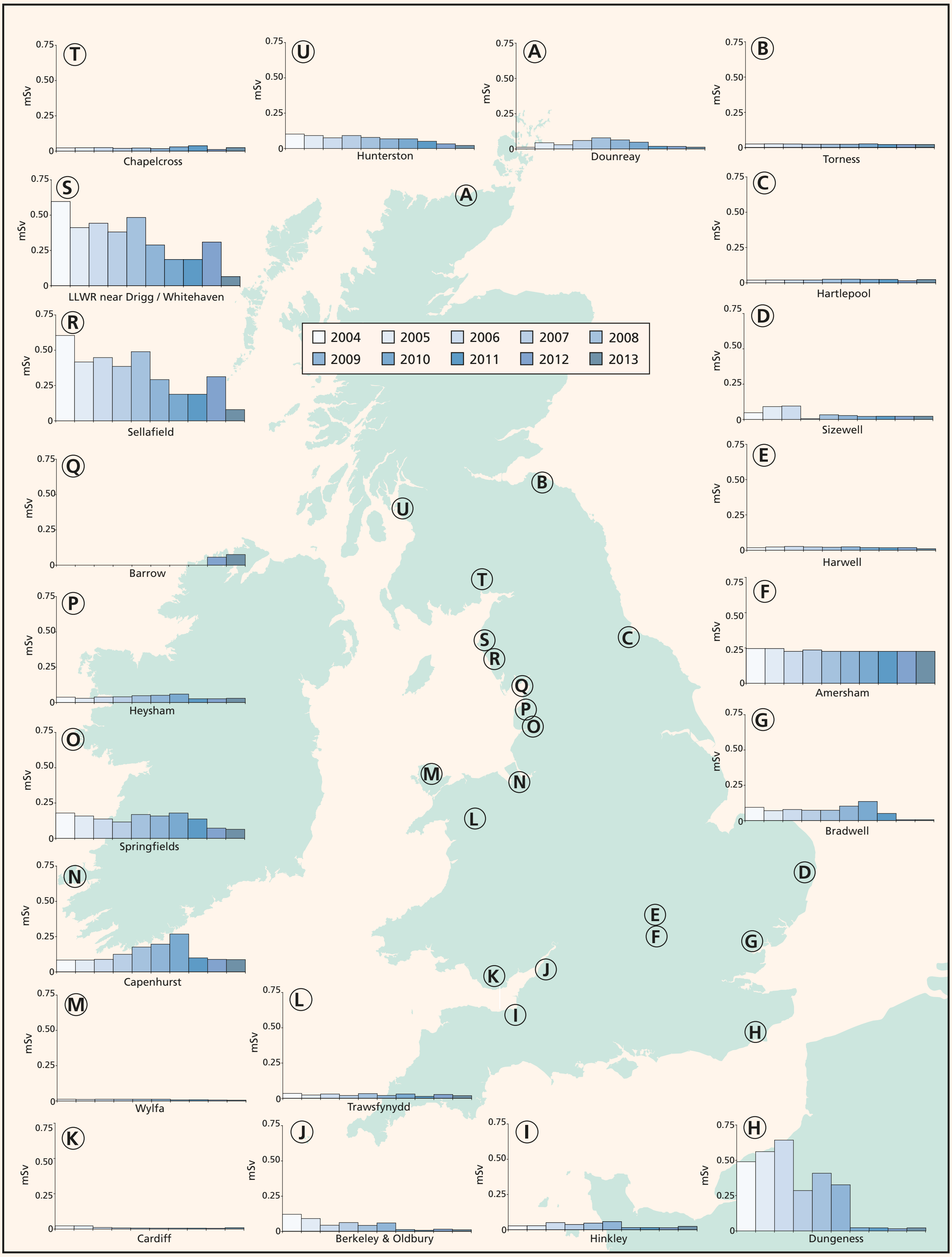


Figure 1.2. *Total doses* around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2013). (Exposures at Sellafield/Whitehaven/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear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

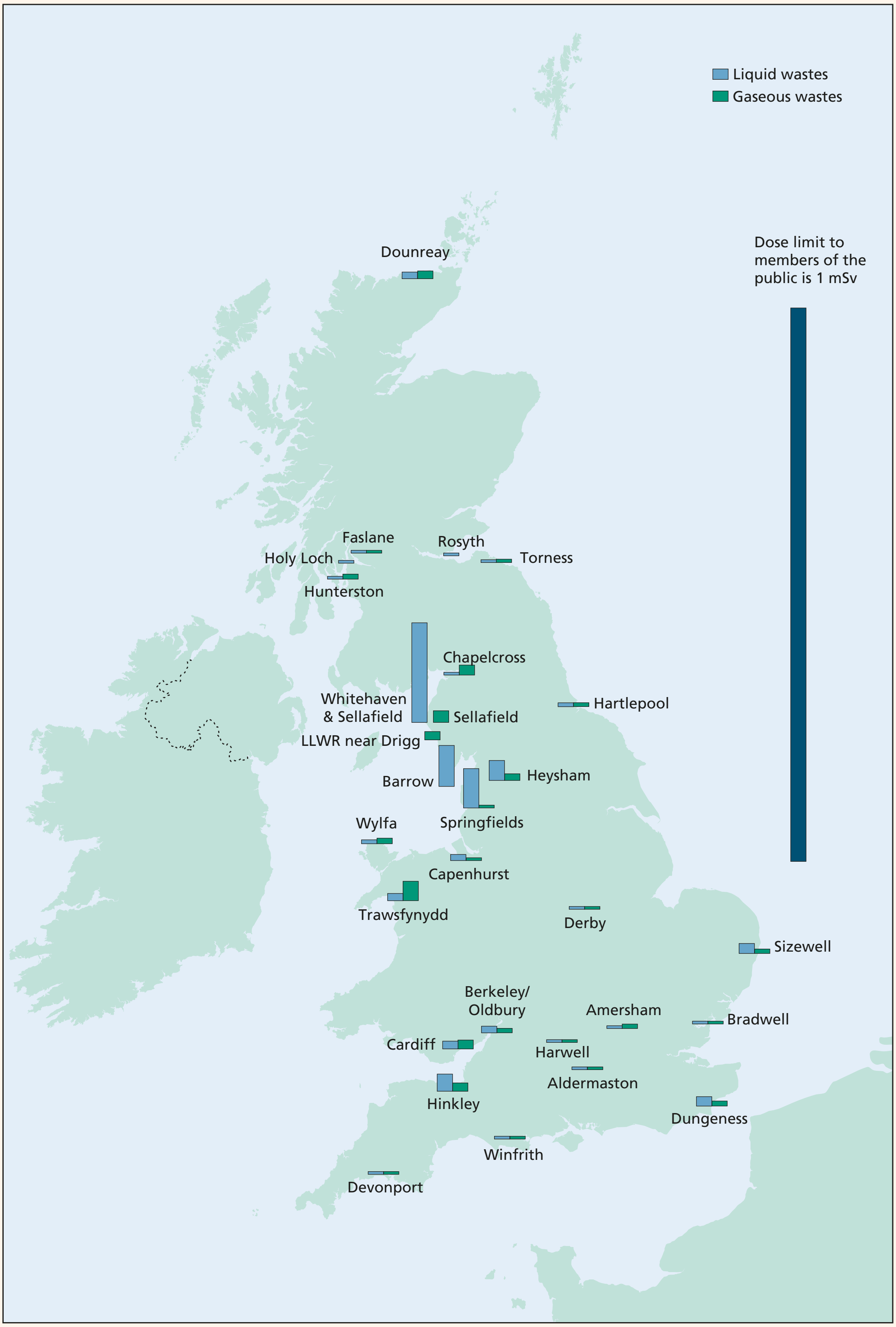


Figure 1.3. Source specific doses in the UK, 2013 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

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)

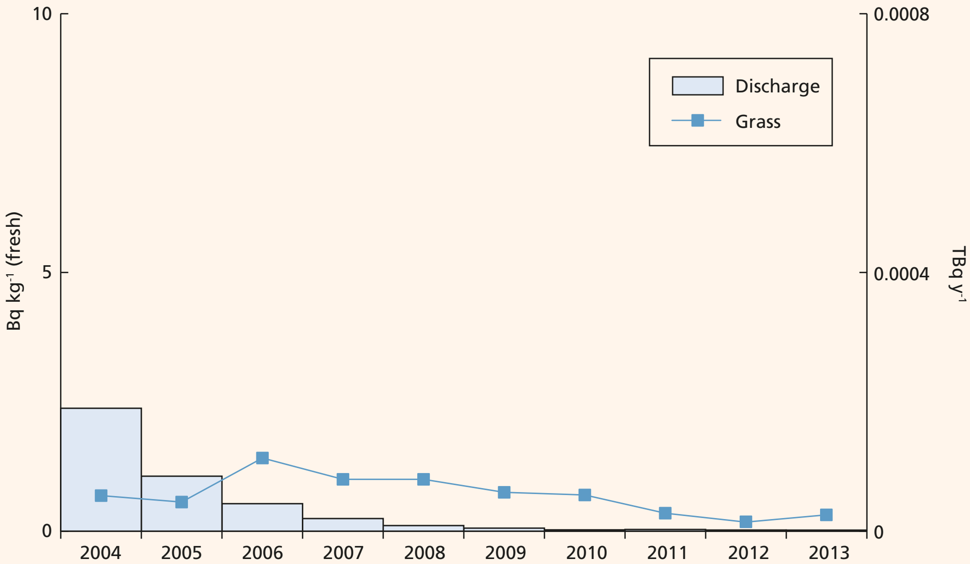
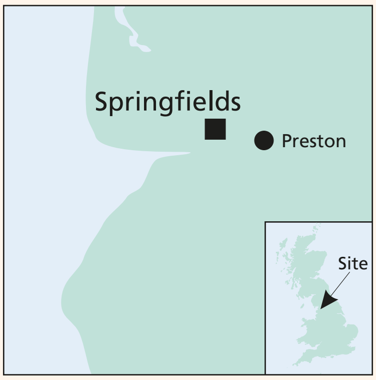


Figure 2.2. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2004-2013

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

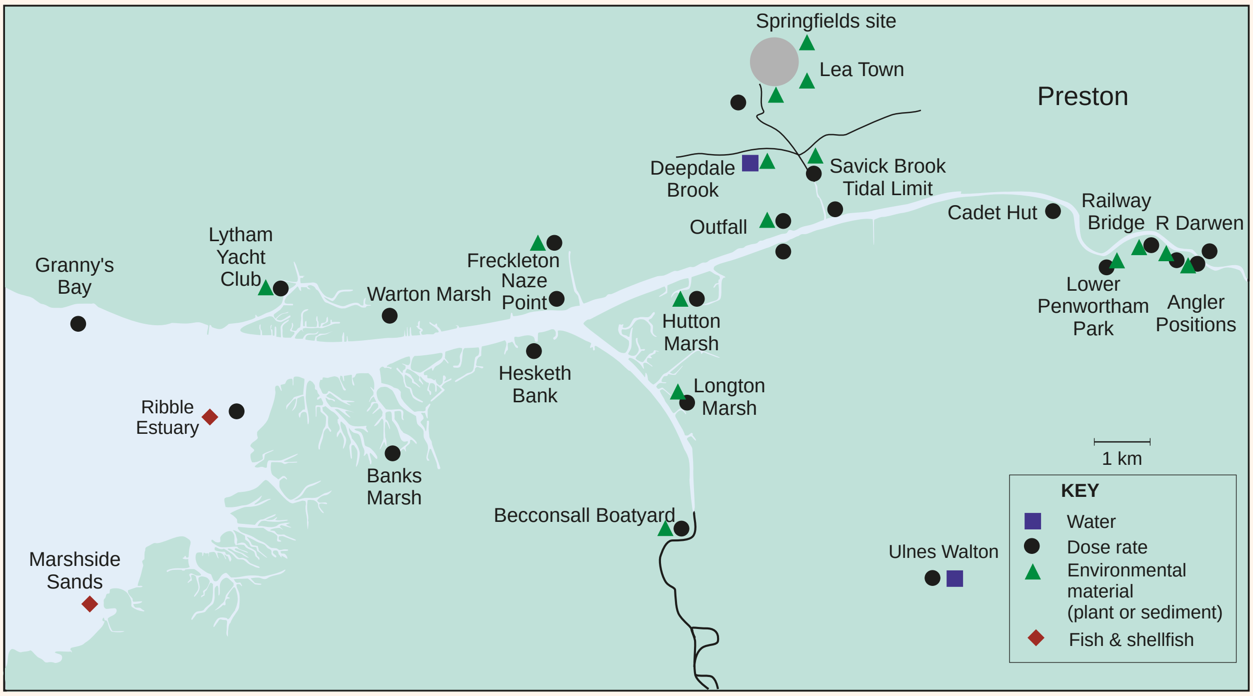


Figure 2.3. Monitoring locations at Springfields, 2013 (not including farms)

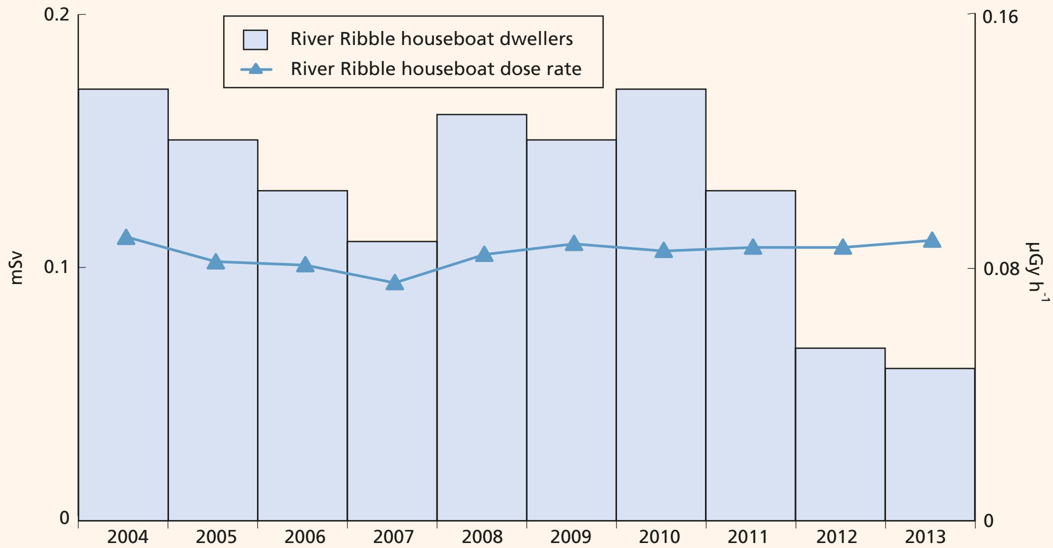


Figure 2.4. *Total dose* from all sources and dose rates at Springfields, 2004-2013

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.

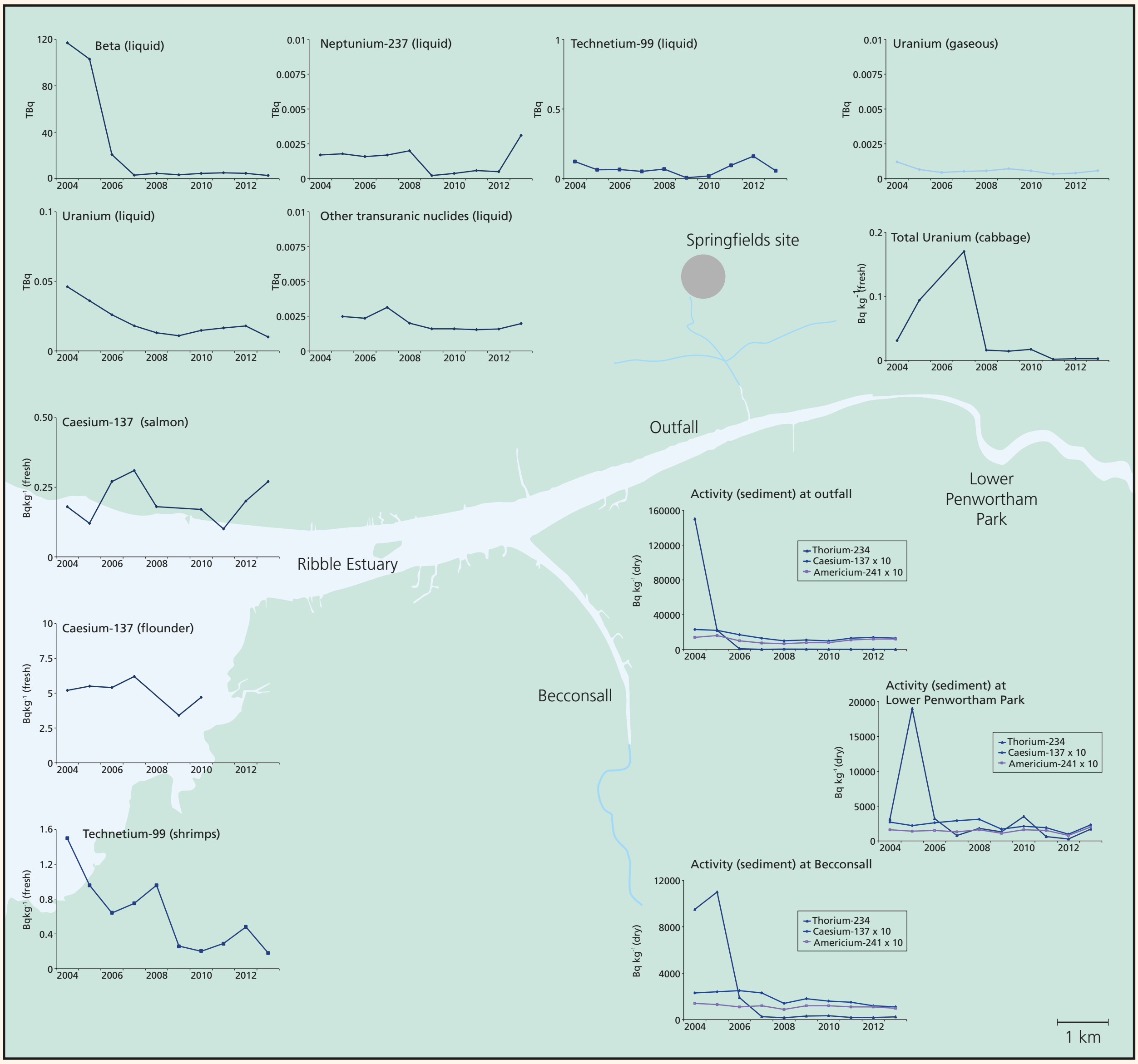


Figure 2.5. Discharges of gaseous and liquid radioactive wastes and monitoring of the environment, Springfields 2004–2013 (Note different scales used for discharges and activity concentrations)

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

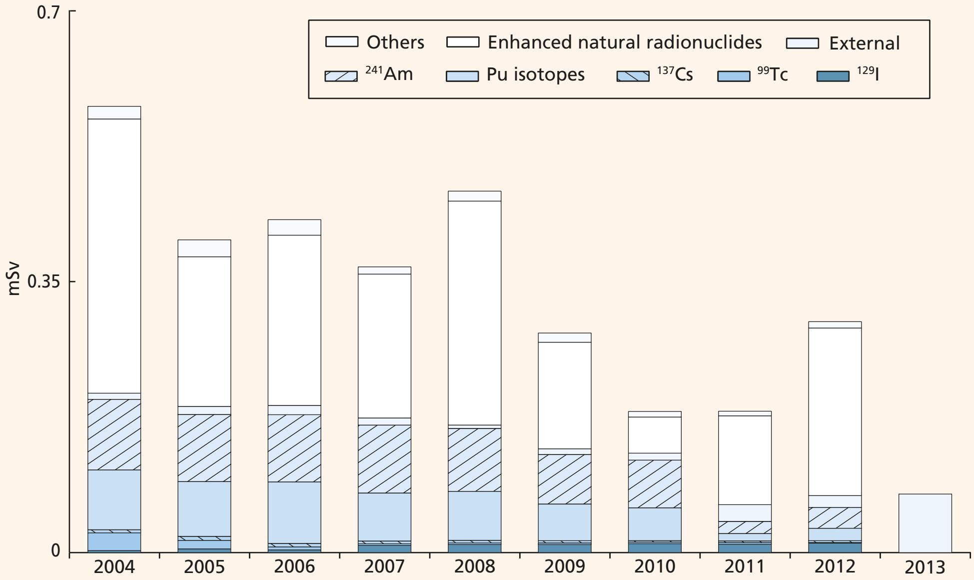


Figure 2.6. Contributions to *total dose* from all sources at Sellafield, 2004-2013

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

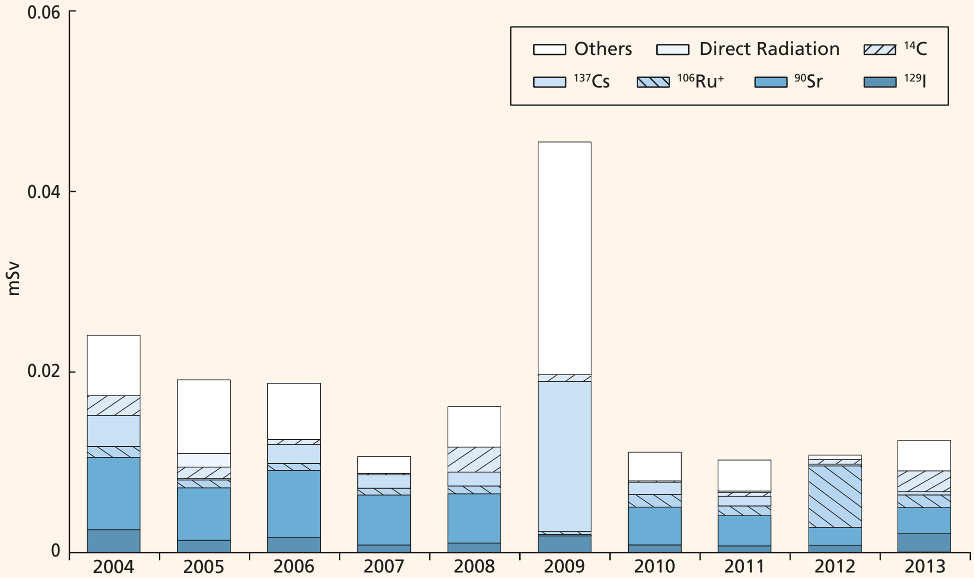


Figure 2.7. Contributions to *total dose* from gaseous discharge and direct radiation sources at Sellafield, 2004-2013 (+ based on limits of detection for concentrations in foods)

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

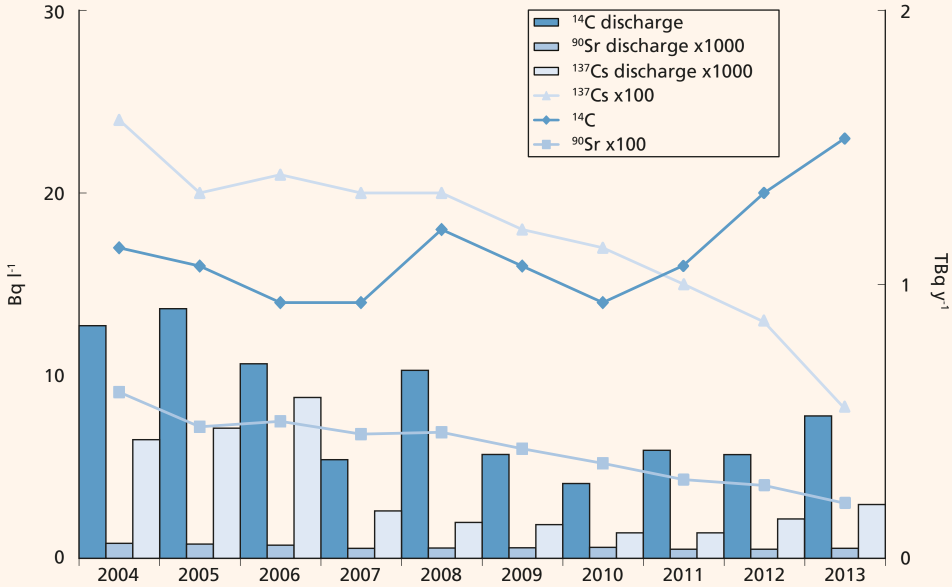


Figure 2.8. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2004-2013

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.

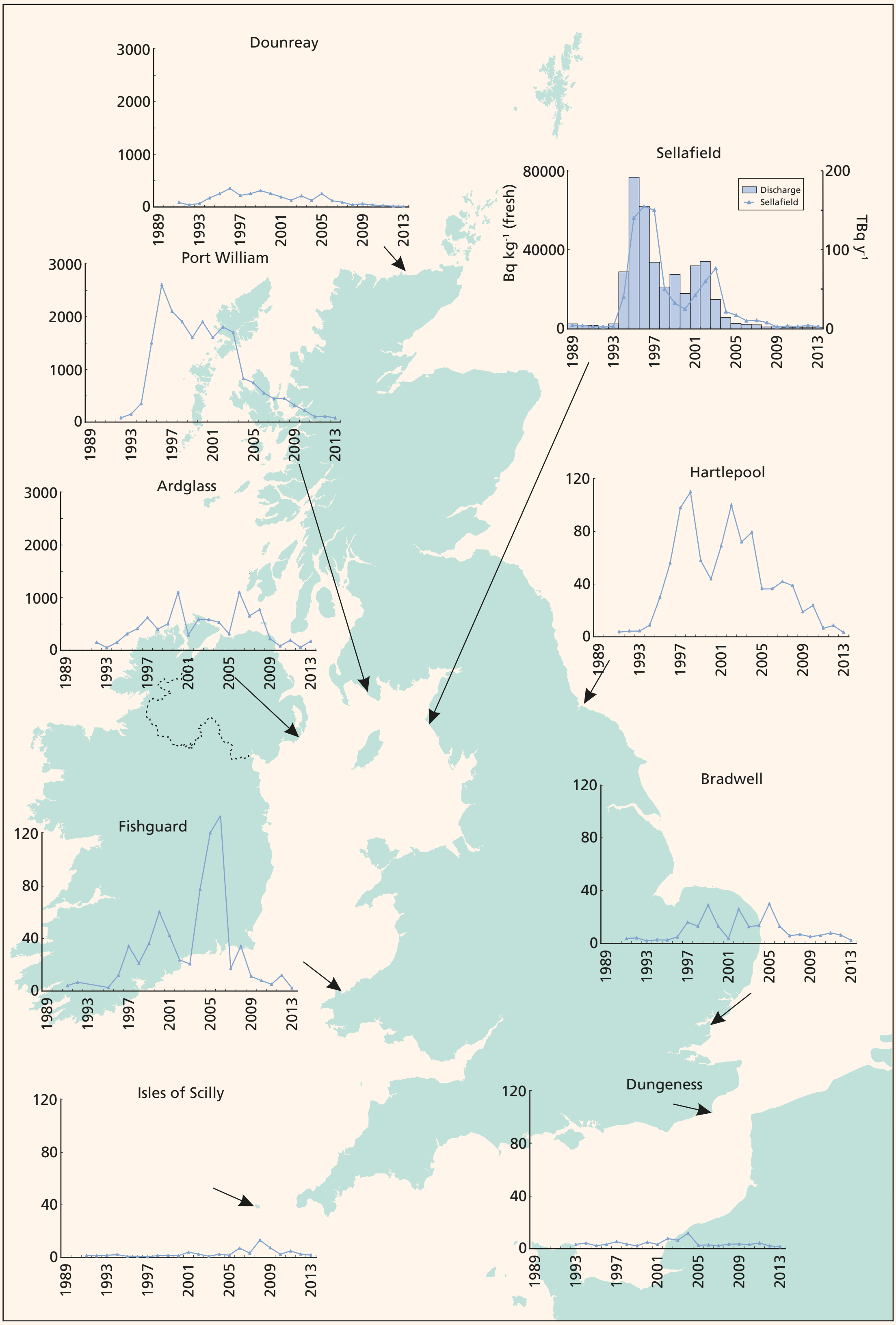


Figure 2.9. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2013 (Note different scales used for Ardglass, Dounreay, Port William and Sellafield)

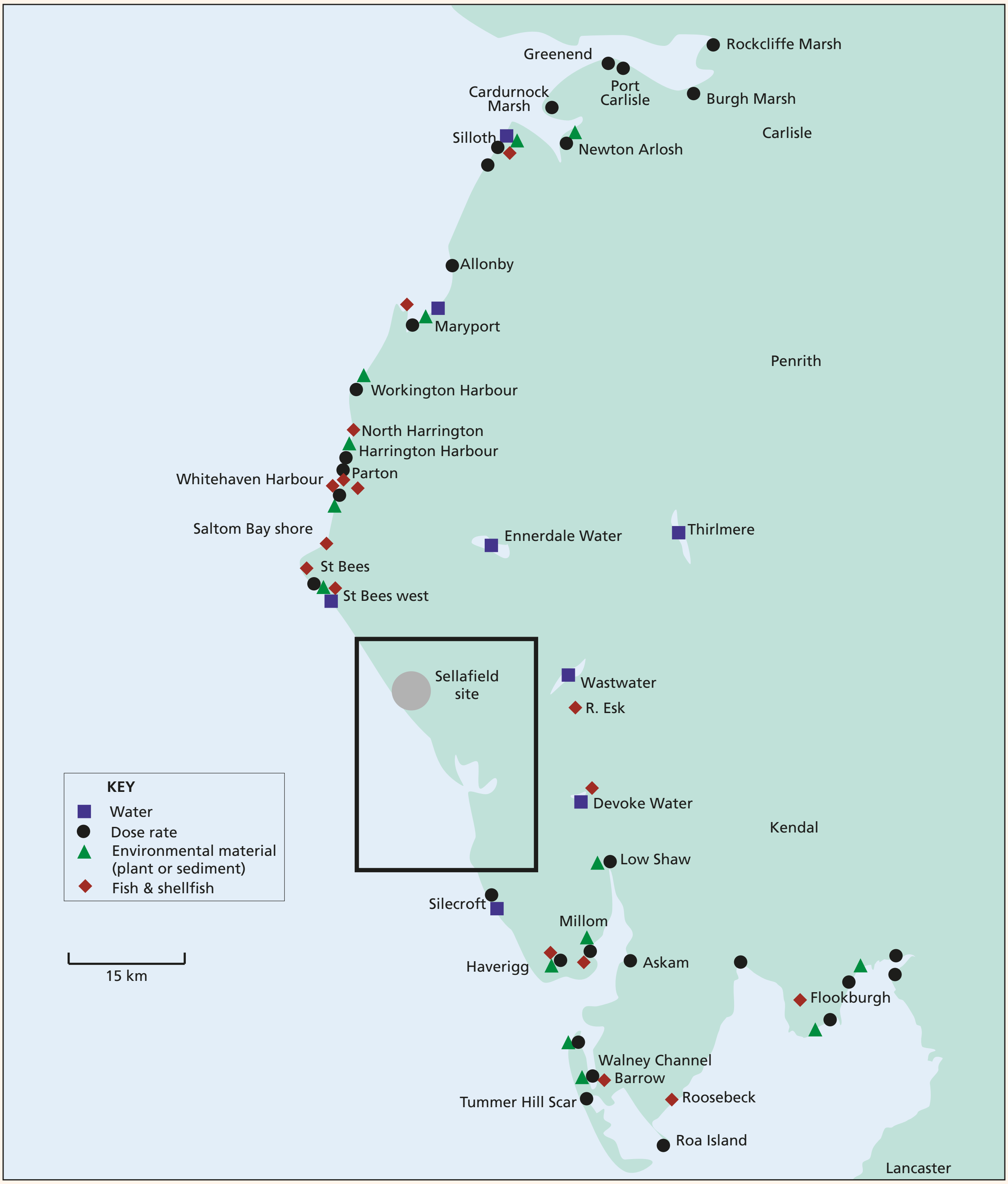


Figure 2.10. Monitoring locations in Cumbria, 2013 (not including farms)

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)

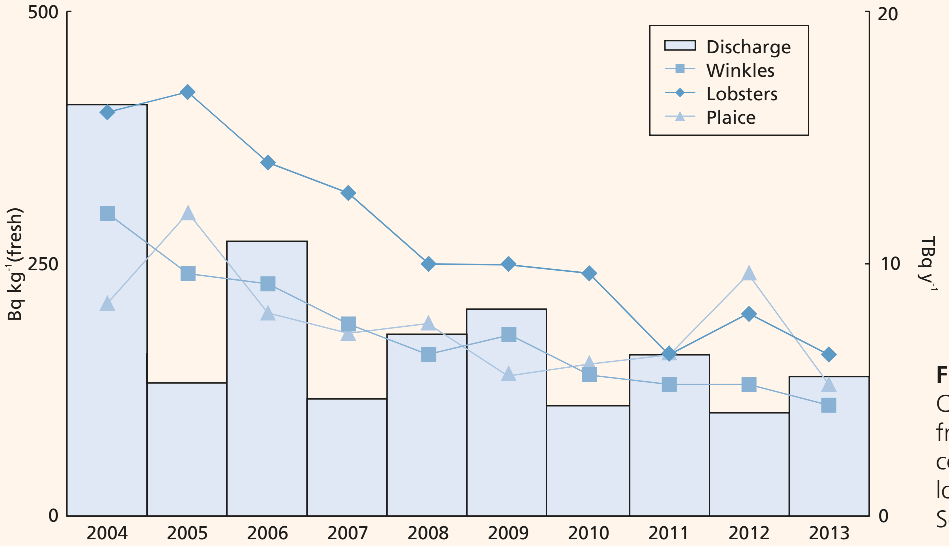


Figure 2.12.
Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

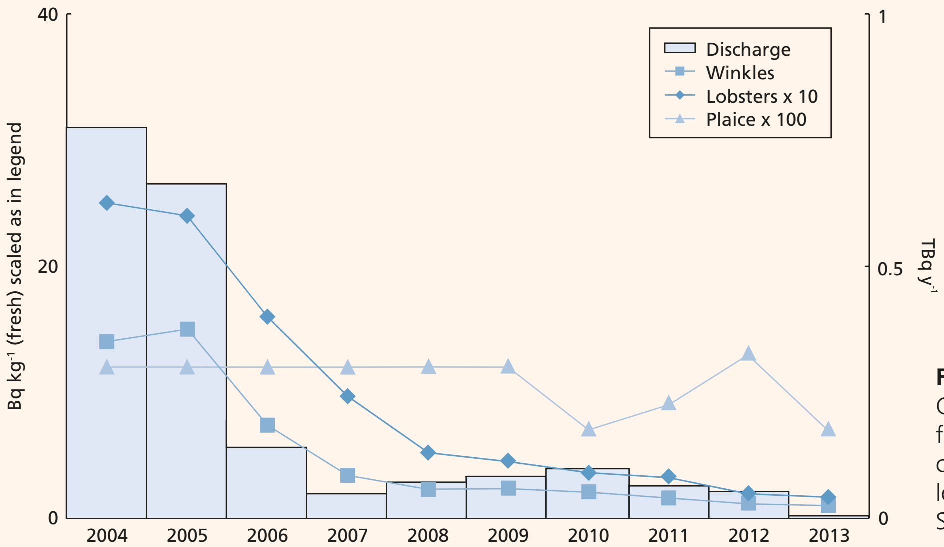


Figure 2.13.
Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

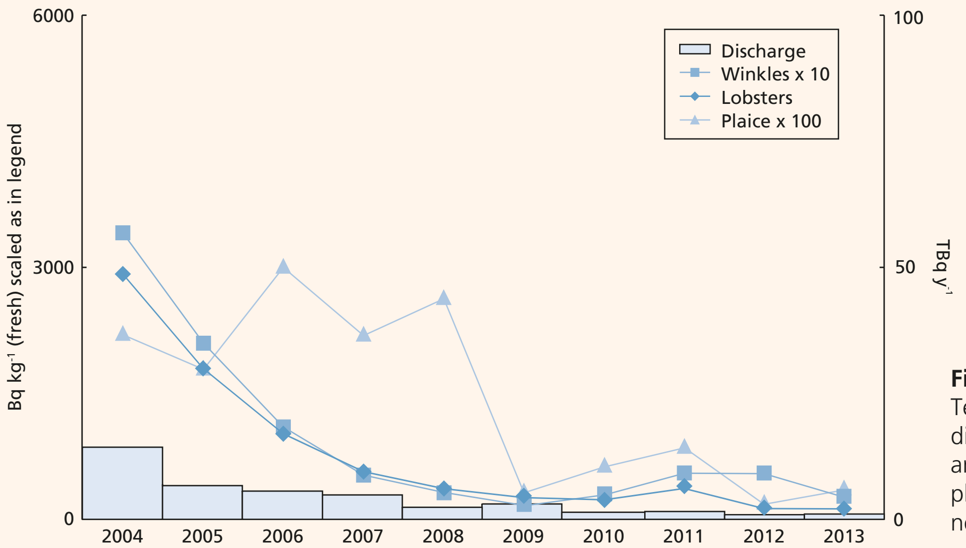


Figure 2.14.
Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

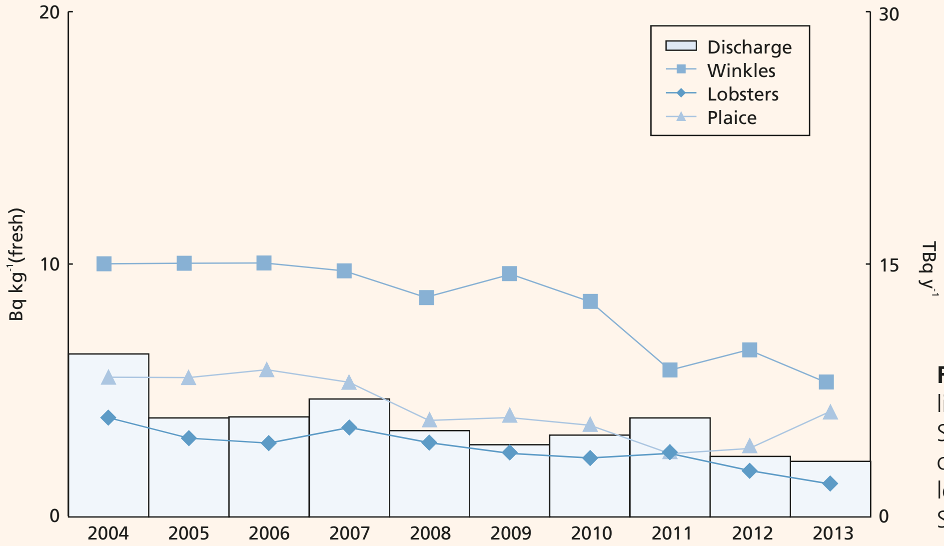


Figure 2.15. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

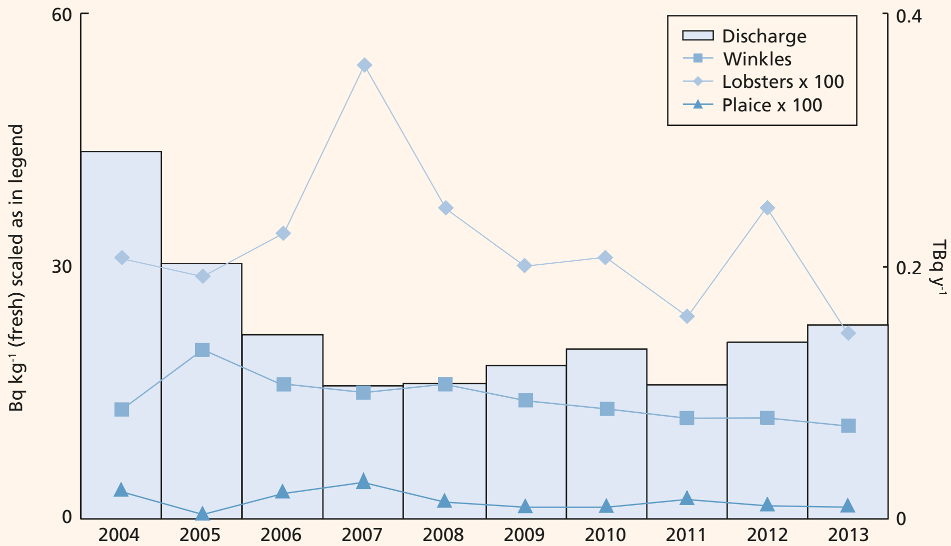


Figure 2.16. Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

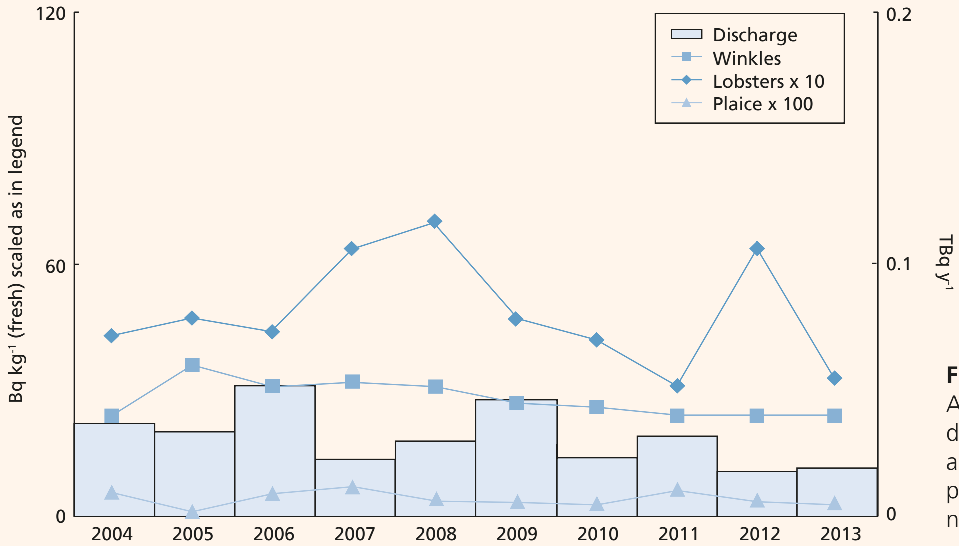


Figure 2.17. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2013

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.

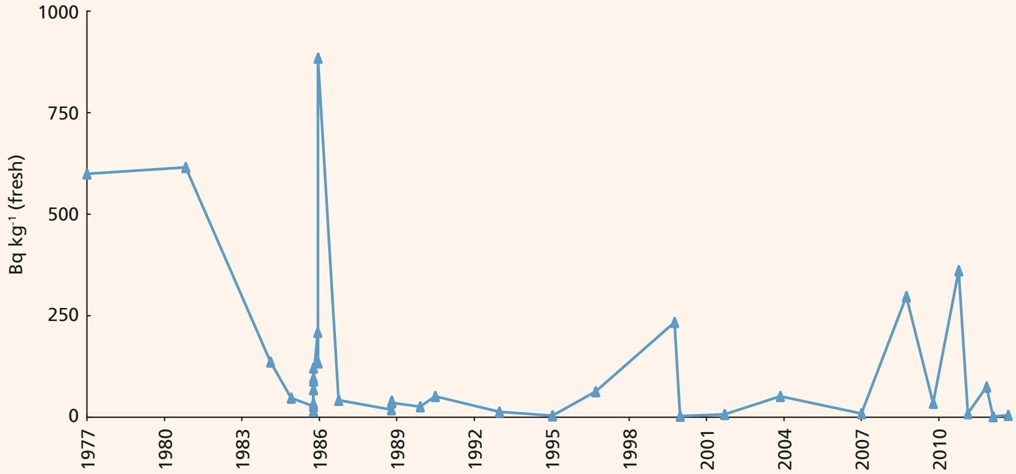


Figure 2.18. Concentration of caesium-137 in River Calder brown trout, 1977-2013

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,

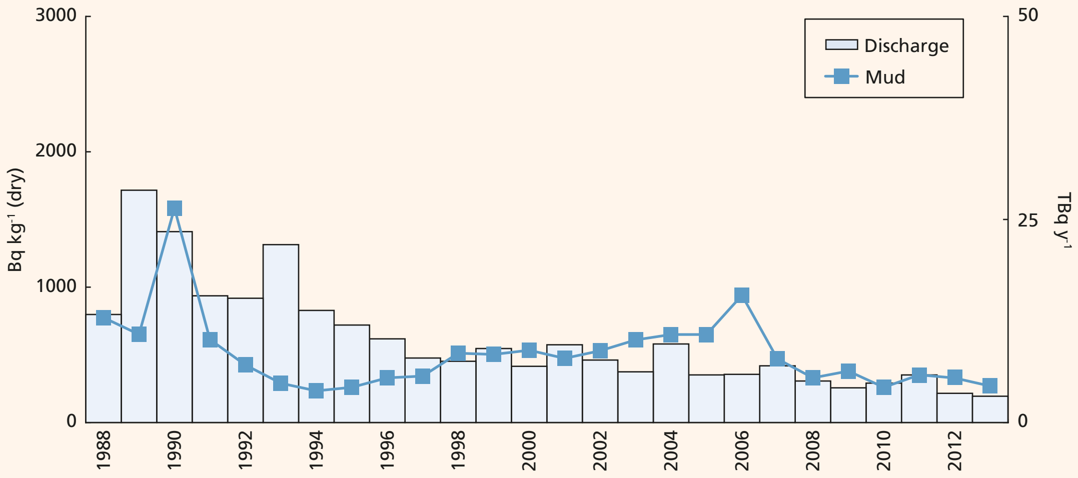


Figure 2.19. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

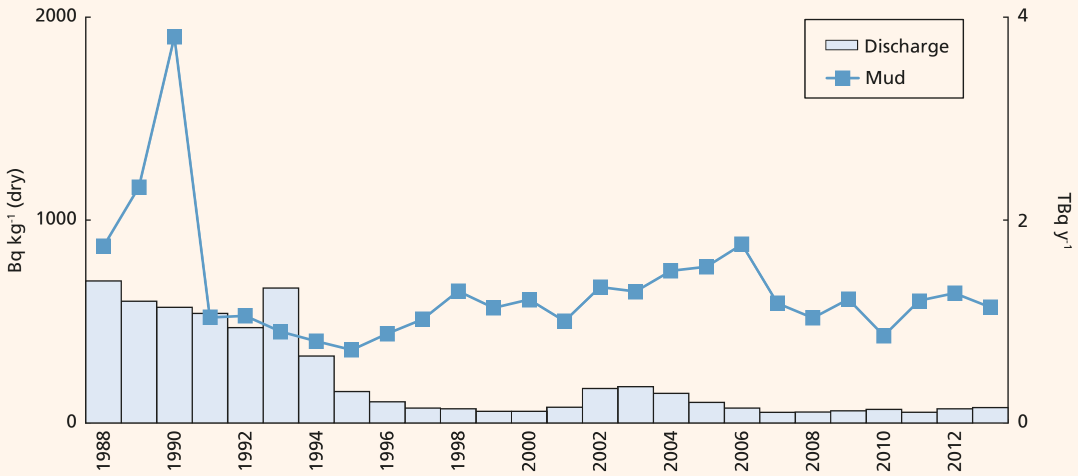


Figure 2.20. Plutonium-alpha liquid discharge from Sellafield and plutonium-239+240 concentration in mud at Ravenglass, 1988-2013

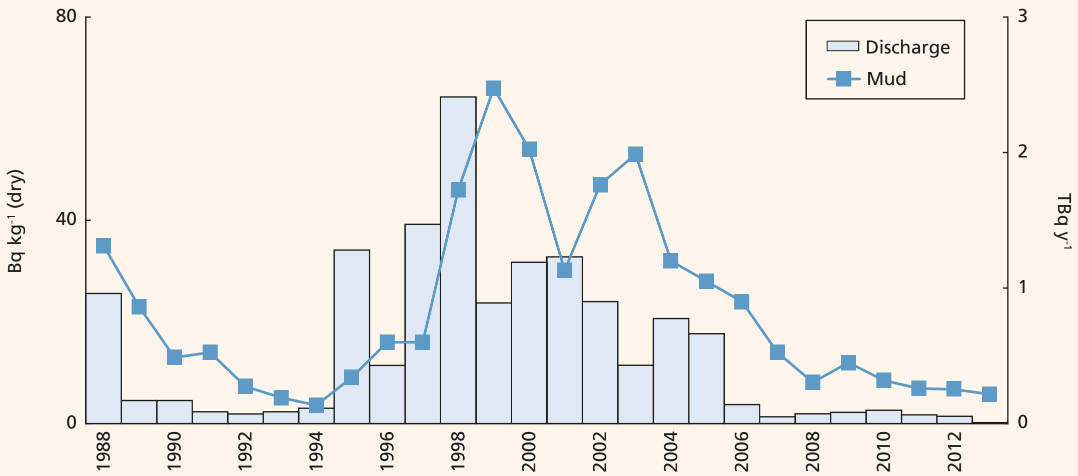


Figure 2.21. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

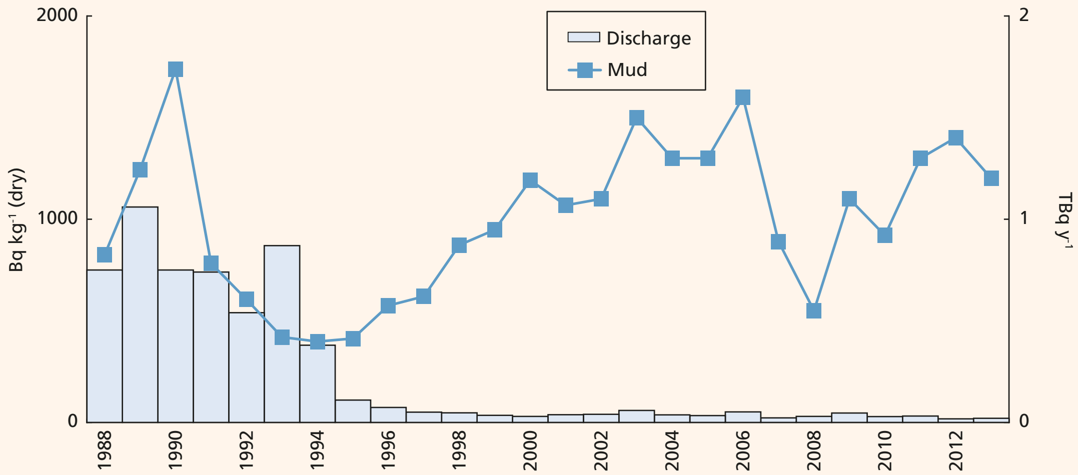


Figure 2.22. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2013

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

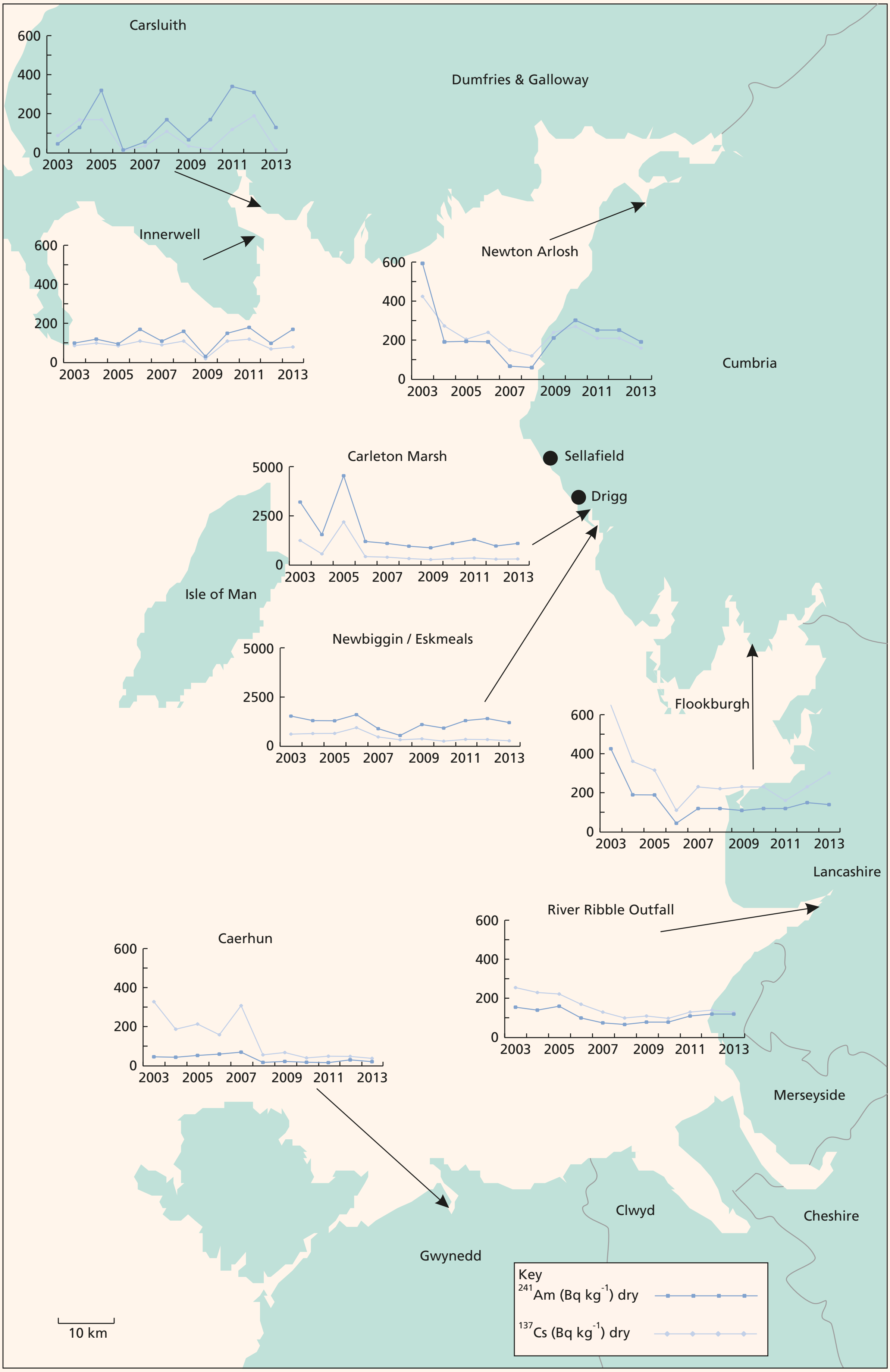


Figure 2.23. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2003-2013 (Note different scales used for Newbiggin and Carleton Marsh)

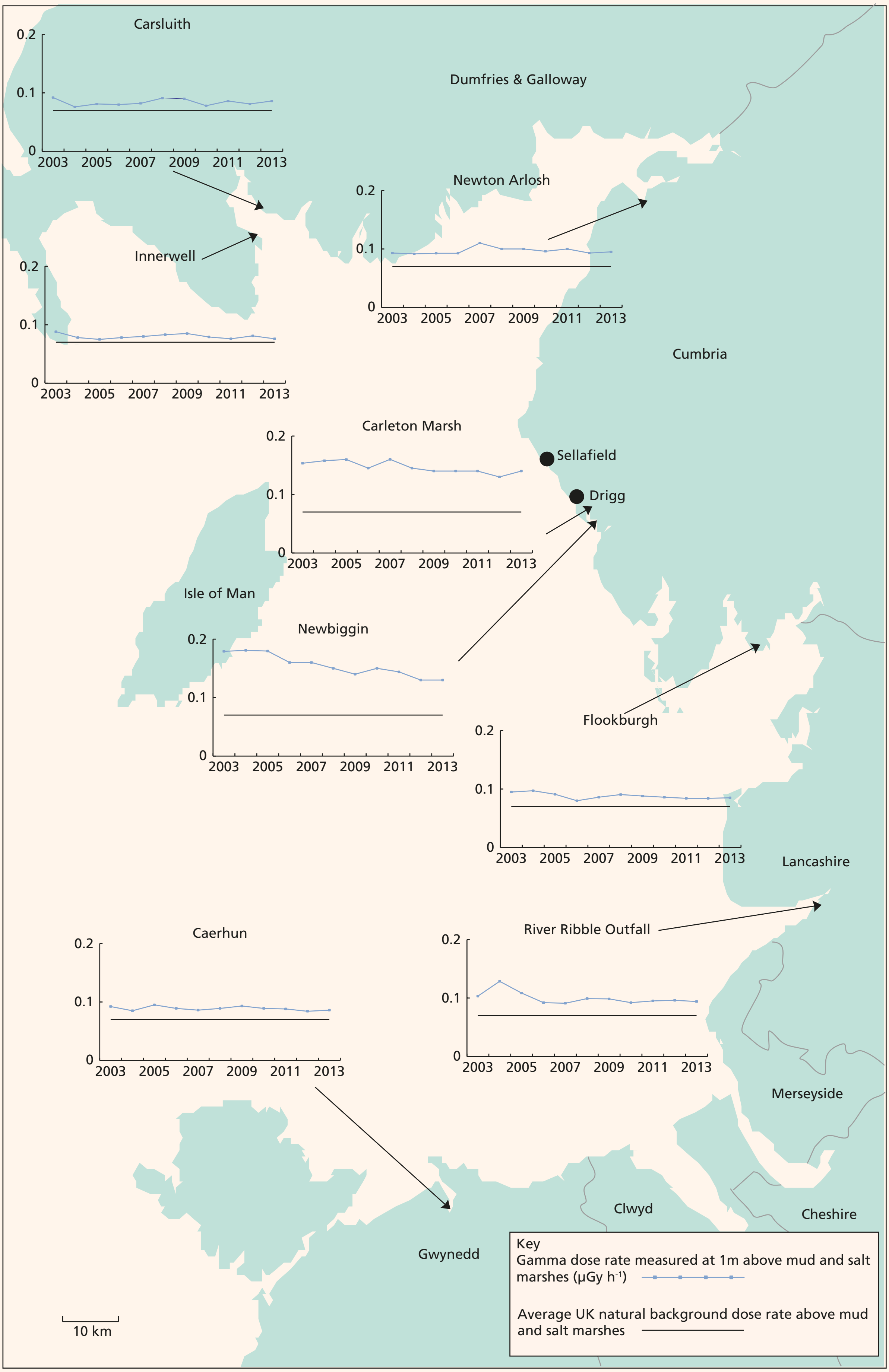


Figure 2.24. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2003-2013

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 specific doses	Infant consumer of locally grown food[d]	<0.005	–	<0.005	–	–	<0.005	–
	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 specific doses	Seafood consumer	0.023	<0.005	–	0.021	–	–	–
	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 observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{131}I
Milk		16	<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, $\mu Gy\ h^{-1}$
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, $\mu Gy\ h^{-1}$
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, $\mu Gy\ h^{-1}$
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, $\mu Gy\ h^{-1}$
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, $\mu Sv\ h^{-1}$
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 observ-ations[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 observ-ations[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

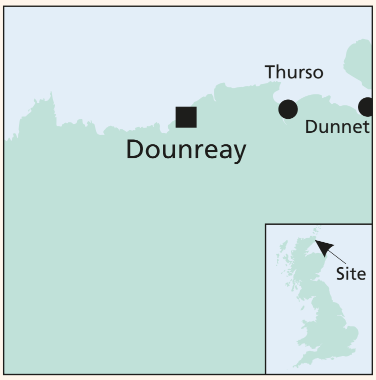
Harwell, Oxfordshire

- *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.*

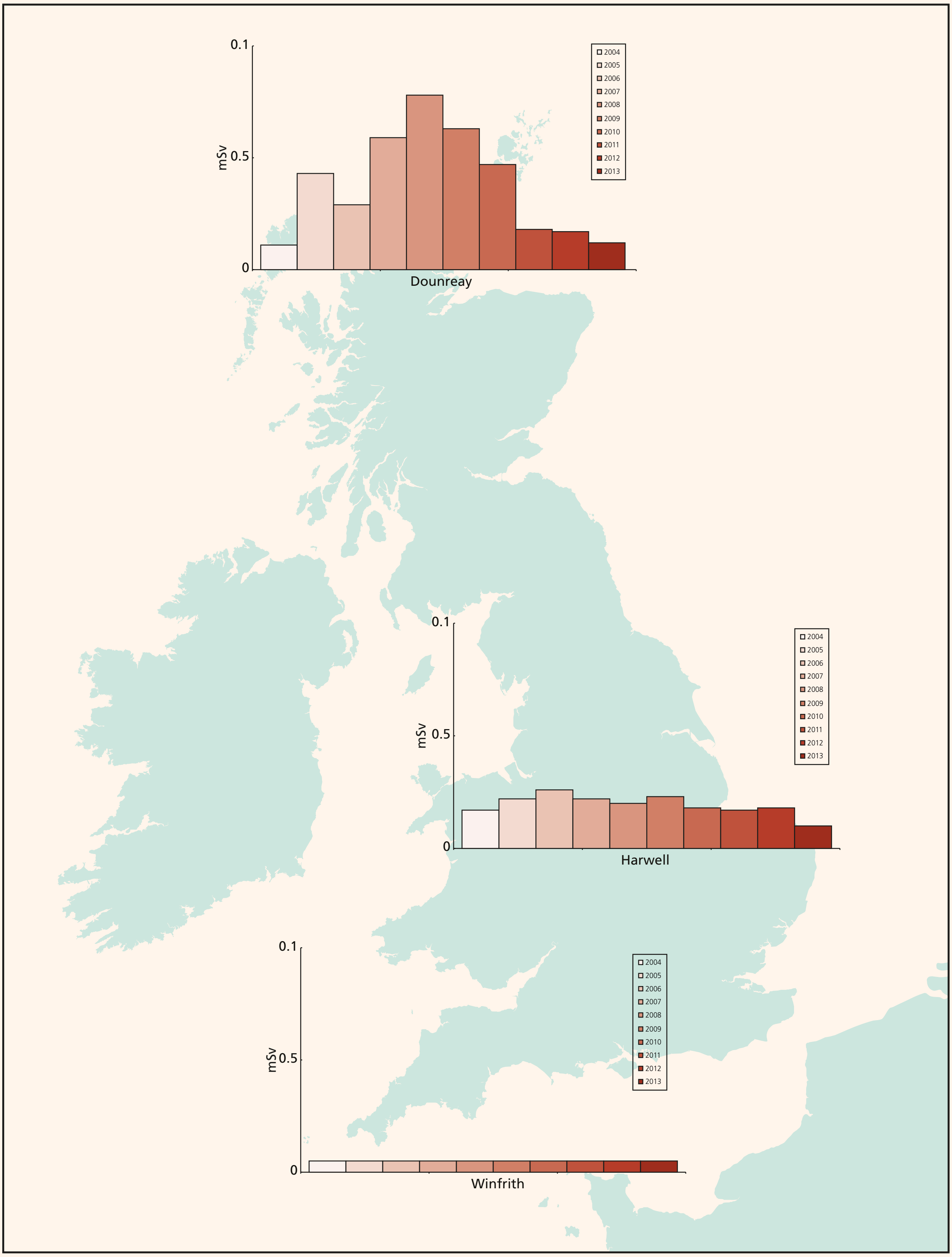


Figure 3.1. *Total dose* at research establishments, 2004-2013
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

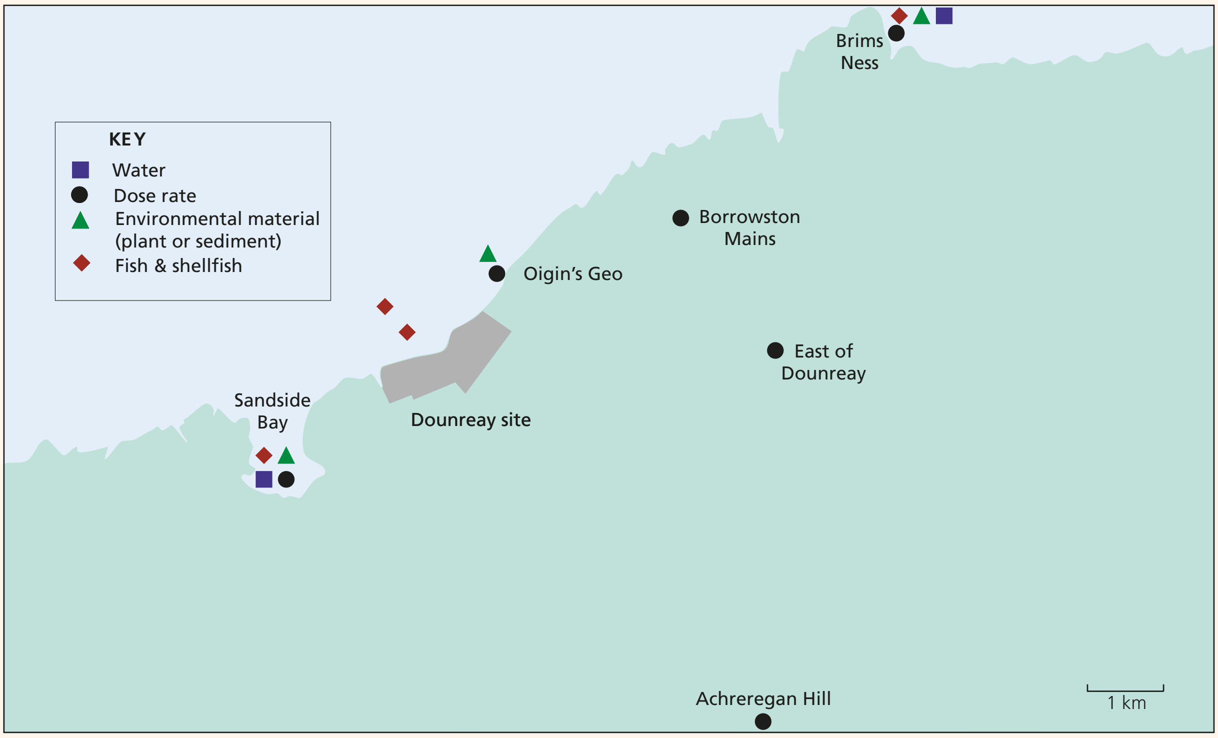


Figure 3.2. Monitoring locations at Dounreay, 2013 (not including farms)

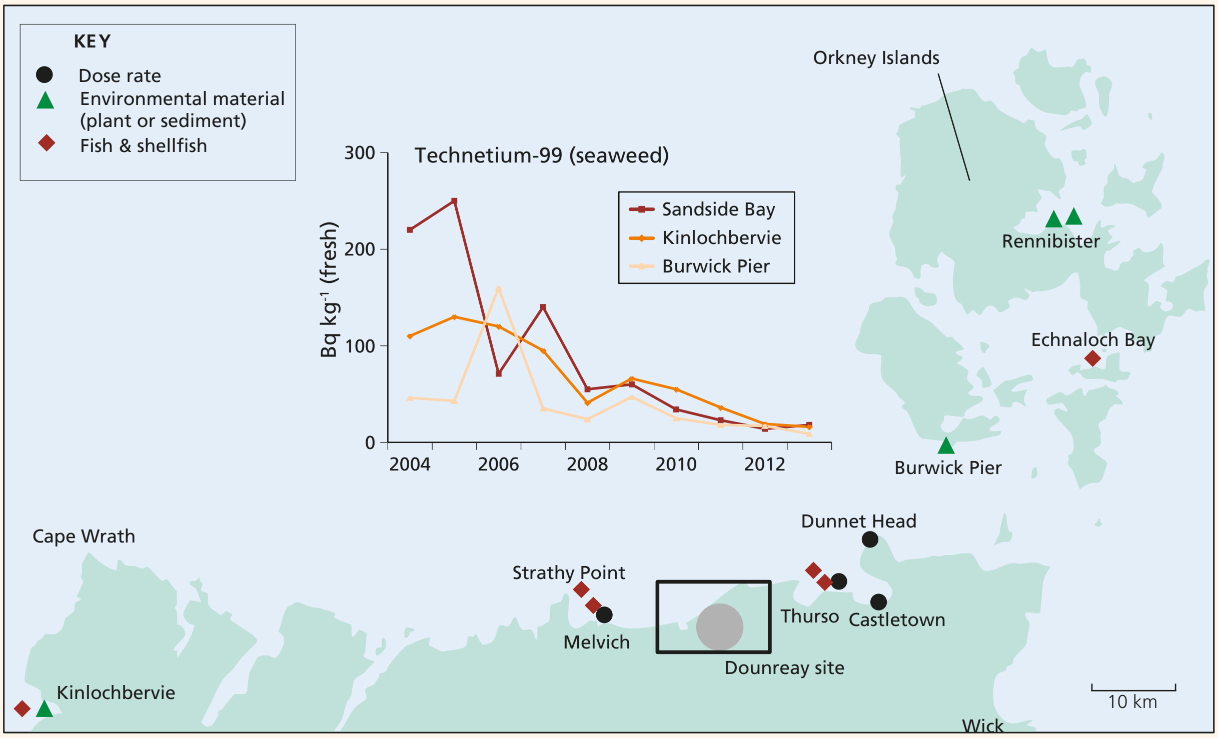
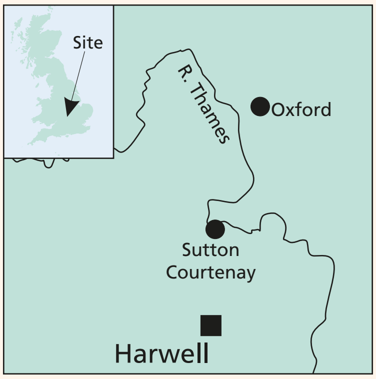


Figure 3.3. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2013 (not including farms)

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

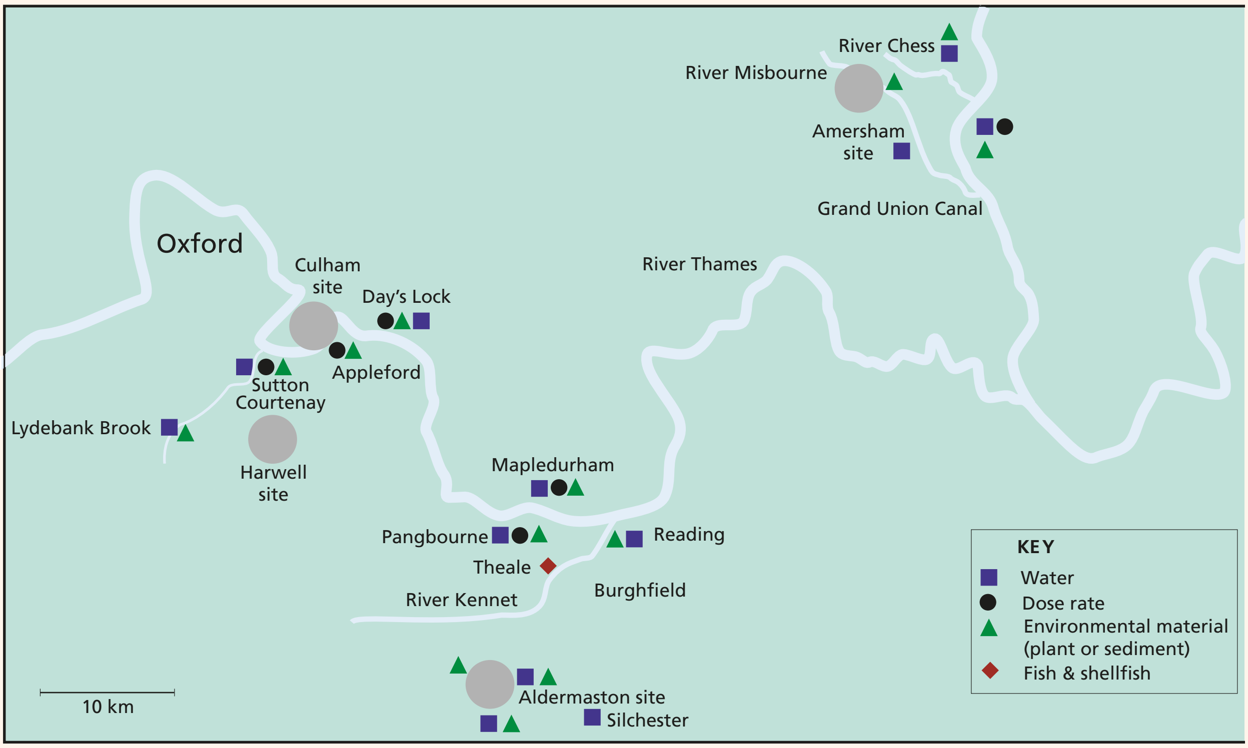


Figure 3.4. Monitoring locations at Thames sites, 2013 (not including farms)

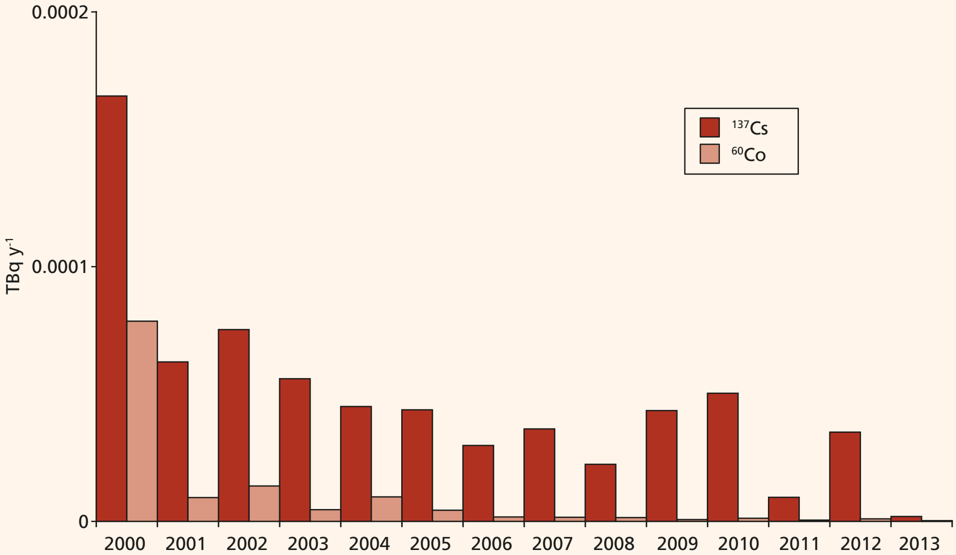
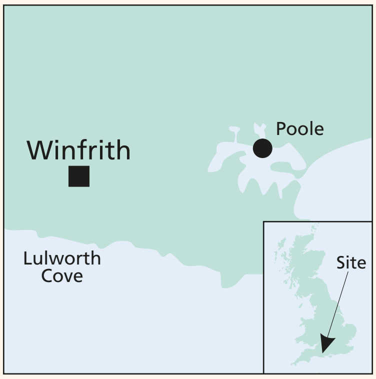


Figure 3.5. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2013

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.

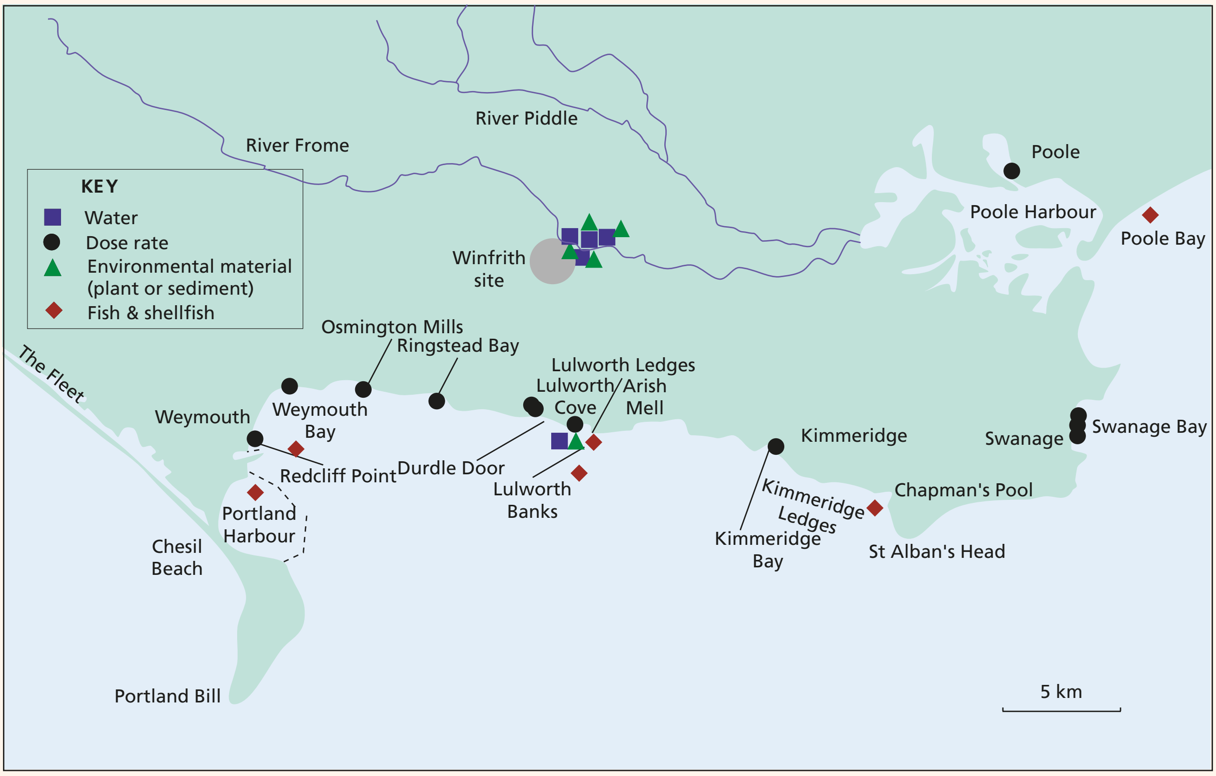


Figure 3.6. Monitoring locations at Winfrith, 2013 (not including farms)

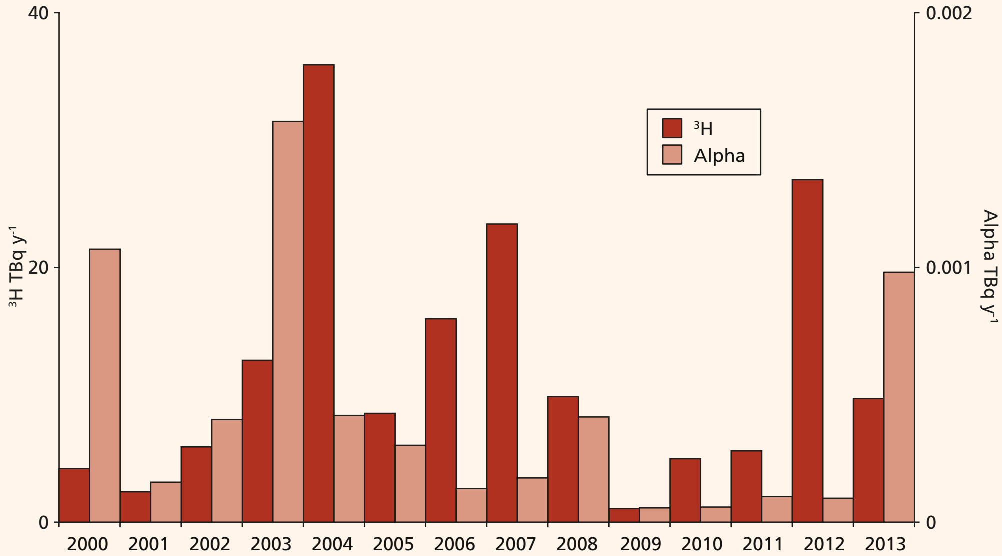
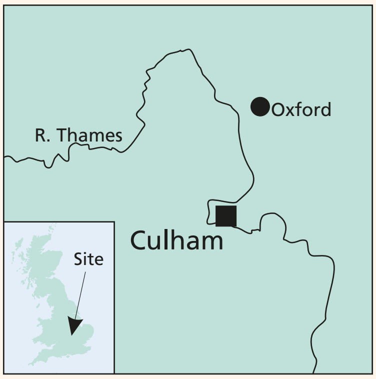


Figure 3.7. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2013

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 observ-ations	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 observ-ations	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 observ-ations[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*