RIFE - 20

Radioactivity in Food and the Environment, 2014

Environment Agency

Food Standards Agency food.gov.uk

Food Standards Scotland

Cyfoeth Naturiol Cymru Natural Resources Wales

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

SEPA Scottish Environment Protection Agency

2015

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Radioactivity in Food and the Environment, 2014

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October 2015

This report was compiled by the Centre for Environment, Fisheries and Aquaculture Science on behalf of the Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resource Wales, 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 2014 for the UK-wide monitoring programmes of the environment agencies and the Food Standards Agency (FSA). The monitoring programmes conducted by these agencies are independent of, and also used as a check on, site operators' programmes.

The results of these monitoring programmes are used to assess the dose received by members of the public in the vicinity of nuclear licensed sites and industrial and landfill sites. Information on diets and occupancy habits of people living near nuclear licensed sites gathered during habit surveys is also used in these dose assessments. Habit surveys were carried out at Berkeley, Oldbury, Hartlepool and Sellafield during 2014. Radiation doses to people living around nuclear licensed sites from authorised releases of radioactivity were well below the UK national and European limit of 1 millisievert per year in 2014.

Direct monitoring in upland lakes, for the effects of the Chernobyl accident in 1986, ceased in 2014 following the risk-based review of the FSA's monitoring programme. Controls on imports of food and feed from Japan put in place continued in 2014, following the accident at Fukushima Dai-ichi nuclear power station in 2011. None of the imports to the UK from Japan which were monitored contained activity exceeding the maximum permissible levels.

Work to address radioactive contamination at Dalgety Bay is ongoing. Public protection measures have been established and were maintained during 2014. The Food and Environment Protection Act (FEPA) order issued by the FSA in Scotland (now Food Standards Scotland (FSS)) prohibiting the collection of seafood from the Dalgety Bay area remains in force. Following the publication of the risk assessment, a recommendation has been made by the Committee on Medical Aspects of Radiation in the Environment (COMARE) that effective remediation of the affected area is undertaken as soon as possible. In 2014, the MoD published its broad management strategy and timescale for implementation of its preferred management option.

Naturally occurring radioactive material (NORM) contained in waste generated through industrial activities such as oil and gas extraction, mining and mineral processing is subject to existing regulatory systems. Following a broad ranging consultation to identify improvements in these systems the UK NORM waste strategy was published in 2014. The strategy is based on reform of the existing policy and regulatory framework and on supporting the industry to generate better data about NORM waste arising in order to stimulate investment in the waste management supply chain.

Technical summary

The technical summary is divided into sections to highlight the five 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 measured around UK nuclear licensed sites, 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 2014, 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 2014, the locations where the public received the highest doses were near Sellafield (0.22 mSv), Capenhurst (0.17 mSv) and Amersham (0.14 mSv). In comparison, the highest doses in 2013 were just at Amersham. The increase in the ranking of the Sellafield site was established following the detailed assessment of exposure pathways in 2014 including observations of increased consumption of seafood. The doses received near Capenhurst and Amersham were dominated by direct radiation from sources on the sites.

In 2014, the representative person in the vicinity of the Sellafield site was a mollusc consumer. The person also consumed significant quantities of other seafood. Their dose of 0.22 mSv includes a contribution of 0.15 mSv from the past discharges from the former phosphate processing plant at Whitehaven. The equivalent local seafood consumer in 2013 received a dose of 0.061 mSv. The increase in dose at Sellafield was due to (i) a significant increase in the proportion of lobsters in the diet of high-rate seafood consumers and (ii) a return to a wide range of seafood species being consumed by individuals. With these changes, the largest contribution to dose to seafood consumers at Sellafield is now from polonium-210 from the former phosphate processing plant at Whitehaven.

The highest dose near 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 0.009 mSv in 2014, a reduction from the value for 2013 of 0.012 mSv. The person was an adult in 2014 and the dominant contribution to their dose was direct radiation from the site. The change in dose was largely due to changes in the monitoring programme for foods, and in contributions of direct radiation, near Sellafield from year to year.

In Scotland, the representative person who received the highest dose from authorised releases of radioactivity consumed fish, shellfish and wildfowl on the Dumfries and Galloway coast. The dose in 2014 was 0.045 mSv. Most of this was due to the effects of past discharges from the Sellafield site.

In Wales, the representative person who received the highest dose from authorised releases of radioactivity

* *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.*

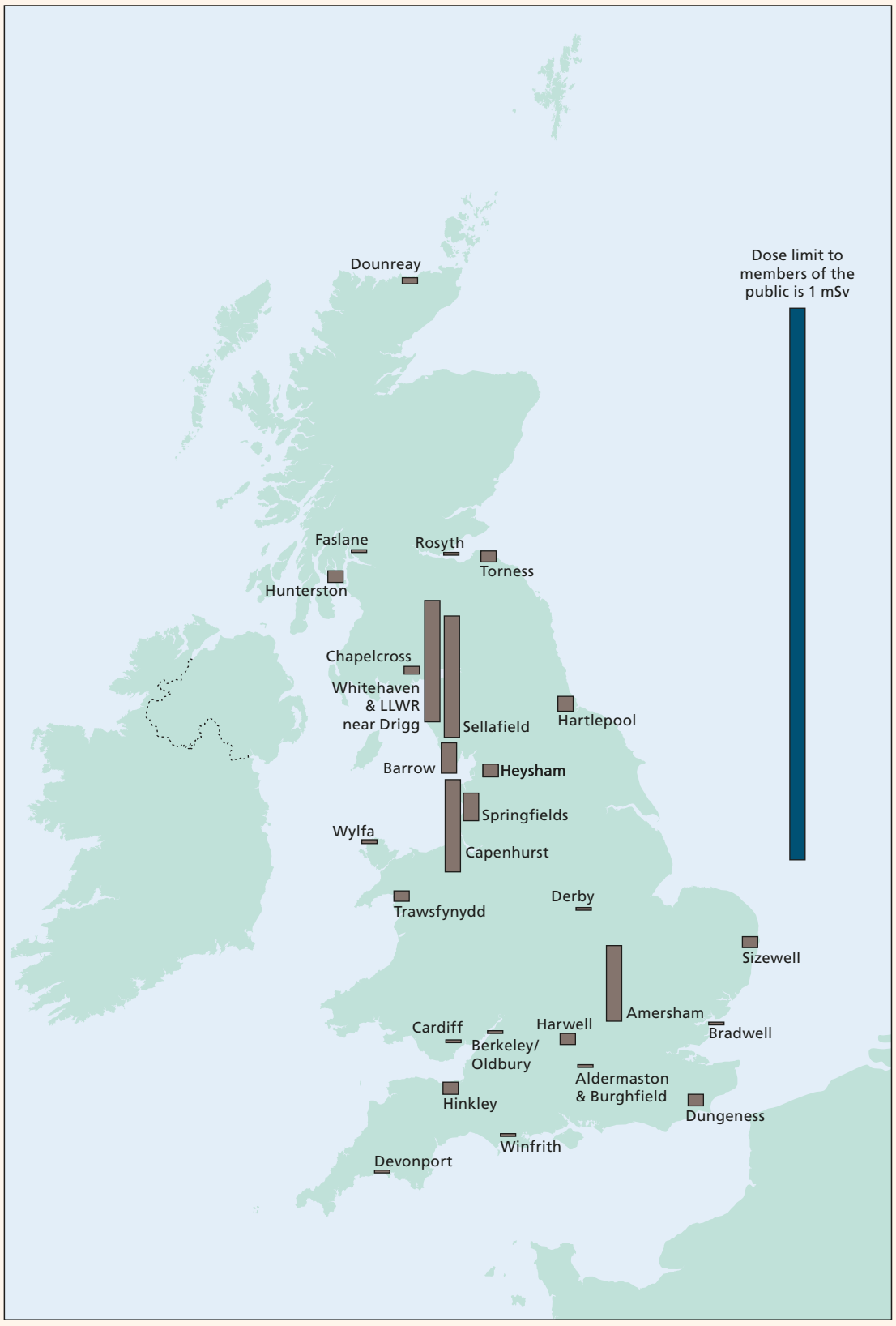


Figure S. *Total doses* in the UK due to radioactive waste discharges and direct radiation, 2014
(Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S. *Total doses* due to all sources at major UK sites, 2014[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.17	Direct radiation
Springfields	0.050	Gamma dose rate over sediment
Sellafield[e]	0.22	Crustaceans, molluscs, ^{210}Po
Research establishments		
Dounreay	0.012	Direct radiation, potatoes
Harwell	0.016	Direct radiation
Winfrith	<0.005	Fish, ^{241}Am
Nuclear power stations		
Berkeley and Oldbury	<0.005	Milk, ^{14}C, ^{35}S
Bradwell	<0.005	Fish, ^{137}Cs, ^{241}Am
Chapelcross	0.014	Gamma dose rate over sediment
Dungeness	0.021	Direct radiation
Hartlepool	0.027	Direct radiation, gamma dose rate over sediment
Heysham	0.023	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	0.020	Direct radiation
Torness	0.020	Direct radiation
Trawsfynydd	0.013	Milk, ^{241}Am
Wylfa	0.007	Gamma dose rate over sediment
Defence establishment		
Aldermaston and Burghfield	<0.005	Milk, ^{3}H[d], ^{137}Cs[d]
Barrow	0.055	Gamma dose rate over sediment
Derby	<0.005	Root vegetables, ^{241}Am[d]
Devonport	<0.005	Exposure over sediment
Faslane	<0.005	Gamma dose rate over sediment
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.14	Direct radiation
Cardiff	<0.005	Milk, ^{14}C, ^{32}P[d], ^{35}S
Industrial and landfill		
LLWR near Drigg[e]	0.22	Crustaceans, molluscs, ^{210}Po
Whitehaven[e]	0.22	Crustaceans, molluscs, ^{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 doses from man-made and naturally occurring radionuclides were 0.068 and 0.15 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*

consumed locally grown food at Trawsfynydd. The dose in 2014 was 0.025 mSv.

Habits surveys near UK nuclear licensed sites

In 2014, 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 Berkeley, Oldbury, Hartlepool and Sellafield in England. 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. This describes how the UK will implement the commitments in the OSPAR Radioactive Substances Strategy (RSS) 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 the Scottish Environment Protection Agency (SEPA) have continued to support the Strategy and in 2014, they issued new authorisations/permits, or varied existing ones, at three sites, Dounreay, Hunterston A and Oldbury, 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 2014 compared to those in 2013.

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 2014, 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. However, concentrations of technetium-99 have shown a strong trend downward from their peak in 2003.

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 25 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 2014, 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. The higher level is not due to discharges from the power station but is 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 2014 compared with 2013. 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 2014, 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 (383 in financial year 2014/15). 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 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 2014.

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.

Controls on food imports from Japan took two forms, and these controls continued in 2014. 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 European Union (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/node/1182). 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.

Direct monitoring of fish in relation to the effects of the 1986 Chernobyl accident ceased in upland lakes in 2014 as part of the overall review of the FSA's monitoring programme. All restrictions on moving, selling and slaughtering sheep in upland areas of the UK were removed earlier.

Food imported into the UK may contain radioactive contamination from Chernobyl and other known or unknown sources. A monitoring system is in place to detect radioactivity in consignments. In 2014, the instruments were triggered at Harwich by the presence of caesium-137 in a consignment of blueberries being brought into the UK from Lithuania. A sample was analysed and the activity concentration was 156 Bq kg^{-1}. At this concentration, FSA considered that there was no food safety requirement to limit the placement of the consignment on the market for human consumption.

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 2014 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. The representative person in the area who consumed large amounts of seafood was estimated to receive a dose of 0.22 mSv, with about 70% from polonium-210. The dose includes a contribution from the effects of discharges from the adjacent sites at Sellafield and, to a much lesser extent, at the Low Level Waste Repository (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

* *"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.*

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. Public protection measures have been established and these were maintained during 2014 and into 2015. A continuing monthly beach monitoring and particle recovery programme was begun in 2012 by a contractor working on behalf of the MoD. The fence demarcating the area where the highest activity particles were discovered remains in place, as well as the information signs advising the public of the contamination and precautions to be taken. In addition, the FEPA Order issued by the FSA in Scotland (now FSS) prohibiting the collection of seafood from the Dalgety Bay area remains in force. 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 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 SEPA's website (www.sepa.org.uk). As work in this area is ongoing, an update will be provided in next year's RIFE report.

Regional monitoring

Monitoring artificial radioactivity in Northern Ireland showed that consumer doses were all less than 1 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 2014, no requests were received by the Marine Management Organisation (MMO) to apply for additional licenses for the disposal of dredged material at sea and, therefore, no assessments of the radiological impact of such disposals were required.

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, FSA and FSS 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 (NRW) and the Welsh Government. Overall, around 10,000 analyses and dose rate measurements were completed in 2014.

The results of the analysis of food samples collected near nuclear licensed sites in England and Wales are published on FSA'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 2014 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, FSA and FSS 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 2014

1.1 Purpose and scope of the monitoring programmes

In England and Wales, FSA conducts food monitoring, whilst the Environment Agency carries out environmental and dose rate monitoring*. In Scotland, SEPA carries out food, environmental and dose rate monitoring, working closely with FSA and FSS* on its programme, and in Northern Ireland this is carried out by the Northern Ireland Environment Agency (NIEA). Surveillance of imports through points of entry continued in 2014. The regular programme of monitoring of drinking water, air and rain continued on behalf of DECC, NIEA and the Scottish Government. The FSA and SEPA (as part of the joint SEPA/FSS monitoring programme) also carry out UK monitoring of milk and canteen meals that are collected remotely from nuclear licensed sites. The marine environment of the whole of the British Isles away from nuclear licensed sites is monitored for Defra.

FSA was given responsibility for food safety throughout the UK under the Food Standards Act 1999. The Food Standards Act 1999 was amended by the Food (Scotland) Act 2015 and responsibility for food safety in Scotland was transferred to the newly formed FSS on 1st April 2015. The Environment Agency, NRW, NIEA and SEPA, referred to together as the environment agencies in this report, are responsible for environmental protection in England, 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 environmental protection 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 monitoring of food imports from Japan to confirm that controls on the effects of the Fukushima-Daiichi accident in 2011 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 EC. Guidance on planning and implementing routine environmental programmes has been published (Environment Agency, FSA and SEPA, 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

* *Created in April 2013, 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 NRW to undertake some specific activities on its behalf in Wales including some environmental monitoring and aspects of radioactive substances regulation.*
In April 2015, Food Standards Scotland (FSS) was established by the Food (Scotland) Act 2015, taking over the responsibilities, with an increased role to that previously carried out in Scotland by the FSA. As the public sector food body for Scotland, FSS is part of the Scottish Administration, alongside, but separate from, the Scottish Government

radiation (EC, 2014a). Specifically it provides estimates of doses to members of the public from authorised practices and enables such results to be made available to stakeholders.

FSA completed a public consultation exercise following the risk-based review into the way it monitors radioactivity in food in June 2013 (FSA, 2012a and 2013). This has resulted in a revised monitoring programme taking effect in 2014 with reductions in sampling and analysis of some foods representing a very low radiological risk.

In 2012/2013 SEPA undertook a review of its environmental radioactivity monitoring programme coordinated through SEPA's Environmental Radioactivity Monitoring Task Team (ERMTT). The ERMTT includes representatives from SEPA, the Scottish Government, PHE, the FSA/FSA in Scotland and Scottish Natural Heritage. The review took into account new habits data, recent environmental monitoring data and the joint guidance published by SEPA, FSA and the Environment Agency concerning planning and implementing routine environmental radiological monitoring programmes (Environment Agency, FSA and SEPA, 2010). Minor modifications were made to the programme which came into effect on 1st January 2014.

In 2014, the Environment Agency began a review of their environmental monitoring around nuclear sites. The review is to ensure the programmes are appropriate and are consistent with advice in the joint Agency technical guidance (Environment Agency, FSA and SEPA, 2010). The review will be completed in 2015. Further information on the outcomes of the review will be provided in next year's Rife report.

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 trends in monitoring data and doses for 2004 – 2008 has been published (Environment Agency, FSA, NIEA and SEPA, 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 2014, 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 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

* *On 1st 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.*

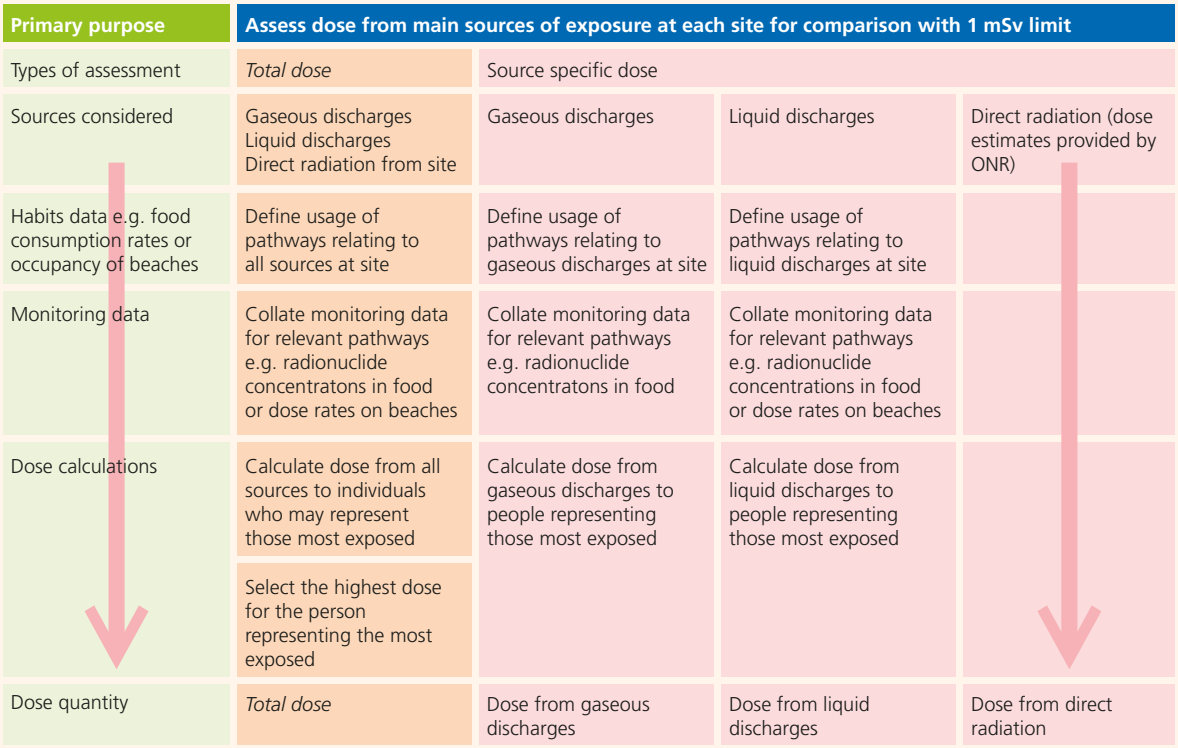


Figure 1.1. The dose assessment process for major nuclear sites

relevant factor to be considered (Dale *et al.,* 2008). All dose limits are based on recommendations made by the ICRP (ICRP, 1991) and are consistent with EU legislation (EC, 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 EC has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for the gaseous and liquid waste disposals in the years 2004 to 2008 (Jones *et al.*, 2013).

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 2014

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 2014 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 doses* were received by a representative person, who consumed molluscan shellfish at high-rates (and other seafood) near Sellafield. The *total dose* (from all sources) at this site is combined with the effects of all local sources, including specifically the effects historic discharges of natural radionuclides from the former phosphate processing plant at Whitehaven and (to a lesser extent) the effects of discharges from LLWR near Drigg. The next highest *total doses* were received by persons living near the

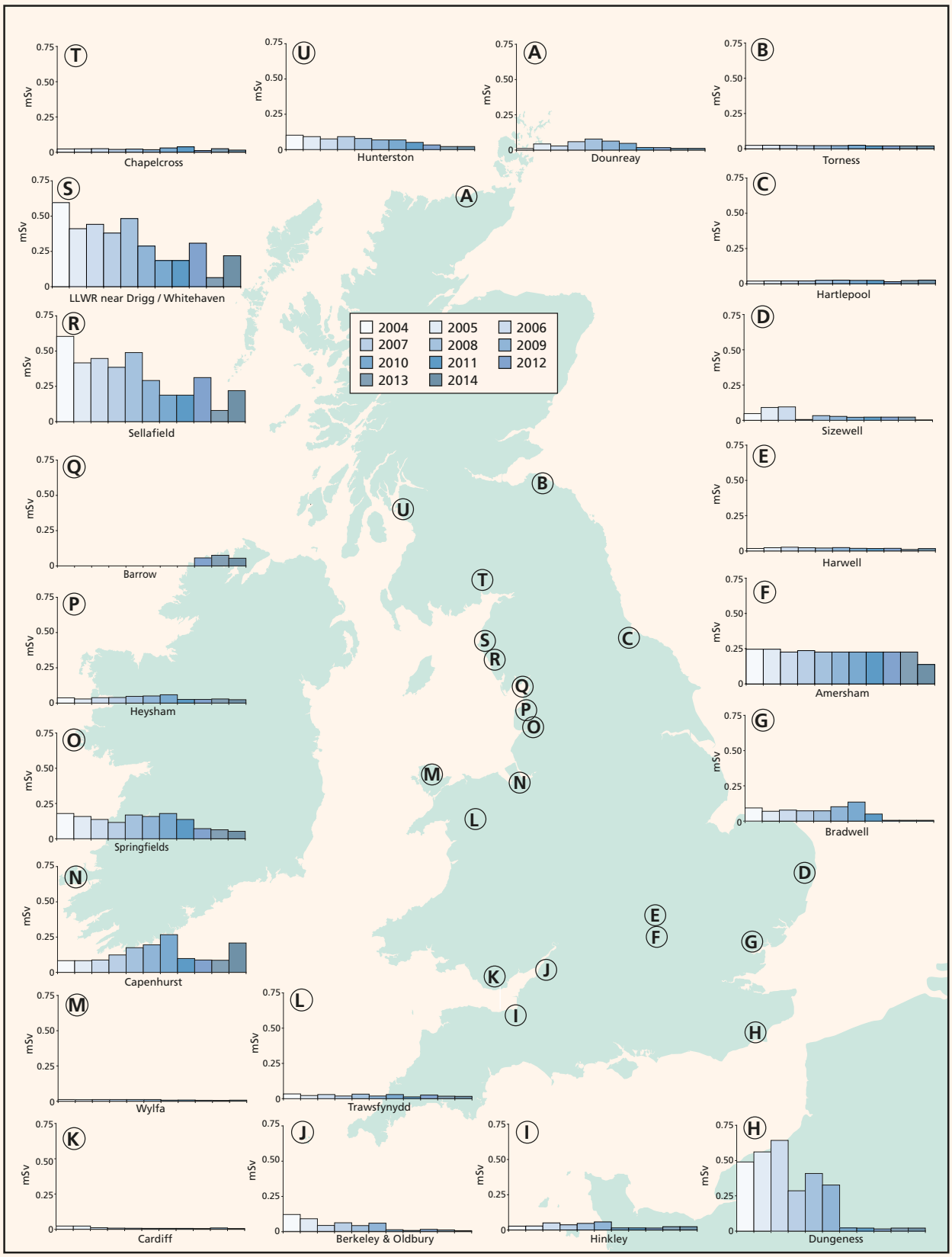


Figure 1.2. *Total doses* around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2014). (Exposures at Sellafield/Whitehaven/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Capenhurst and Amersham sites; these doses were almost entirely due to direct radiation emanating from the sites.

1.2.3 *Total dose* trends

A time-series of *total dose* from 2004 - 2014 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. Following the cessation of power production by Magnox reactors at Dungeness and Sizewell, the effect has been a reduction in direct radiation at these sites. 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 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. Indeed in 2014, the dose to these people increased due to changes in consumption rates of local seafood.

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 2014

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, at Sellafield and at Whitehaven where seafood consumption dominated, and at Barrow and at Springfields where external exposure on houseboats dominated. At the LLWR near Drigg, at Sellafield and at 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 largely due to activity in sediments beneath the houseboat, also from 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 (ICRP, 2007). In pursuit of this aim, ICRP has considered the use of a set of Reference Animals and Plants (RAPs) (ICRP, 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 (ICRP, 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 (CEC, 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 Union. 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 (Defra, 2005c). In relation to radioactivity,

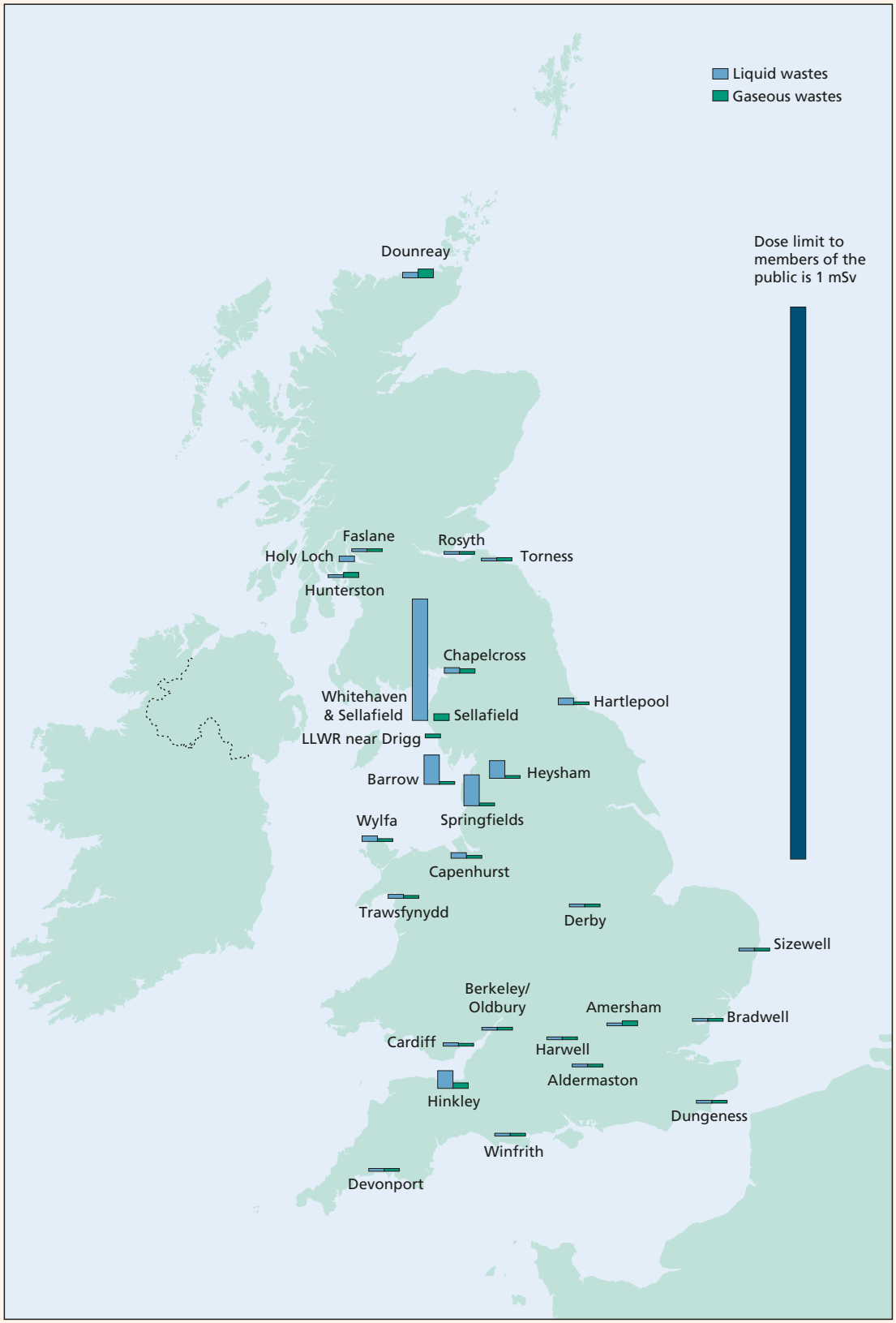


Figure 1.3. Source specific doses in the UK, 2014 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

the environment agencies have characterised the aquatic environment using a screening tool, which estimates the potential environmental impact of radioactive waste sources. The outcome of the assessment has been published and provided to the EC (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, NRW and SEPA review new and existing authorisations/permits to ensure that they do not have an adverse effect on the integrity of Natura 2000 habitat sites. 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.

The Environment Agency has assessed the dose rates to reference organisms and feature species for authorised discharges under RSA 93 and, since April 2010, EPR10 (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.

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 (CEC, 1999a, b). These amendments were consolidated into a single Regulation in each country of the UK in 2009 as part of the FSA 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 FSA. The facility was not inspected during 2014 as no food has been treated for several years. The FSA continues to monitor the situation and the requirement to inspect this facility is kept under review.

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 can be transferred to the new Dounreay LLW Facility which began accepting waste for disposal in April 2015. These discharges and disposals are regulated by the environment agencies under RSA 93 or EPR 10*.

* *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 nuclear site sources of radioactive waste disposal in the UK, 2014 (Showing main initial operation. Some operations are undergoing decommissioning)

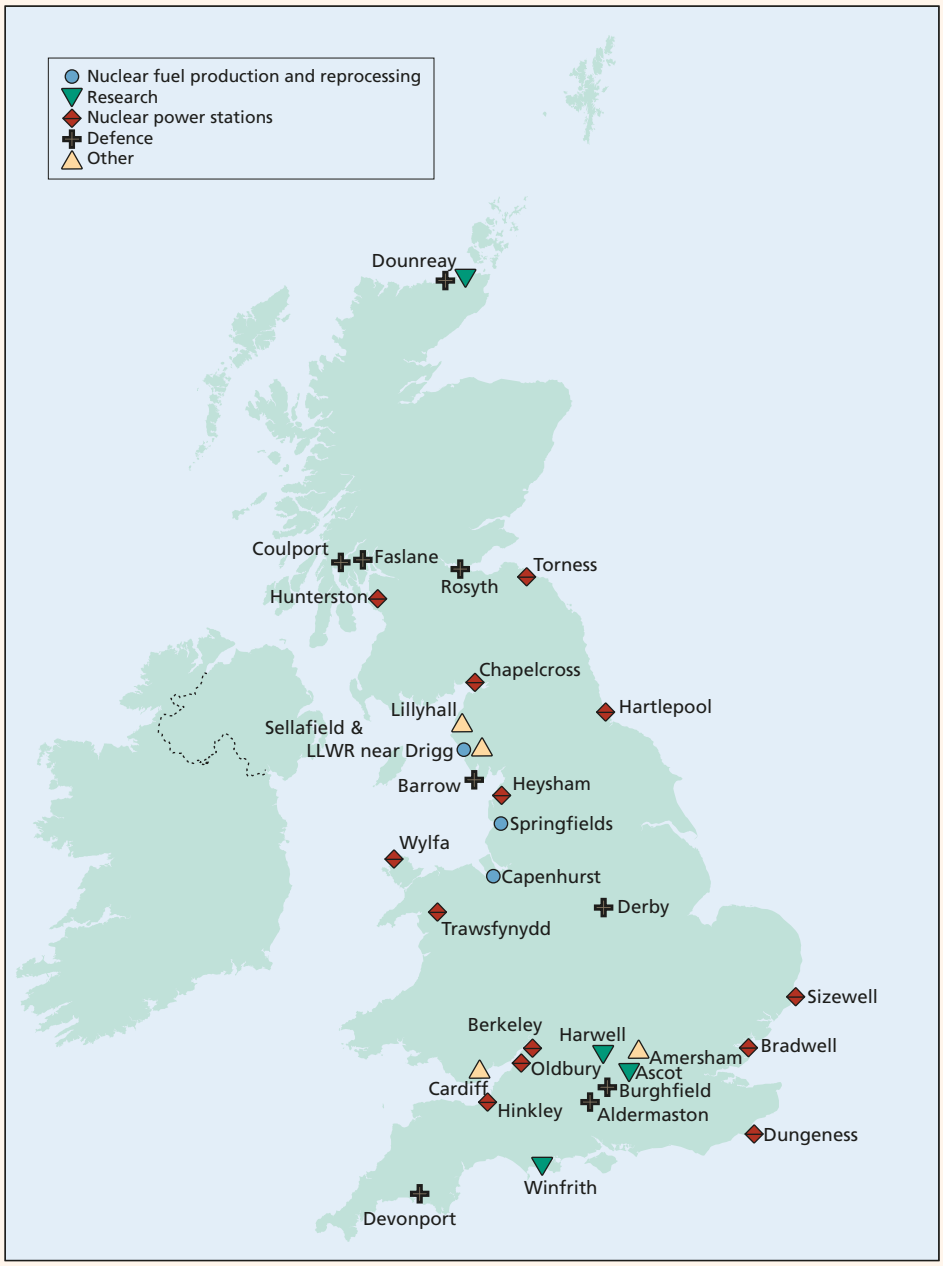


Figure 1.4 shows the nuclear licensed sites that produce waste containing artificial radionuclides. Nuclear licensed sites are authorised to dispose of radioactive waste (United Kingdom - Parliament, 1993). They are also subject to the Nuclear Installations Act (United Kingdom - Parliament, 1965). The 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 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 2014. The tables also list the main

discharge and disposal limits that are specified or, in the case of the MoD, administratively agreed. In 2014, discharges and disposals were all below the limits. 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 site will be below the source and site dose constraints of 0.3 and 0.5 mSv per year respectively if discharges occurred at the limits (Environment Agency, SEPA, NIEA, HPA and FSA, 2012). The determination of discharge limits also take into account the dose due to consumption of food. 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 (BPM) are applied in Scotland (SEPA, 2012a).

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 FSA. 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 2014.

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 (RSS) 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 (Defra, 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 (DECC, 2009). DECC and the Devolved Administrations have issued a revised Strategy (DECC, Department of the Environment Northern Ireland, the Scottish Government and Welsh Assembly Government, 2009).

The new Strategy was built on the 2002 publication, and expanded 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 RSS intermediate objective for 2020
- To provide a clear statement of Government policy and a strategic framework for discharge reductions, sector by sector, to inform decision making by industry and regulators

The expected outcomes of the UK Strategy are:

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

To support implementation of 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 (DECC 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 BAT (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 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, 2015). 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. 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 BAT has also been published (OSPAR, 2013). Progress by Contracting Parties towards meeting the objectives in RSS 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 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 (CEC, 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 (EC, 2012a).

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 (Defra, 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 (Defra, 2005a, b; Defra, Department of the Environment Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005) and has completed a new assessment *"Charting Progress 2"* in 2010 (Defra, 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).

In the 2008 White Paper "Meeting the Energy Challenge", (Department for Business, Enterprise and Regulatory Reform, 2008), the UK Government set out its view that new nuclear power stations should have a role to play in this country's future energy mix alongside other low-carbon sources; that it would be in the public interest to allow energy companies the option of investing in new nuclear power stations and that the Government should take active steps to facilitate this. Further to this a number of national policy statements relating to energy infrastructure were developed and published including that for nuclear power generation (DECC, 2011a). The Nuclear National Policy Statement (NNPS) statement, following Parliamentary approval, was designated under the Planning Act 2008 in July 2011. The NNPS purpose is to inform the planning process for any new nuclear power stations and includes:

- The need for new nuclear power stations
- The 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
- A list of potentially 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. Statutory Instruments have been issued which give affect to the decisions by the Secretary of State for DECC that the social, economic or other benefits outweigh the health detriment of ionising radiation due to operation of the AP1000, UK-EPR and Advanced Boiling Water (ABWR) designs. The Scottish Government is opposed to the development of new nuclear power stations in Scotland (Statutory Instruments, 2010a and b, 2015). 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.

In 2007 the ONR and the Environment Agency introduced a new approach for assessing the design of potential new nuclear power stations. The assessment process, called "Generic Design Assessment" (GDA), enables the regulators to assess the safety, security and environmental implications of new power station designs when it is most effective and efficient. The process begins before an application is made to build that design at a specific site in England or Wales. The Environment Agency's assessment of new nuclear power station designs is to make sure that, if they were built, the stations' generic design and 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 the AP1000 (Westinghouse) and UK-EPR (EDF and AREVA) designs, 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). 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 (ONR, 2012). The GDA process is continuing in 2015 with consideration of the Hitachi-GE UK ABWR reactor design, as well as progress towards closure of the AP1000 GDA (Environment Agency and ONR, 2015). In 2014, the Environment Agency issued an initial assessment of the UK ABWR design (Environment Agency, 2014).

GDA does not replace the need for operators to make site specific applications for new nuclear power stations and to obtain all relevant approvals for their proposed developments. 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 is 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 an environmental permit for the proposed Hinkley Point C development to enable NNB GenCo to discharge (non-radioactive) waste water discharges from construction (Environment Agency, 2012a). In addition, in 2013, the Environment Agency issued three further "operational" 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. Also in 2013, the Secretary of State for DECC granted a Development Consent Order for the construction of a new nuclear power station at Hinkley Point C.

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 (IAEA, 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, DECC, 2010; 2011b, 2014a).

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. 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 (NDA, 2012) and the plan for 2015/18 is available (NDA, 2015). In accordance with the Energy Act, the NDA is required to review its strategy at least every five years. A revised strategy is due to be published for consultation in late 2015, prior to any revised strategy being issued from April 2016. A report in 2012 has considered the financial implications of nuclear decommissioning and waste management (MacKerron, 2012). NDA published an up-to-date inventory and forecast of radioactive wastes in the UK jointly with DECC in 2014 (NDA and DECC, 2014).

In 2007, the UK Government and Devolved Administrations issued a UK-wide policy for managing low level waste (Defra, 2007), which includes:

- Maintaining a focus on safety whilst allowing greater flexibility in managing LLW
- An emphasis on community involvement
- 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

A public consultation exercise was initiated in January 2015 to review a UK Strategy for the management of solid low level waste from the nuclear industry (DECC, Scottish Government, Welsh Government and Northern Ireland Department of Environment, 2015). In 2010, The NDA developed and published the "UK Strategy for the Management of Solid Low-Level Radioactive Waste from the Nuclear Industry", known as the "Nuclear LLW Strategy". A review of this took place in 2014, culminating in a public consultation on a revised version in January 2015. A final revision is expected to be published later this year.

More generally, consideration of the development of strategy for LLW from the non-nuclear industry resulted in the development and publication of the strategy in two parts:

Part 1 – Arisings of wastes mainly containing anthropogenic radionuclides (DECC, Scottish Government, Welsh Government and the Northern Ireland Department of the Environment, 2012), and most recently,

Part 2 – Arisings of wastes containing Naturally Occurring Radioactive Materials (NORM) in 2014 (DECC, Scottish Government, Welsh Government and the Northern Ireland Department of the Environment, 2014)

UK Government policy is that geological disposal is the best available means of managing 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 (Defra, Department for Business, Enterprise and Regulatory Reform, Welsh Assembly Government and Northern Ireland Assembly, 2008). Additional information describing the siting process is available in the previous RIFE report (Environment Agency, FSA, NIEA, NRW and SEPA, 2014).

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 (DECC, 2014b). It set out a number of initial actions to implement this policy framework; actions which will be led by DECC and the developer for a GDF (Radioactive Waste Management Limited, a wholly owned subsidiary company of NDA). Formal discussions between interested communities and the developer will not begin until the initial actions set out in the White Paper have been completed. This is expected in 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 MRWS programme to promote the interests of the people of Wales. In 2015, the Welsh Government adopted a policy for geological disposal for the long term management of higher activity radioactive waste (Welsh Government, 2015). The Welsh Government supports the policy of voluntary engagement where potential host communities are able to seek discussions, without prior commitment, about potentially hosting a GDF. The Welsh Government subsequently issued a further consultation in 2015, in parallel with the policy document, regarding proposals for the siting processes and arrangements should a community in Wales seek to open discussions about potentially hosting a GDF. Further information on the consultation is available on the Welsh Government's website: http://gov.wales/consultations/environmentandcountryside/geological-disposal-of-higher-activity-radioactive-waste-community-engagement-and-implementation-processes/?status=open&lang=en

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 (CoRWM, 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 can be disposed of at the new Dounreay LLW 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 NIEA (2009), Environment Agency, NIEA and SEPA (2009) and Environment Agency (2013a)). In addition, SEPA has issued a policy statement which specifies how it will regulate the disposal of LLW 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, 2012b).

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, DECC, the Scottish and Welsh Governments and the Department of the Environment Northern Ireland published the UK NORM Waste Strategy in July 2014 (DECC, the Scottish Government, the Welsh Government and the Department of the Environment Northern Ireland, 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 (OECD, 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 are presented in Section 8 and confirm that the radiological impact of these disposals was insignificant.

In England, 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 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 Northern Ireland, respectively. As of 1st 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 IAEA (1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (IAEA, 2003) and which has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2014, no requests were received by MMO to apply for additional licenses for the disposal of dredged material at sea and, therefore, no assessments of the radiological impact of such disposals were required.

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 2014. Low concentrations of radionuclides were detected in the marine environment around the Channel Islands (Section 8) and these may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague in France.

The exploration for, and extraction of, gas from shale rock is being actively investigated in the UK with support from DECC. 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; NIEA, 2013; SEPA, 2013). The Environment Agency has now granted permits for Cuadrilla to carry out shale gas exploration at their site in Roseacre Wood near Elswick in Lancashire (Environment Agency and DECC, 2015). A review of potential public health impacts of exposures to radioactivity as a result of shale gas extraction has been issued by PHE (Kibble *et al.*, 2014). Monitoring of exploration and extraction of shale gas in the environment and food is not undertaken by the environment agencies, FSA or FSS 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 (Defra, 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 (DECC, 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 designated 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 (Defra, 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.

The 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, 2014

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.17
Sellafield	0.005
Springfields	<0.020
Research establishments	
Dounreay	0.007
Harwell	0.016
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	0.14
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 (0.005) not used*
[e] *Datum for Sizewell B. Sizewell A (Bgd[a]) not used*

Table 1.2. *Total doses* integrated across pathways, 2014

Site	Representative person[a]	Exposure, mSv	
		Total	Dominant contributions[b]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Infant milk consumer	<0.005[g]	Milk, ^{3}H[c], ^{137}Cs[c]
Amersham	Prenatal children of local inhabitants (0–0.25km)	0.14[g]	Direct radiation
Barrow	Prenatal children of potato consumer	<0.005	Gamma dose rate over sediment, potatoes, ^{3}H[d]
Berkeley and Oldbury	Infant milk consumers	<0.005	Milk, ^{14}C, ^{35}S
Bradwell	Prenatal children of green vegetable consumer	<0.005	Green vegetables, ^{14}C
Capenhurst	Local adult inhabitants (0–0.25km)	0.17[g]	Direct radiation
Cardiff	Infant milk consumer	<0.005	Milk, ^{14}C, ^{32}P[c], ^{35}S
Chapelcross	Infant milk consumer	0.011	Milk, ^{35}S[c], ^{90}Sr
Derby	Adult consumers of domestic fruit	<0.005[g]	Root vegetables, ^{241}Am[c]
Devonport	Prenatal children of root vegetable consumer	<0.005	Fish, root vegetables, ^{3}H[c], ^{14}C
Dounreay	Adult wild fruit and nut consumer	0.012	Direct radiation, potatoes
Dungeness	Local adult inhabitants (0–0.25km)	0.021	Direct radiation
Faslane	Adult consumer of cattle meat	<0.005	Cattle meat, ^{137}Cs, ^{241}Am[c]
Hartlepool	Local adult inhabitants (0–0.25km)	0.027	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0–0.25km)	0.016[g]	Direct radiation
Heysham	Local adult inhabitants (0–0.25km)	0.021	Direct radiation
Hinkley Point	Prenatal children of occupants for direct radiation	0.013	Direct radiation, gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25–0.5km)	0.021	Direct radiation
LLWR near Drigg	Local infant inhabitants (0.5–1km)	0.034	Direct radiation
Rosyth[d]	-	–	
Sellafield	Local adult inhabitants (0–0.25km)	0.009[g]	Direct radiation, potatoes, ^{137}Cs
Sizewell	Local adult inhabitants (0–0.25km)	0.020	Direct radiation
Springfields	Adult consumer of pig meat	0.020[g]	Direct radiation
Torness	Local adult inhabitants (0.5–1km)	0.020	Direct radiation
Trawsfynydd	Infant local inhabitants (0.25–0.5km)	0.013	Milk, ^{241}Am
Winfrith	Infant milk consumer	<0.005	Milk, root vegetables, ^{3}H[c], ^{14}C
Wylfa	Local inhabitants aged 1y (0.25–0.5km)	<0.005	Milk, ^{14}C, ^{35}S
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants over riverbank	<0.005	Exposure over riverbank
Amersham	Adult occupants over riverbank	<0.005	Gamma dose rate over riverbank
Barrow	Adult occupants on houseboats	0.055	Gamma dose rate over sediment
Berkeley and Oldbury	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Bradwell	Adult fish consumer	<0.005	Fish, ^{137}Cs, ^{241}Am
Capenhurst	Occupants over riverbank aged 10y	0.007	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	<0.005	Gamma dose rate over sediment
Chapelcross	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Derby	Adult consumers of locally sourced water	<0.005	Water, ^{60}Co[c]
Devonport	Adult occupants on houseboats	<0.005	Exposure over sediment
Dounreay	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dungeness	Prenatal children of occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Adult occupants over sediment	0.02	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of occupants over sediment	<0.005	Gamma dose rate over riverbank
Heysham	Adult mollusc consumer	0.023	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupants over sediment	0.022	Gamma dose rate over sediment
Hunterston	Adult mollusc consumer	<0.005	Gamma dose rate over sediment, molluscs
LLWR near Drigg[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Sizewell	Infant crustacean consumer	0.008	Direct radiation
Springfields	Adult occupants on houseboats	0.050	Gamma dose rate over sediment
Torness	Adult crustacean consumer	<0.005	Crustacean, fish, ^{241}Am
Trawsfynydd	Adult fish consumer	0.010	Exposure over sediment, fish, ^{90}Sr, ^{137}Cs, ^{241}Am
Whitehaven[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Winfrith	Adult fish consumer	<0.005	Fish, ^{241}Am
Wylfa	Adult occupants over sediment	0.007	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[g]	Milk, ^{3}H[c], ^{137}Cs[c]
Amersham	Prenatal children of local inhabitants (0–0.25km)	0.14[g]	Direct radiation
Barrow	Adult occupants on houseboats	0.055	Gamma dose rate over sediment
Berkeley and Oldbury	Infant milk consumer	<0.005	Milk, ^{14}C, ^{35}S
Bradwell	Adult fish consumer	<0.005	Fish, ^{137}Cs, ^{241}Am
Capenhurst	Local adult inhabitants (0–0.25km)	0.17[g]	Direct radiation
Cardiff	Infant milk consumer	<0.005	Milk, ^{14}C, ^{32}P[c], ^{35}S
Chapelcross	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Derby	Adult consumer of domestic fruit	<0.005[g]	Root vegetables, ^{241}Am[c]
Devonport	Adult occupants on houseboats	<0.005	Exposure over sediment
Dounreay	Adult wild fruit and nut consumer	0.012	Direct radiation, potatoes
Dungeness	Local adult inhabitants (0–0.25km)	0.021	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Hartlepool	Local adult inhabitants (0–0.25km)	0.027	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0–0.25km)	0.016[g]	Direct radiation
Heysham	Adult mollusc consumer	0.023	Fish, gamma dose rate over sediment, molluscs, ^{137}Cs, $^{239/240}Pu$, ^{241}Am
Hinkley Point	Adult occupants over sediment	0.022	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25–0.5km)	0.021	Direct radiation
LLWR near Drigg[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Sizewell	Local adult inhabitants (0–0.25km)	0.020	Direct radiation
Springfields	Adult occupants on houseboat	0.050	Gamma dose rate over sediment
Torness	Local adult inhabitants (0.5–1km)	0.020	Direct radiation
Trawsfynydd	Infant local inhabitants (0.25–0.5km)	0.013	Milk, ^{241}Am
Whitehaven[e]	Adult mollusc consumer	0.22[f]	Crustaceans, molluscs, ^{210}Po
Winfrith	Adult fish consumer	<0.005	Fish, ^{241}Am
Wylfa	Adult occupants over sediment	0.007	Gamma dose rate over sediment

[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 as there are no sources 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 beacuse their effects are manifested in a common area of the Cumbrian coast*

[f] *The doses from man-made and naturally occurring radionuclides were 0.068 and 0.15 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] *Includes a component due to natural sources of radionuclides*

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

Site	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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	<0.005
Amersham		0.24	0.24	0.22	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.14
Barrow										0.057	0.076	0.055
Berkeley and Oldbury		*0.12*	*0.090*	*0.042*	0.061	0.041	0.058	0.011	0.006	0.014	0.010	<0.005
Bradwell		*0.09*	*0.067*	*0.075*	0.070	0.070	0.098	0.13	0.048	<0.005	<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	0.17
Cardiff	0.038	0.023	0.023	0.011	0.008	0.007	0.006	0.006	0.006	0.005	0.010	<0.005
Chapelcross		*0.022*	0.023	0.024	0.019	0.021	0.017	0.029	0.037	0.011	0.024	0.014
Derby							<0.005	<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	<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	0.012
Dungeness		*0.48*	0.55	0.63	0.28	0.40	0.32	0.022	0.021	0.015	0.021	0.021
Faslane		*<0.005*	*<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	0.027
Harwell		*0.017*	*0.022*	*0.026*	0.022	0.020	0.023	0.018	0.017	0.018	0.010	0.016
Heysham		*0.036*	*0.028*	0.037	0.038	0.046	0.049	0.057	0.025	0.025	0.028	0.023
Hinkley Point		*0.026*	*0.027*	0.048	0.035	0.045	0.055	0.014	0.014	0.013	0.022	0.022
Hunterston		0.10	0.090	0.074	0.090	0.077	0.067	0.067	0.050	0.032	0.021	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	0.22
Rosyth		*<0.005*	<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]	0.22
Sizewell		*0.045*	0.086	0.090	<0.005	0.031	0.026	0.020	0.021	0.021	0.021	0.020
Springfields		*0.17*	*0.15*	0.13	0.11	0.16	0.15	0.17	0.13	0.068	0.060	0.050
Torness		*0.024*	*0.025*	0.024	0.022	0.022	0.022	0.025	0.020	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	0.013
Whitehaven[b]	0.66	0.58	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.061	0.22
Winfrith	<0.005	<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	0.007

[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 people living in houseboats near Barrow*

Table 1.4. Source specific doses due to discharges of radioactive waste in the United Kingdom, 2014*

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	0.010[i]	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 and external in intertidal areas	L	0.021[i]	Ext
	Terrestrial foods, external and inhalation near site	G	<0.005[i]	^{14}C, $^{129}I^{d}$, ^{234}U
	External in intertidal areas (children playing)[a,h]	L	<0.005[i]	Ext
	Occupancy of houseboats	L	0.056	Ext
	External in intertidal areas (farmers)	L	0.036	Ext
	Wildfowl consumption and external in intertidal areas	L	0.006[i]	Ext
Sellafield[f]	Fish and shellfish consumption and external in intertidal areas (2010-2014 surveys) (excluding naturally occurring radionuclides)[l]	L	0.089	Ext, $^{239/240}Pu$, ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2010-2014 surveys) (including naturally occurring radionuclides)[m]	L	0.22	Ext, ^{210}Po, ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2014 surveys) (excluding naturally occurring radionuclides)[l]	L	0.094	Ext, $^{239/240}Pu$, ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[j]	G	0.012[i]	14C, ^{90}Sr, ^{129}I
	Terrestrial foods at Ravenglass[j]	G/L	0.017[i]	$^{106}Ru^{d}$, $^{144}Ce^{d}$
	External in intertidal areas (Ravenglass)[a]	L	0.012	Ext
	Occupancy of houseboats (Ribble estuary)	L	0.056	Ext
	Occupancy of houseboats (Barrow)	L	0.053	Ext
	External (skin) to bait diggers	L	0.069[g]	Beta
	Handling of fishing gear	L	0.077[g]	Beta
Research establishments				
Culham	Water consumption[o]	L	<0.005	$^{137}Cs^{d}$
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site	G	0.016	^{137}Cs, $^{238}Pu^{d}$, $^{239/240}Pu^{d}$, $^{241}Am^{d}$
Harwell	Fish and shellfish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005[i]	^{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	$^{3}H^{d}$, ^{14}C, $^{137}Cs^{d}$
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext
	Occupancy of houseboats	L	0.022	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C
Chapelcross	Wildfowl and fish consumption and external in intertidal areas	L	0.010	Ext, $^{241}Am^{d}$
	Crustacean consumption	L	<0.005	^{137}Cs
	Terrestrial foods, external and inhalation near site[j]	G	0.008	$^{35}S^{d}$, ^{90}Sr
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Occupancy of houseboats	L	0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S, $^{60}Co^{d}$
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S, $^{60}Co^{d}$
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.032	Ext, $^{239/240}Pu$, ^{241}Am
	External in intertidal areas (turf cutters)	L	0.016	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S, $^{60}Co^{d}$
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.032	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.010	^{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	<0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S

Table 1.4. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[e]	Exposure, mSv[b] per year	Contributors[c]
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{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	0.007	Ext, ^{137}Cs, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	0.025	^{241}Am
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[j]	G	<0.005	^{14}C, ^{35}S[d]
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005[l]	Ext
	Terrestrial foods, external and inhalation near site[j]	G	<0.005[i]	^{3}H[d], ^{137}Cs[d], ^{234}U, ^{238}U
Barrow	Occupancy of houseboats	L	0.053	Ext
	Terrestrial food consumption[p]	G	<0.005	^{3}H[d]
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[p]	L	<0.005	Ext, ^{3}H[d], ^{14}C
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[p]	G	<0.005	^{3}H[d], ^{14}C
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Terrestrial food consumption	G	<0.005	^{137}Cs, ^{241}Am[d]
Holy Loch	External in intertidal areas	L	0.011	Ext
Rosyth	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am[d]
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.009[i]	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[p]	L	0.006	Ext
	Terrestrial foods, external and inhalation near site[j]	G	0.005	^{14}C, ^{32}P[d], ^{35}S
	Recreational users of the River Taff[a]	L	<0.005	^{14}C, ^{125}I[d], ^{137}Cs
Industrial and landfill				
LLWR near Drigg	Terrestrial foods[j]	G	0.007	^{14}C, ^{90}Sr, ^{106}Ru[d], ^{144}Ce[d]
	Fish and shellfish consumption and external in intertidal areas (2010-2014 surveys) (including naturally occurring radionuclides)[f,m]	L	0.22	Ext, ^{210}Po, ^{241}Am
	Water consumption[o]	L	<0.005	^{134}Cs[d], ^{137}Cs[d], ^{210}Po[d]
Whitehaven	Fish and shellfish consumption and external in intertidal areas (2010-2014 surveys) (excluding artificial radionuclides)[f]	L	0.13	^{210}Po
	Fish and shellfish consumption and external in intertidal areas (2010-2014 surveys) (including artificial radionuclides)[f,n]	L	0.22	Ext, ^{210}Po, ^{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. The representative person is an adult unless otherwise stated*

[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*

[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 22 per cent (or less) of the dose limit for all assessed sites. *Total doses* increased at Sellafield, compared to the values in 2013, but remained well below the limit
- Doses, discharges, environmental concentrations and dose rates in 2014 were broadly similar to those in 2013

Capenhurst, Cheshire

- *Total dose* for the representative person increased in 2014

Springfields, Lancashire

- *Total dose* for the representative person was lower in 2014 and 5 per cent of the dose limit. The highest exposure was represented by occupancy on a houseboat; this was the lowest reported value for a number of years
- Gaseous discharges of carbon-14, and liquid discharges of technetium-99, decreased in 2014
- Gamma dose rates were lower in the vicinity of the houseboats in 2014

Sellafield, Cumbria

- *Total doses* for the representative person were 22 per cent (or less) of the public dose limit in 2014, up from 8 per cent in 2013
- The highest *total doses* were from seafood affected by past phosphate processing at Whitehaven. Historical discharges from Sellafield made a lesser contribution
- The consumption of seafood contributed to approximately 92 per cent of the *total dose*
- The representative person changed from a houseboat dweller near Barrow in 2013 to a high-rate seafood consumer near Sellafield in 2014
- Radiation dose from natural radionuclides was significantly higher in 2014, mostly due to the changes in seafood consumption. The contribution to *total dose* to this consumer from Sellafield discharges also increased due to changes in seafood consumption
- Gaseous discharges were generally similar to 2013, except iodine-129 increased by a small amount and tritium and carbon-14 decreased in 2014
- Liquid discharges were generally similar to 2013
- Concentrations of Sellafield derived radionuclides and dose rates were generally similar to those in 2013. Plutonium radionuclides and americium-241 were generally similar in shellfish

This section considers the results of monitoring, by the Environment Agency, FSA, NIEA and SEPA, 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. 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 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 January 2015, the Government approved NDA's recommendation for a change to the management arrangements at Sellafield. Subsequently, the NDA announced that from 1st April 2016 the NDA will become the owner of Sellafield Limited, the Site Licence Company responsible for managing and operating Sellafield on behalf of the NDA. The new arrangements will replace the current parent body organisation model and therefore ownership of Sellafield Limited by NMP.

The Windscale site, also owned by 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 2014, 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 have been considered in a summary report (Environment Agency, FSA, NIEA and SEPA, 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 NDA, comprising uranic material storage facilities and activities associated with decommissioning, and the other owned by UUK, operating three plants producing enriched uranium for nuclear power stations. In 2012, NDA completed the transfer of its Capenhurst site with the transition of Sellafield Limited activities to CNS, creating one nuclear licensed site owned and managed by UUK. The major operators at the site are now UUK, CNS and 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 collaborative habits survey undertaken on behalf of the Environment Agency, the FSA and ONR (including all exposure pathways from liquid discharges, gaseous discharges and direct radiation) was conducted in 2008 on behalf of the Environment Agency, the FSA and the Health and Safety Executive (HSE) (Tipple *et al.*, 2009). However in 2013, an independent habits survey was carried out by Cefas on behalf of UUK. The main aim of the UUK survey was to collect occupancy data for people exposed to direct radiation from the site (living or spending time within 1 km of the site). The UUK survey showed an increase in occupancy in comparison to an equivalent direct radiation survey conducted in 2004.

Doses to the public

The *total dose* from all pathways and sources is assessed to have been 0.17 mSv (Table 2.1) in 2014, or 17 per cent of the dose limit. This dose was almost entirely due to direct radiation from the Capenhurst site. The *total dose* increased in 2014 (from 0.080 mSv in 2013) due to an increase in the occupancy rate (incorporating the revised habits information from the independent habits survey in 2013) in the 2014 assessment. The dose assessment identifies a local adult living near to the site as the representative person. The trend in *total dose* over the period 2004 – 2014 is given in Figures 1.2 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 give 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 2014 (Table 2.1). The dose for 10-year-old children (who play near the brook and may inadvertently ingest water and sediment) was 0.010 mSv in 2014 and similar to those in recent 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). The focus for terrestrial sampling was on the content of technetium-99 and uranium in food (including milk), grass and soil. Results for 2014 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. Figure 2.2 shows the trend of technetium-99 concentrations in grass from 2005. The overall trend reflects the reductions in discharges of technetium-99 from recycled uranium. The most recently observed variability (from year to year) in the technetium-99 concentrations is largely based on data reported as less than values. 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.

Figure 2.1. *Total dose* at nuclear fuel production and reprocessing sites, 2004-2014
(Exposures at Sellafield/Whitehave/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

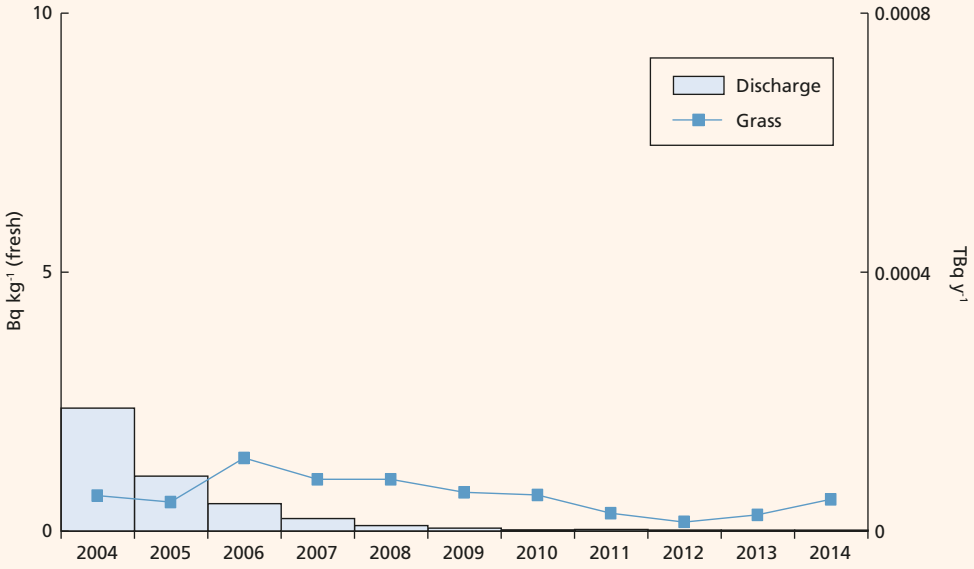


Figure 2.2. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2004-2014

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 neptunium-237). In 2014, discharges from Capenhurst were similar to those in 2013.

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 2014 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 and mussels was detected in 2014, reported just above the LoD. Downstream of the Rivacre Brook (at the location where children play), dose rates were generally similar to those in 2013. The low concentrations in fish and shellfish reflect the distant effects of discharges from Sellafield. As in previous years, 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, on behalf of NDA. 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 NDA, who retain responsibility for the historic nuclear liabilities on the site. Research and development, carried out by the National Nuclear Laboratory, produces small amounts of other gaseous radionuclides that are also discharged under permit (see Appendix A2.1).

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 (UOC) 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 2014 habits information, based on a five-year rolling average (2010 – 2014) 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 2014, the *total dose* from all pathways and sources is assessed to have been 0.050 mSv (Table 2.1), or 5 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 2014 was lower than in 2013 (0.060 mSv). The reduction in *total dose* was mostly due to slightly lower gamma dose rates (measured beneath the houseboats at Becconsall). *Total doses* (together with dose rates) over the period 2004 – 2014 are given in Figure 2.4. Most recently, the estimated *total dose* has decreased, with the lowest reported value in 2014, due to direct measurements beneath houseboats being available in recent years.

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 2014, the source specific assessment gave an estimated dose to a high-occupancy houseboat dweller of 0.056 mSv or less than 6 per cent of the dose limit for members of the public of 1 mSv, and down from 0.071 mSv in 2013. The lower value in 2014 was due to a combination of the revised habits information (a reduction in the occupancy rate) and a decrease in the external exposure (from activity in muddy sediments beneath the houseboat). This value is marginally higher than the *total dose* of 0.050 mSv assessed for the same representative person. The *total dose* assessment is based on more realistic assumptions.

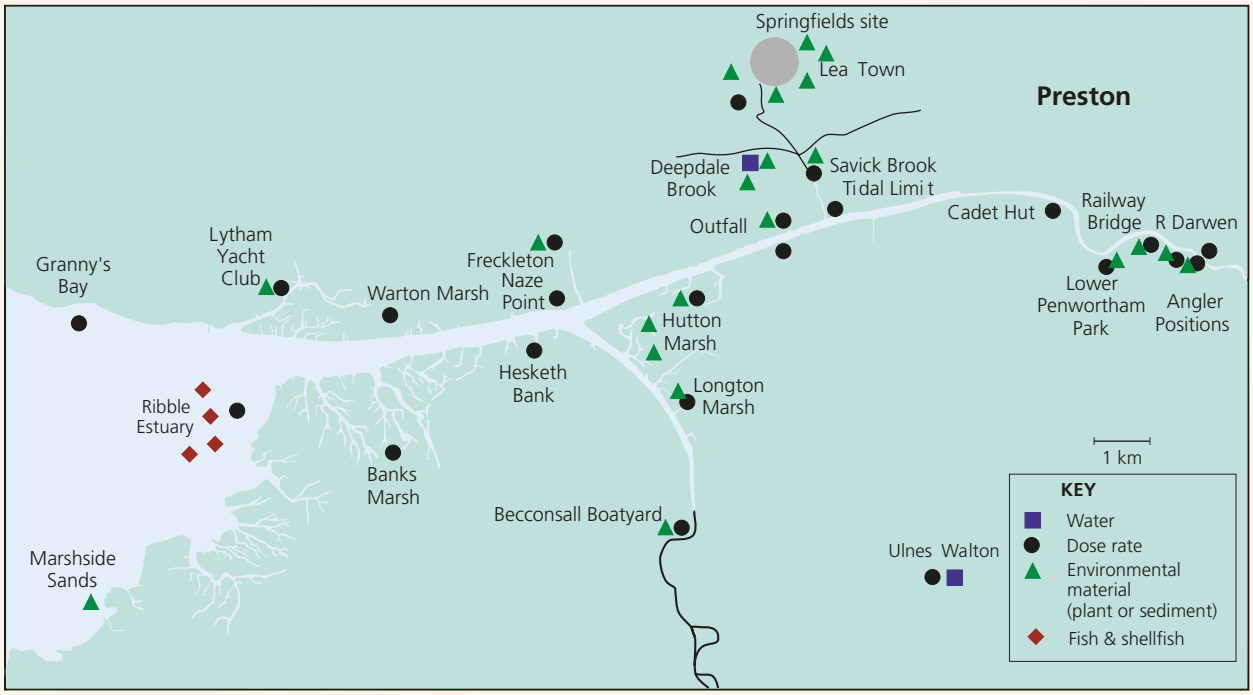


Figure 2.3. Monitoring locations at Springfields, 2014 (not including farms)

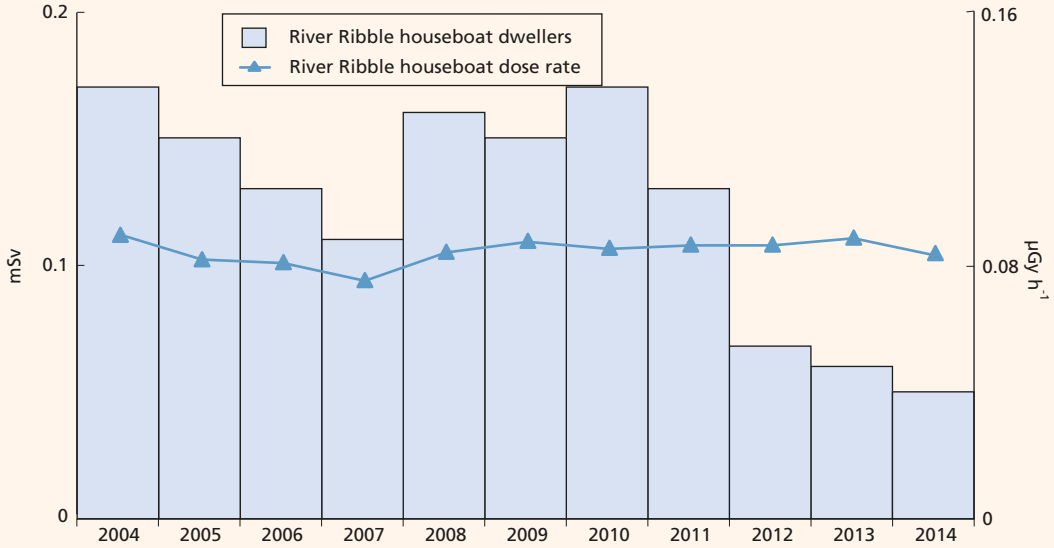


Figure 2.4. *Total dose* from all sources and dose rates at Springfields, 2004-2014

The dose to the representative person for high-rate consumers of seafood (including a contribution from external exposure) was 0.021 mSv in 2014. Of this dose, approximately 0.020 mSv was from external exposure and the remainder was from the consumption of fish and shellfish. The dose in 2013 was 0.023 mSv. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site.

As in recent years, assessments were undertaken to determine the dose to wildfowlers from external exposure over salt marsh and the consumption of game, the dose to farmers from external exposure, the dose to high-rate consumers of locally grown food and the dose to children playing on the banks of the estuary, at Springfields. The estimated doses in 2014 were 0.006 mSv, 0.036 mSv, less than 0.005 mSv and less than 0.005 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 carbon-14 decreased, from the research and development facilities in 2014, in comparison to 2013.

The 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, and vegetables. Grass and soil samples were collected and analysed for isotopes of uranium. Data for 2014 are given in Table 2.3(a). As in previous years, elevated concentrations of uranium isotopes 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 vegetables and grass. The carbon-14 concentration in beetroot was lower (in comparison to that in 2013), but above the default value used to represent the background level. Most other concentrations of radionuclides are reported as less than values. Results were broadly similar to those of previous years.

Figure 2.5 shows the trends over time (2004 – 2014) of uranium discharges and total uranium radionuclide concentrations in food (cabbage; 2004 – 2013; beetroot in 2014). 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 (and beetroot) 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. In comparison to those in most recent years, discharges in 2014 were generally lower, including the short half-life beta-emitting radionuclides (mostly thorium-234) that have decreased following the end of the 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 most recent years. 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 2014, technetium-99 discharges were decreased in comparison to those 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 and shellfish were analysed by gamma-ray spectrometry and for thorium and plutonium isotopes. Results for 2014 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 radionuclide thorium-234, from Springfields, were also found. Concentrations of the latter were closely linked to recent discharges from the Springfields site. In 2014, thorium-234 concentrations in sediments (over the range of sampling sites) were generally similar compared to those in 2013. Over a much longer timescale (2004 – 2014), 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 UOC 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 – 2014) 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 generally decreased overall (but peaked in 2012). Caesium-137 concentrations in flounder and salmon showed variations between years and this was most likely due to natural changes in the environment. Concentrations of technetium-99 in shrimps generally 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 2014, gamma dose rates in the estuary, excluding rates taken for houseboat assessments, were generally lower

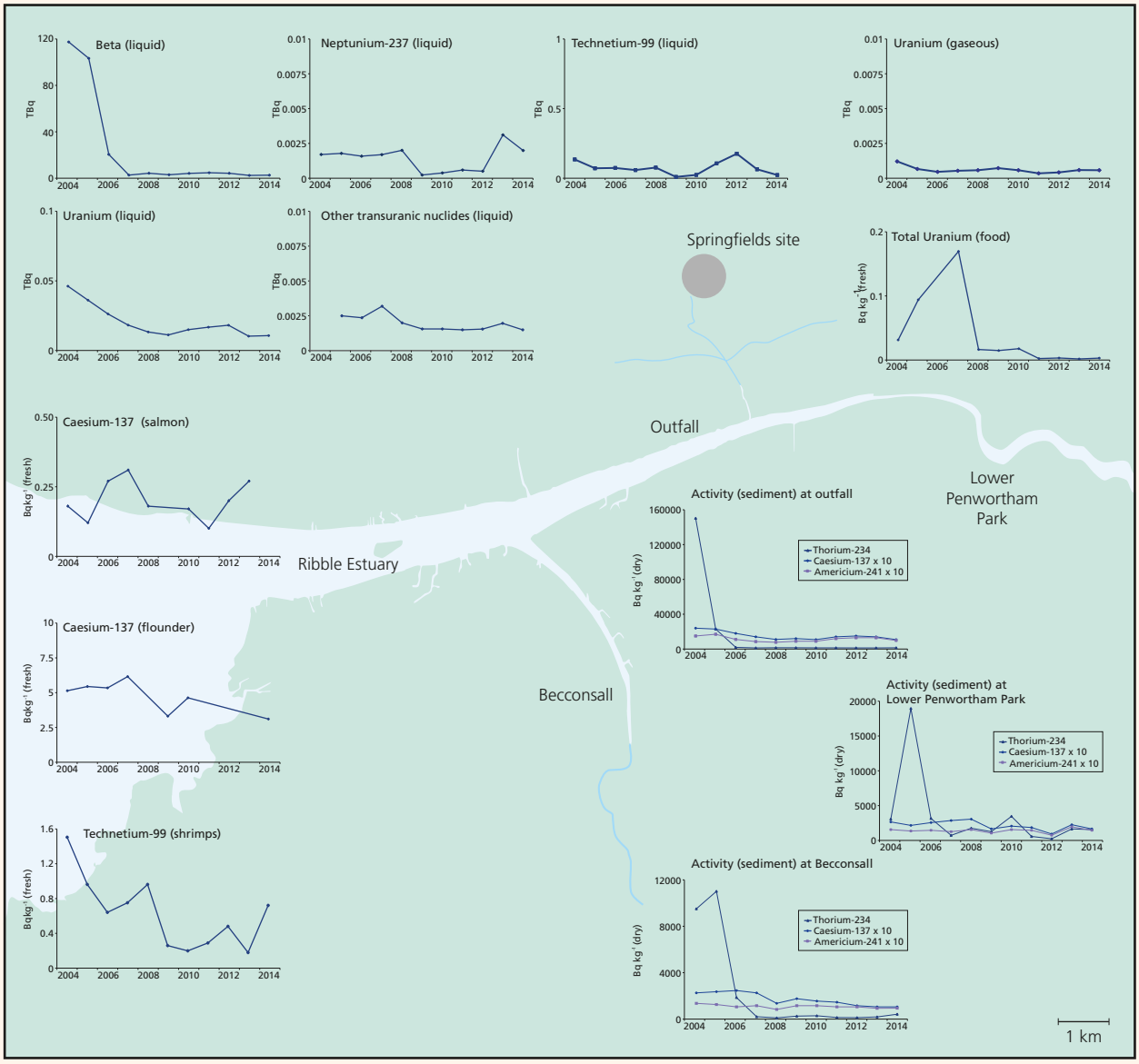


Figure 2.5. Discharges of gaseous and liquid radioactive wastes and monitoring of the environment, Springfields 2004–2014 (Note different scales used for discharges and activity concentrations)

than those in 2013, but with some small variations at some sites. Gamma dose rates measured in the vicinity of houseboat dwellers in 2014 (at Becconsall) were also lower than those in 2013. Where comparisons can be made from similar ground types and locations, beta dose rates from sediments in 2014 were generally similar to those in recent years.

2.3 Sellafield, Cumbria

This site is operated by Sellafield Limited (formerly called British Nuclear Group Sellafield Limited (BNGSL)), but is owned by 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. De-fuelling of Calder Hall is expected to be completed between March 2017 and March 2019 according to the NDA Magnox Operating Plan. The Windscale site is located at Sellafield, and is discussed in Section 2.4.

In 2011, Sellafield Limited and NDA published their plans for decommissioning of the Sellafield site (http://www.sellafieldsites.com/wp-content/uploads/2012/08/Sellafield_Plan.pdf). Sellafield Limited commenced the first retrievals of sludge from legacy pond facilities in early 2015 and 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 2014, a number of decommissioning projects continued including that of the Calder Hall reactors.

During the financial year 2014/15, 386 tonnes of spent oxide fuel (346 tonnes in 2013/14) was reprocessed in THORP, compared with an original performance (stretch) target of 439 tonnes. The reprocessing of spent Magnox fuel for 2014/15 was a total of 523 tonnes of fuel (470 tonnes in 2013/14), compared with an original performance target of 520 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 full habits survey was conducted in 2013 (Clyne *et al.*, 2014). In 2014, changes were found in the amounts and mixes of species consumed from the full habits survey conducted in 2013 (Garrod *et al.*, 2015a). Further afield, the most recent habits surveys were conducted in 2012, to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast (Garrod *et al.*, 2013a) and around Barrow and the south-west Cumbrian coast (Garrod *et al.*, 2013b). 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.*, 2008; 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 2014 (Garrod *et al.*, 2015a). 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 2014, the highest *total dose* relating to the effects of Sellafield was assessed to have been 0.22 mSv, or 22 per cent of the dose limit to members of the public (Table 2.17). The representative person was an adult, consuming molluscan shellfish at high-rates near Sellafield. The person also consumed significant quantities of other seafood. This represents a change in the representative person from an adult who was living on a houseboat on the Cumbrian coast (near Barrow), and a significant increase from the *total dose* of 0.076 mSv, in 2013. This was mostly attributable to (i) an increase in the breadth of seafood species being consumed by individuals (i.e. a return to a wide range of seafood species being consumed by individuals, prior to 2013) and (ii) a significant increase in the proportion of lobster in the diet of high-rate seafood consumers (both from the revision of habits information) in 2014. A much lesser enhancement in *total dose* was due to a small increase in concentrations of polonium-210 in locally caught molluscs and crustaceans consumed by the representative person in 2014 (compared to those in 2013). Direct radiation from the Sellafield site (0.005 mSv, Table 1.1) was considered in the *total dose* assessments, but this made an insignificant contribution to the highest *total dose*.

In percentage terms, the most significant contributors to the *total dose* in 2014 were from crustacean consumption, mollusc consumption, external exposure over sediments

and fish consumption (63, 24, 8 and 5 per cent, respectively), the most important radionuclides were polonium-210, americium-241, and plutonium-239+240 (67, 12, and 5 per cent, respectively).

Artificial radionuclides discharged by Sellafield (including external radiation) and historical discharges of naturally occurring radionuclides from Whitehaven contributed 0.068 mSv and 0.15 mSv, respectively (values are rounded to two significant figures). In 2013, the contributions were 0.040 mSv and 0.021 mSv, respectively. In 2014, the contribution from the external radiation was approximately 0.017 mSv (0.014 mSv in 2013). 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 0.068 mSv in 2014 from artificial radionuclides (including external radiation) was higher than in 2013 (0.040 mSv). In 2014, the contributing radionuclides were mostly americium-241, plutonium-239+240 and carbon-14 (38, 16 and 5 per cent, respectively). External exposure was 25 per cent (33 per cent in 2013) of the *total dose* from artificial radionuclides. The increase in the contribution to the *total dose* from 2013 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 0.15 mSv in 2014 from naturally occurring radionuclides was significantly higher than in 2013 (0.021 mSv). In 2014, the most contributing radionuclide was polonium-210 (96 per cent). The increase in the contribution to the *total dose* from 2013 was mostly due to the changes in seafood consumption (from the revision of habits information), and (to a lesser extent) a small increase in concentrations of polonium-210 in locally caught molluscs and crustaceans, for the representative person in 2014. Polonium-210 concentrations (above expected background) in mollusc samples contributed 0.022 mSv to the *total dose* in 2014; between 2011 and 2013 there was no contribution from molluscs.

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 2004 – 2014. The trend of generally declining dose broadly reflects 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 representative 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 occurring radionuclides contribution to the *total dose* has been a relative increase in the proportion from artificial radionuclides. In 2013, the highest *total dose* (relating to the effects of Sellafield) was entirely due to external radiation from sediments. The change was due to both decreases in naturally occurring radionuclides concentrations (polonium-210) and a revision of habits information, resulting in a change in the representative person.

Other age groups received less exposure than the adult *total dose* of 0.22 mSv in 2014 (10y: 0.11; 1y: 0.062; prenatal: 0.045, 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 gaseous discharges and direct radiation

In 2014, the dose to a representative person receiving the highest *total dose* from the pathways predominantly relating to gaseous discharges and direct radiation was 0.009 mSv (Table 2.17), down from 0.012 mSv in 2013 (values rounded to two significant figures). The most exposed age group was an adult and the dominant contribution to this dose was direct radiation from the site. In 2013, the most exposed age group was an adult who was a high-rate consumer of mushrooms. The change in the *total dose*, and in the most exposed group, were mostly attributable to a combination of reasons resulting from the changes in the FSA monitoring programme and in contributions of direct radiation from year to year. More specifically, attributed as; due to (i) improved detection limits, using the alternative radiochemistry method (i.e. replacing gamma spectrometry), for the analysis of americium-241 in vegetables in 2014, (ii) a reduction in the types and number of vegetables collected in 2014, resulting in lower carbon-14 contributions and (iii) an increase in direct radiation, compared with those contributions in the 2013 assessment.

The most significant contributors in 2014 to the *total dose* for an adult were from direct radiation from the

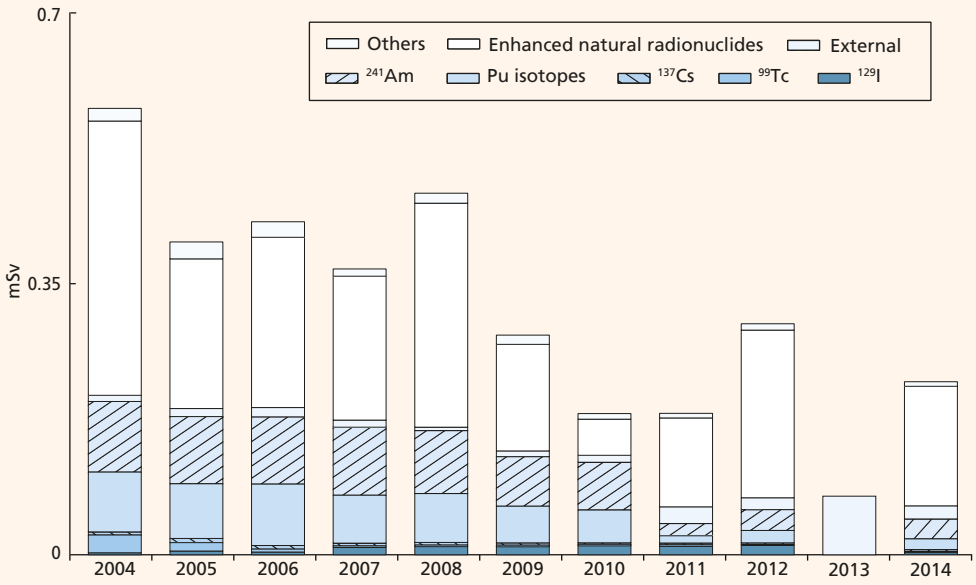


Figure 2.6. Contributions to *total dose* from all sources at Sellafield, 2004-2014

site, the consumption of potatoes, and the combined external and inhalation from the site (56, 27, and 6 per cent, respectively), the most important radionuclide was caesium-137 (17 per cent). Other ages received less exposure than the adult *total dose* of 0.009 mSv in 2014 (10y: 0.008; 1y: 0.008; prenatal: 0.007, equivalent values rounded to one significant figure).

Contributions to the highest *total dose* each year, by specific radionuclides, are given in Figure 2.7 over the period 2004 – 2014. Up until 2007, there was a small decline in *total dose* due to a general reduction in concentrations of radionuclides 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. Over the period 2010 – 2013, *total doses* were generally similar between years. The decrease in *total dose* (from 2013) was mostly due to changes in the monitoring programme in 2014.

Total dose from liquid discharges

The people receiving the highest *total dose* from the pathways predominantly relating to liquid discharges are given in Table 2.17. 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 2014, 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 0.012 mSv (adult: 0.009; 10y: 0.010; prenatal: 0.008) or approximately 1 per cent of the dose limit to members of the public (Table 2.17). The reason for the lower dose (from 0.021 mSv in 2013) is mostly due to a decreased maximum carbon-14 concentration in milk in 2014.

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 (2014 habits survey). The second is based on a five-year rolling average using habits data gathered from 2010 to 2014. Changes were found in the amounts and mixes of species consumed. For molluscs, the consumption rate decreased in 2014 and for the 2010 – 2014 data set. Conversely, crustacean consumption rates increased in 2014, and for the 2010 – 2014 data set. The occupancy rate over sediments increased in 2014, and for the 2010 – 2014 data set. The revised habits data are given in Appendix 1 (Table X2.2). Aquatic

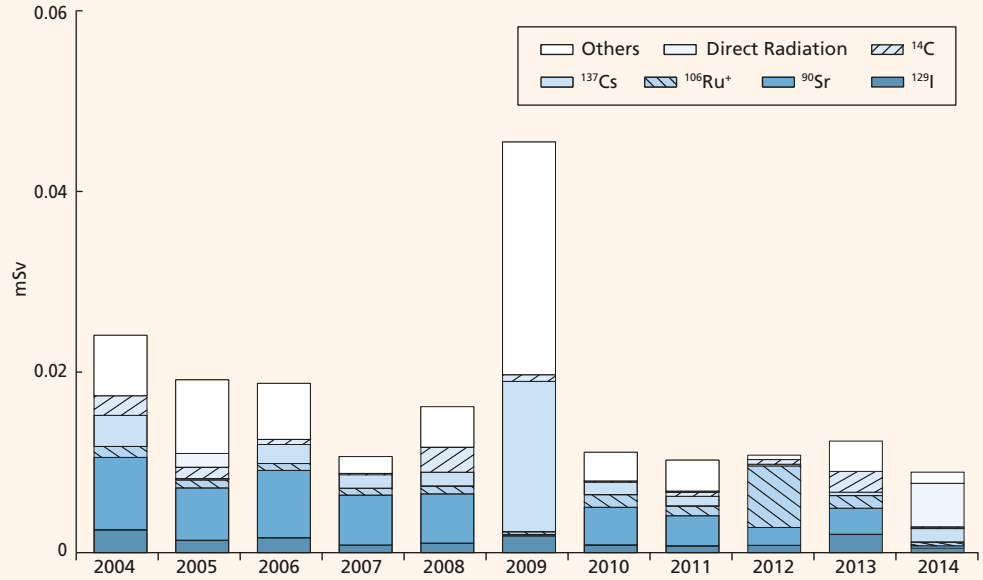


Figure 2.7. Contributions to *total dose* from gaseous discharge and direct radiation sources at Sellafield, 2004-2014 (+ based on limits of detection for concentrations in foods)

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 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 (CEDA) (FSA, 2001a).

Table 2.17 summarises source specific doses to seafood consumers in 2014. The doses from artificial radionuclides to people, who consume a large amount of seafood, were 0.094 mSv and 0.089 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 0.13 mSv in 2014. Most of this was due to polonium-210 (96 per cent). The reason for the large increase in dose in 2014 (from 0.059 mSv in 2013) is the same as that contributing to maximum *total dose*, i.e. mostly attributed to (i) an increase in the breadth of seafood species being consumed by individuals and (ii) a significant increase in the proportion of lobster in the diet of high-rate seafood consumers. 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 2014) was 0.18 mSv (Table 2.17).

Taking artificial and enhanced natural radionuclides together, the source specific doses were 0.27 mSv and 0.22 mSv for annual and five-year rolling average habits data, respectively. These estimates are larger than or equal to the estimate of *total dose* from all sources of 0.22 mSv. The main reason for this is a difference in the approach to selecting consumption rates for seafood for the representative 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, Northern Ireland and North Wales have been kept under review in 2014 (Table 2.17). Those for fisheries in the Isle of Man and Fleetwood have been shown to be generally lower and dose data are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014). 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 2013 (Table 2.16). 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 is also given in Table 2.17. 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 2014.

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 2014 are given in Table 2.9. The results of the assessment of external exposure pathways are included in Table 2.17. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, was received by the representative person living in houseboats in the Ribble Estuary in Lancashire. In 2014, the dose was 0.056 mSv or 6 per cent of the dose limit for members of the public. Other people received lower external doses in 2014. The estimated dose to a person who spends a long time over the marsh in the Ravenglass Estuary was 0.012 mSv and similar to that in 2013 (0.011 mSv). Overall, gamma dose rates measurements in 2014 were generally similar to those in 2013 in the Ravenglass Estuary.

The doses to people in 2014 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.*, 2008; 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 2014, the doses to people from recreational use of beaches varied from 0.007 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, the rates for handling nets and pots and for handling sediments are provided in Appendix 1 (Table X2.2). In 2014, the skin doses to a fisherman from handling fishing gear (including a component due to naturally occurring radiation), and a bait digger and shellfish collector from handling sediment, were 0.077 mSv and 0.069 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 was the representative person from consuming terrestrial foods that were potentially affected by radionuclides transported to land by sea spray. In 2014, the dose (including contributions from Chernobyl and weapon test fallout) was estimated to be 0.017 mSv, which was less than 2 per cent of the dose limit for members of the public. As in 2013, the largest contribution to the dose was from ruthenium-106 in milk. This represents a decrease in the dose, in comparison to that in 2013 (0.032 mSv). The decrease in dose was mostly attributed to a lower reported less than value for ruthenium-106 in milk, and to a lesser extent, the contribution of domestic fruit not being sampled in the assessment, in 2014. The samples collected can vary between years. For example in 2014 domestic fruit was not collected in Ravenglass. FSA will adapt their sampling schedule in future to account for potential dose contributors. This is in line with the risk-based review of the FSA's monitoring programme. As in previous years, sea-to-land transfer was not of radiological importance in the Ravenglass area.

Doses from seaweed and seawashed pasture

Doses from seaweed and seawashed pasture pathways were not assessed due to changes in the monitoring programme in 2014.

In South Wales the food item laverbread, made from the brown seaweed *Porphyra,* is eaten. Only small quantities of samphire, *Porphyra* and *Rhodymenia* (a red seaweed) are generally consumed. Estimated doses for a high-rate consumer of laverbread are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014) establishing that this exposure pathway is of low radiological significance.

Seaweeds are sometimes used as fertilisers and soil conditioners. Estimated doses for a high-rate consumer of vegetables (assuming these foods were obtained from the monitored plots near Sellafield) are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014) Overall doses from this pathway remain similar, and minor variations from year to year are due to different foods being grown and sampled from the monitored plots. Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales are expected to be much lower than near Sellafield.

Animals may graze on seaweeds on beaches in coastal areas. However, there was no evidence of this taking place significantly near Sellafield. FSA 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 2014 (MAFF and SEPA, 1999). A further research study (relevant to the Scottish islands and coastal communities), conducted by PHE on behalf of the FSA 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/environment/radioactive-substances/environmental-monitoring-and-assessment/reports/

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 2014 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 2014 were much less than the permit limits, and were generally similar to those in 2013. Discharges of iodine-129 increased in 2014 by a small amount, whilst tritium and carbon-14 decreased, in comparison to those in 2013.

Monitoring around the site related to gaseous discharges

Monitoring of terrestrial foods in the vicinity of Sellafield is conducted by FSA 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 range of foodstuffs was sampled in 2014 including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials (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 2014 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 with many reported as less than values with only limited evidence of the effects of Sellafield's atmospheric discharges detected in data for carbon-14 and strontium-90. Plutonium concentrations and americium-241 in wood pigeon, when detectable, were low and much lower than those found in seafood.

A range of fruit and vegetables was sampled in 2014 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. As in previous years, iodine-129 was positively detected in milk (just above the less than value) in 2014. 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 2013, antimony-125 concentrations were below limits of detection in foods and soil in 2014, despite relatively enhanced discharges in recent years. Trends in

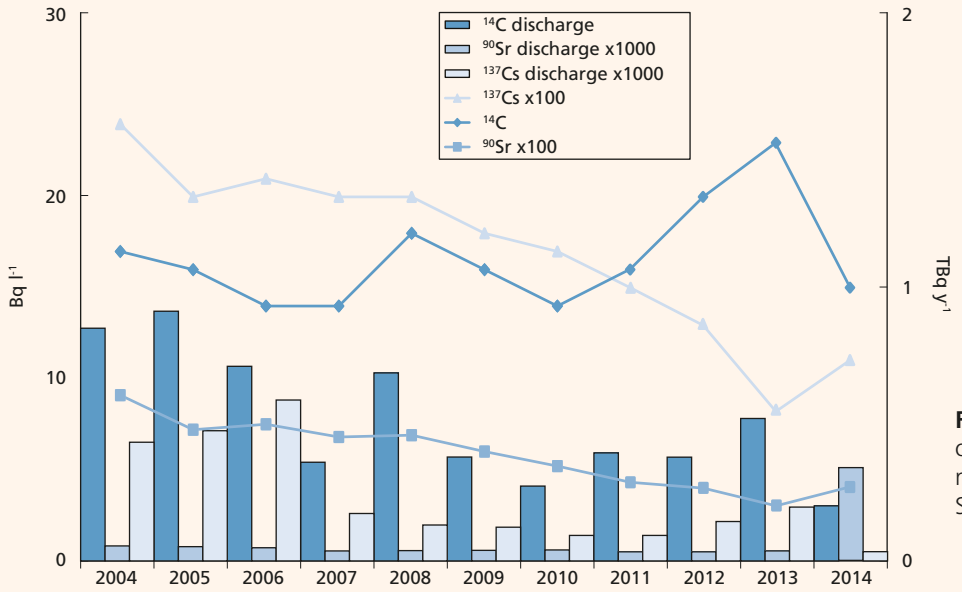


Figure 2.8. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2004-2014

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 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. In March 2015, the Environment Agency issued a varied permit to Sellafield Limited that will allow some liquid wastes to also be discharged via the Calder Interceptor Sewer. As part of this permit variation, a restructuring of the aqueous discharge limits has introduced site annual site limits that are 10 per cent lower than the previous sea pipeline limits for total alpha, beta and tritium. This change reflects the removal of headroom rather than any change in the dose or risk that the discharges represent. Discharges from the Sellafield pipelines during 2014 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 2014 were well below the limits in the permit. Liquid discharges were generally similar in comparison to those 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 2014, to those in 2013. 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 (Defra, 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 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 2014, by the Environment Agency and FSA (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, FSA, NIEA and SEPA, 2010b). The Environment Agency has proposed changes to its future monitoring programme that are due to take effect in 2016 and will be reflected in future RIFE reports.

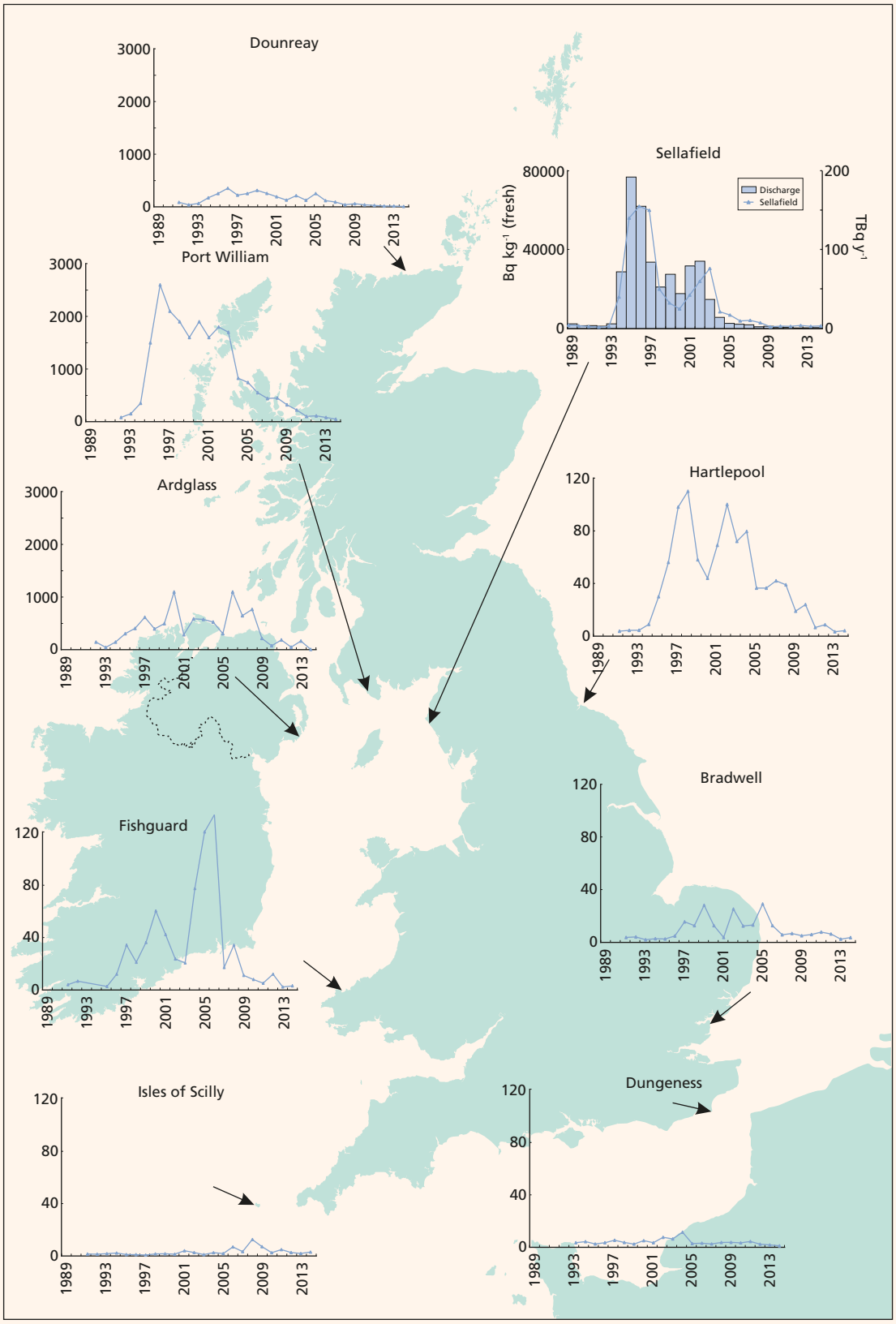


Figure 2.9. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2014 (Note different scales used for Ardglass, Dounreay, Port William and Sellafield)

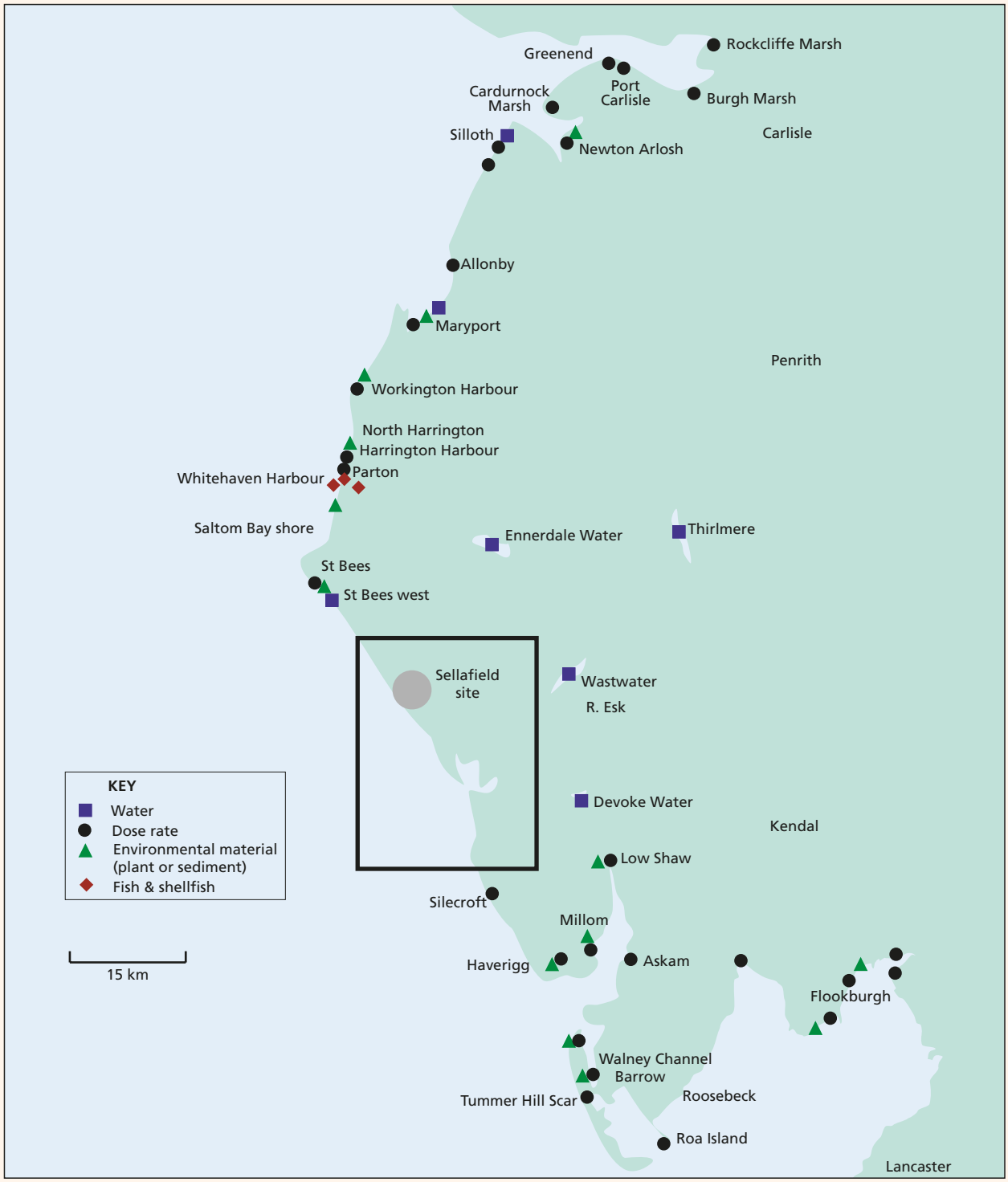


Figure 2.10. Monitoring locations in Cumbria, 2014 (not including farms)

Figure 2.11. Monitoring locations at Sellafield, 2014 (not including farms)

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. Results are available for previous specific surveys in the 'Sellafield Coastal Area' (extending 15 km to the north and to the south of Sellafield, from St Bees Head to Selker, and 11 km offshore) and the smaller 'Sellafield Offshore Area' (consisting of a rectangle, 1.8 km wide by 3.6 km long, situated south of the pipelines) in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014). Concentrations of specific naturally occurring radionuclides in fish and shellfish in the Sellafield area are given in Section 7.

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 2014 were similar to those in 2013. Overall, concentrations of technetium-99 in fish and shellfish have shown a continued reduction, from the relatively elevated levels shown at the beginning of the reported period, 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 of reductions in 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 of plutonium radionuclides and americium-241 in winkles were generally similar (with minor variations) in 2014 compared to those in 2013.

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 2013. Over the longer time period, activity concentrations in fish and shellfish appear to be generally declining (with minor variations) at a slow rate (Figure 2.15). 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.

Up until 2013, brown trout was sampled for analysis from the River Calder, which flows through the Sellafield site. Results for previous measured caesium-137 concentrations, and long-term trend information, are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014). 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.

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 2014, carbon-14 provided the highest activity concentration in marine fish (plaice, 98 Bq kg^{-1}), with lower concentrations of tritium (total) and Organically Bound Tritium (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). 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 2014 and 2013 data across a wide range of sampling locations and shellfish species (where comparisons can be made), technetium-99 concentrations were similar (with minor variations), 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 2014 were also broadly similar (where comparisons can be made) to those in 2013.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2014 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 2014 and 2013 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish were generally similar (where comparisons can be made). Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In comparison to 2013 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

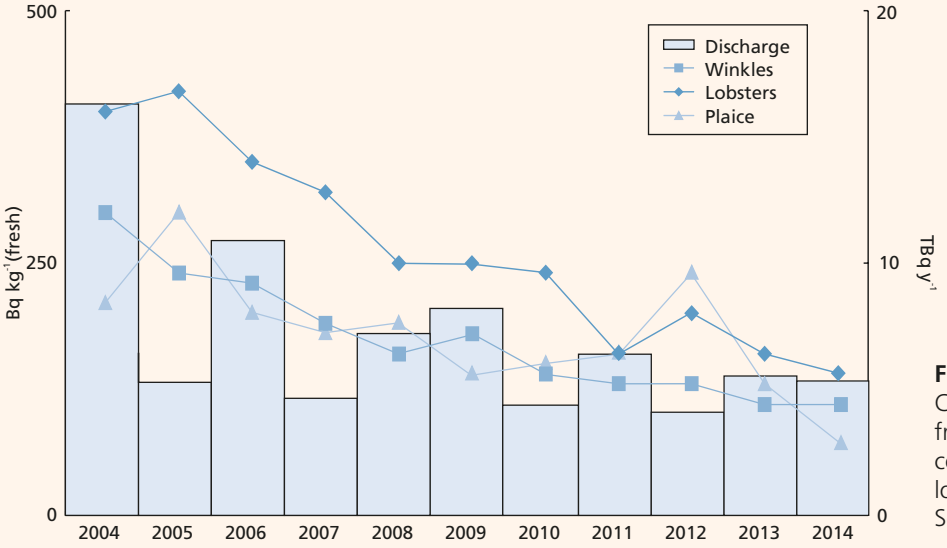


Figure 2.12.
Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

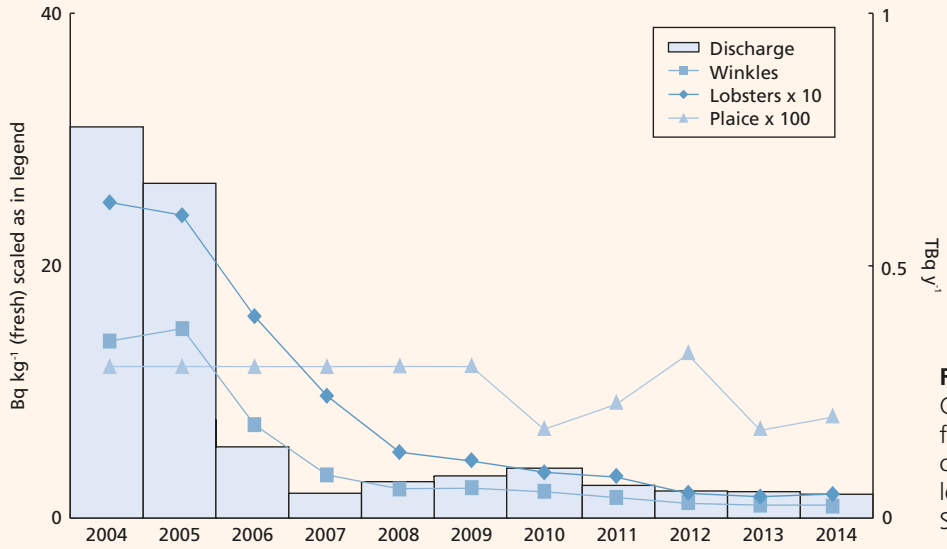


Figure 2.13.
Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

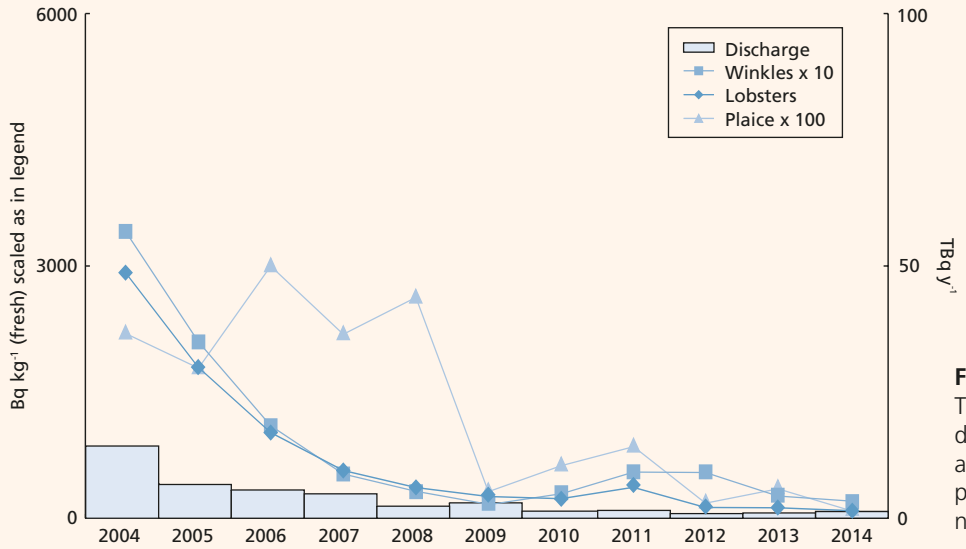


Figure 2.14.
Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

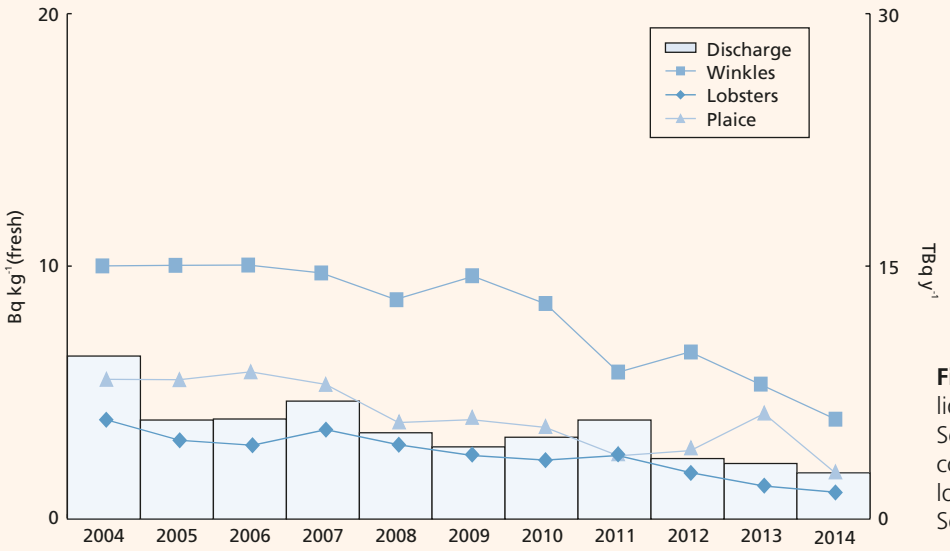


Figure 2.15. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

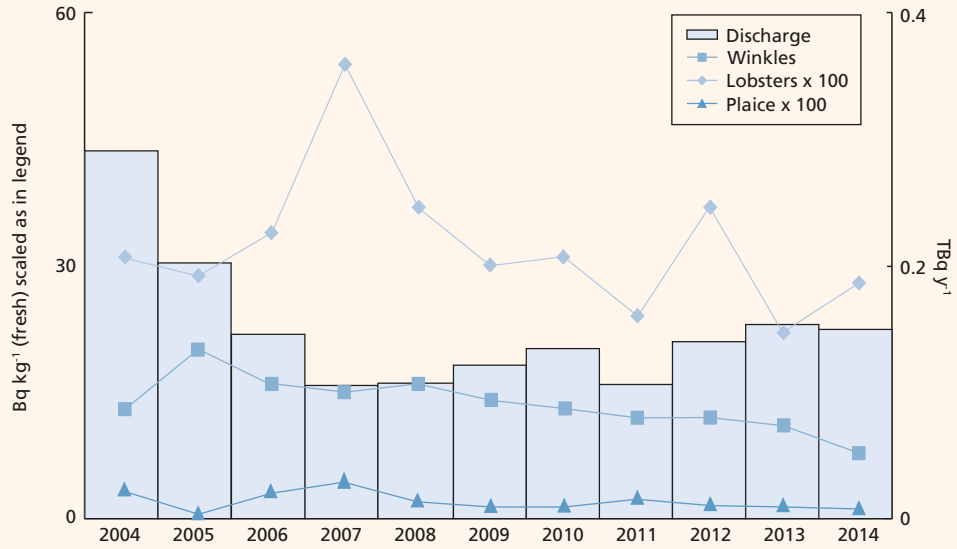


Figure 2.16. Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

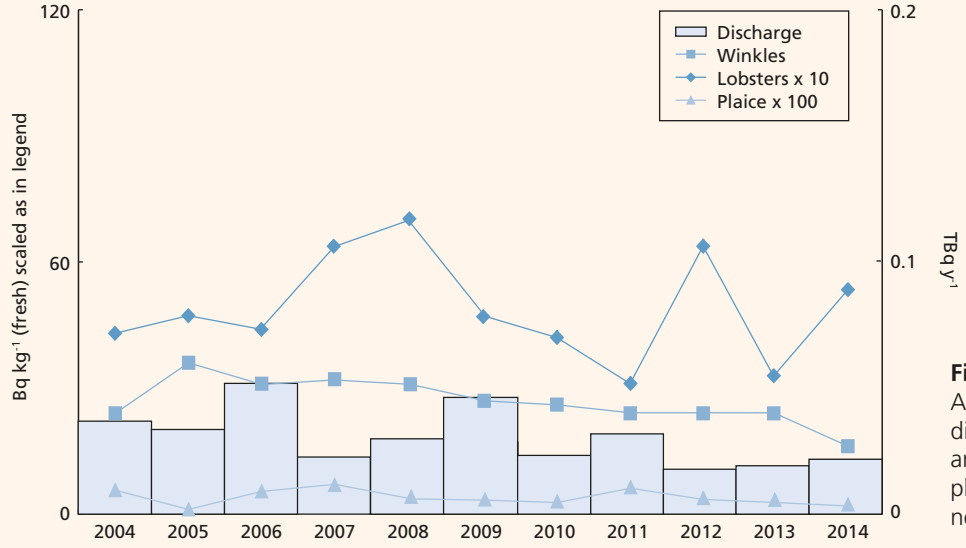


Figure 2.17. Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2004-2014

concentrations in winkles (from Nethertown). 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 2014 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, largely 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 2014 were similar to those in recent years.

The trends over time (1990 – 2014) for activity concentrations in mud from Ravenglass with discharges from Sellafield are shown in Figures 2.18 – 2.21. 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 2.20). The cobalt-60 concentration in mud from Ravenglass is the lowest reported value in 2014. Over the last decade, caesium-137 and transuranic concentrations in sediments have remained relatively constant (Figures 2.18, 2.19 and 2.21). Since the mid-1990s, discharges of caesium-137, plutonium isotopes and americium-241 have remained at low levels, but with some variability. There is as 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 2.22. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations in 2014 at a given location were generally similar to those in 2013, and any fluctuations were most likely due to the normal variability expected to be 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 FSA, 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 at a large number of locations, 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 2014 were generally similar to those in recent years. Any variations between years are likely to have been due to normal variability expected to be present 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, are shown in Figure 2.23. Gamma dose rates at sandy locations are generally lower than those above mud or salt marshes. 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

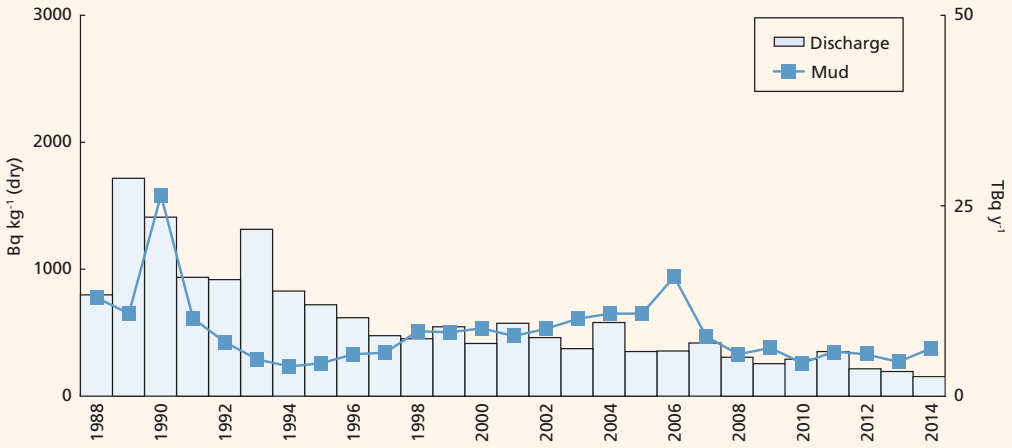


Figure 2.18. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2014

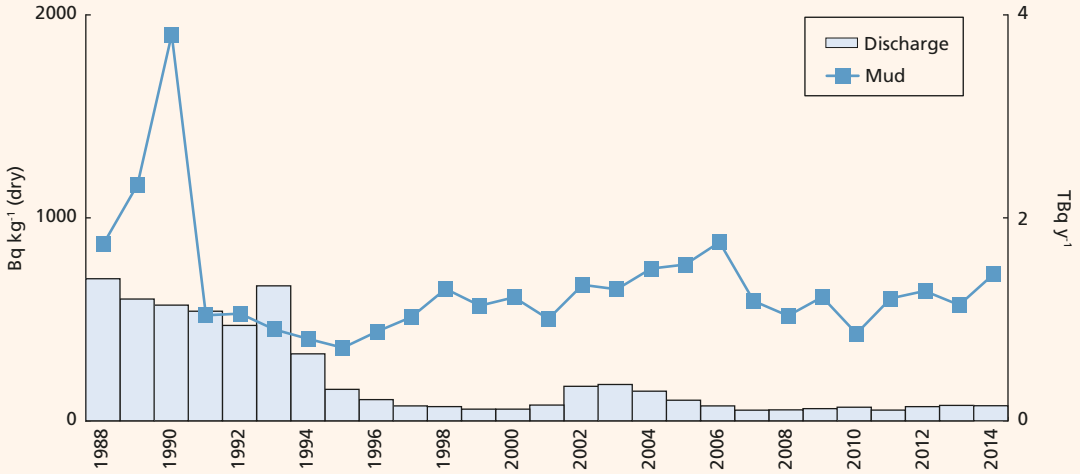


Figure 2.19. Plutonium-alpha liquid discharge from Sellafield and plutonium-239+240 concentration in mud at Ravenglass, 1988-2014

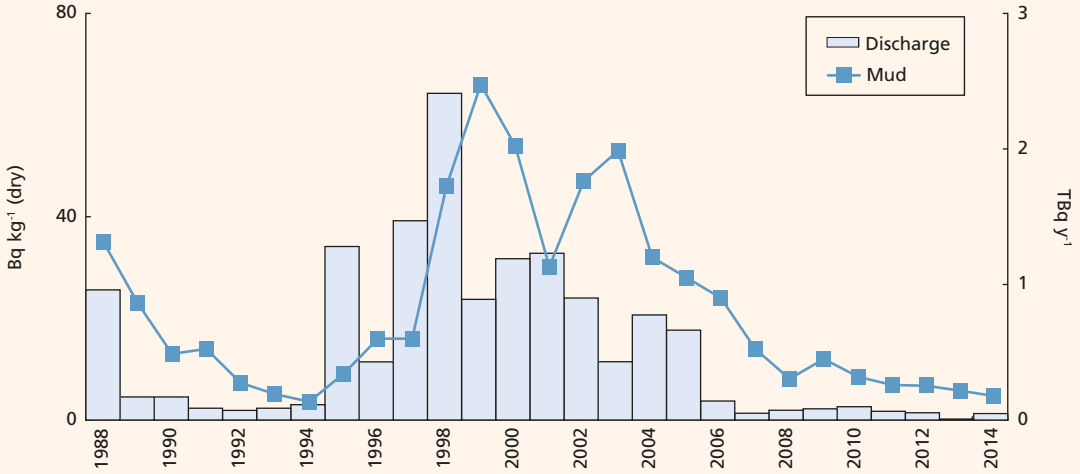


Figure 2.20. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2014

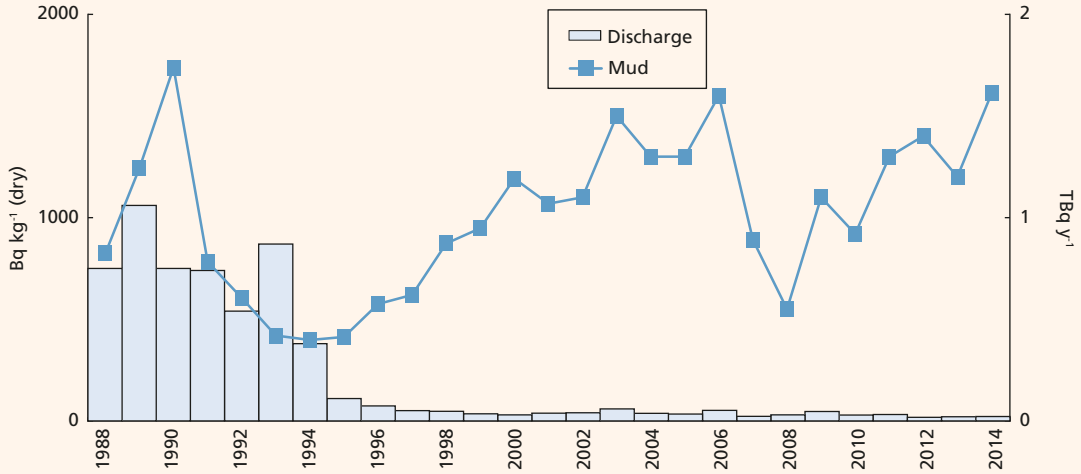


Figure 2.21. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1988-2014

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 value at Newbiggin being in 2014. 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 2.19). 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 2014 are given in Table 2.10. Overall, where comparisons can be made, measured dose rates were lower to those in 2013.

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 were generally higher in 2014, in comparison to those in recent years (where comparisons can be made from similar ground types and locations). Beta dose rates were much higher in sand at Whitehaven (outer harbour), St Bees, Sellafield pipeline and Tarn Bay, and in salt marsh at Ravenglass, in 2014 (compared to 2013).

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 2014, no material was found using

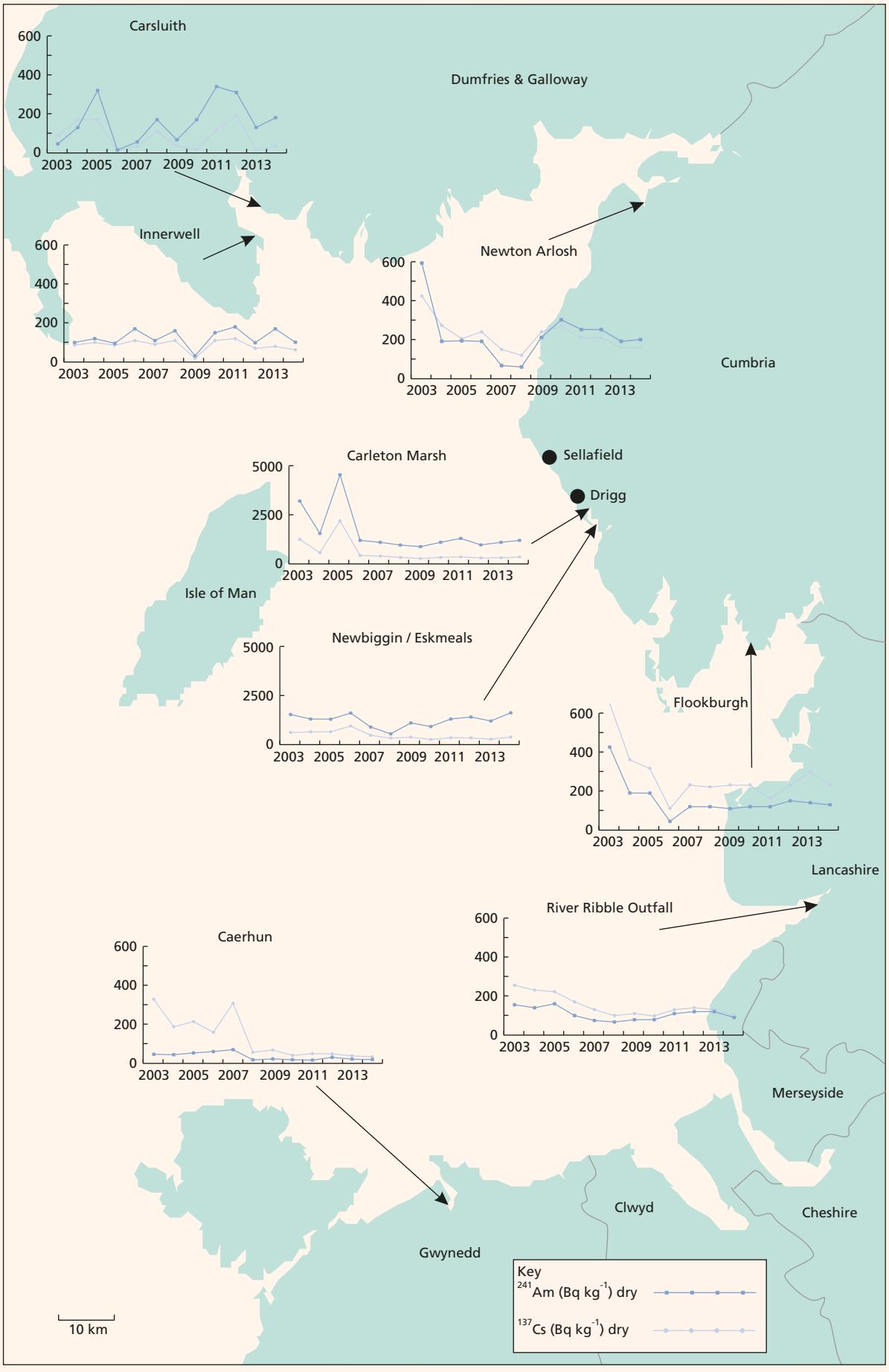


Figure 2.22. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2003-2014 (Note different scales used for Newbiggin and Carleton Marsh)

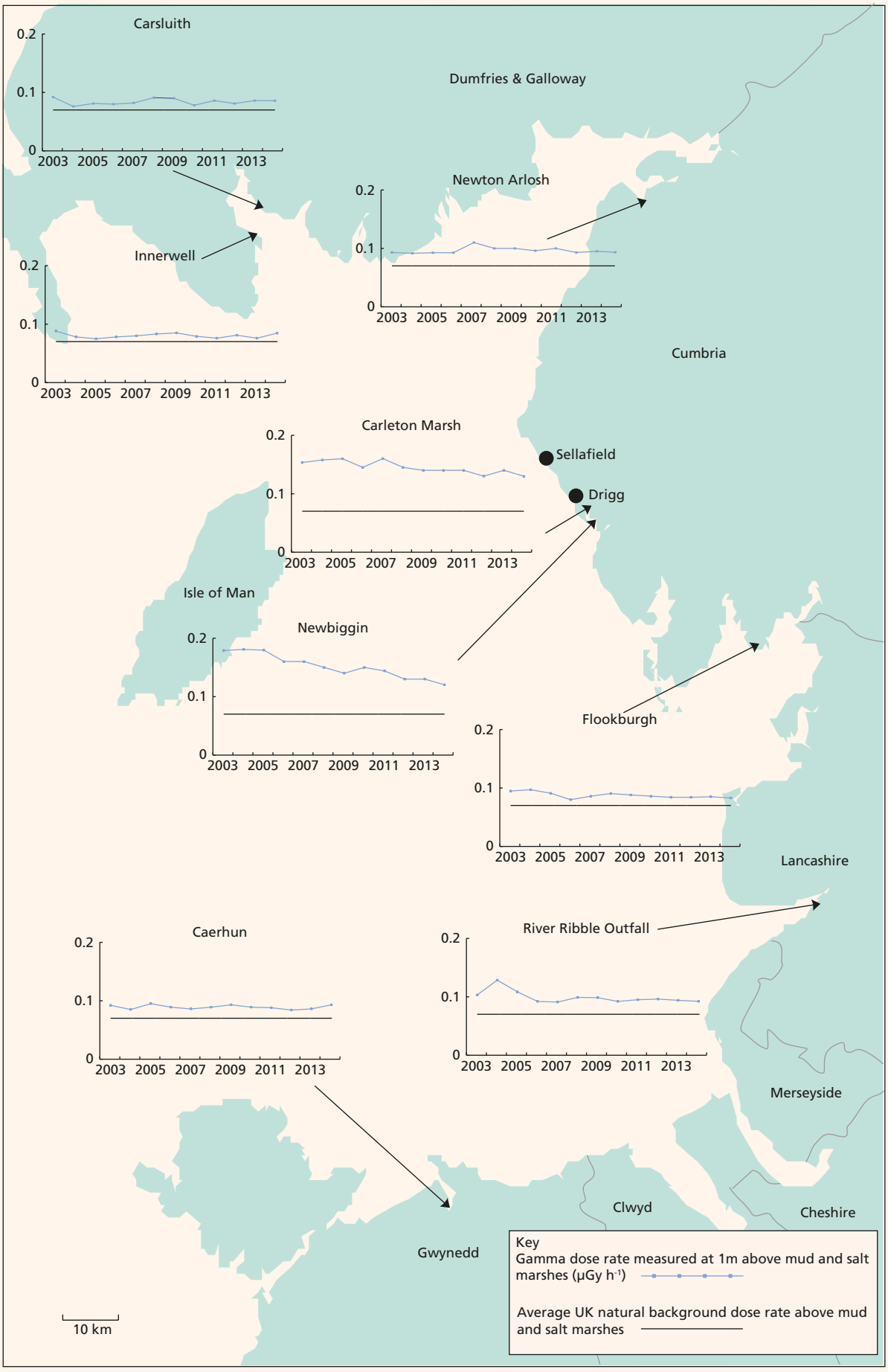


Figure 2.23. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2003-2014

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 2014, approximately 1844 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 2014/15, further beach monitoring was completed in line with the Environment Agency's specification of approximately 160 hectares (Sellafield Limited, 2015). The number of radioactive finds identified in the period from April 2014 to March 2015 was 383 (compared with 117 in the previous year), of which 91 per cent were classified as particles (less than 2 mm in size) and the remainder as stones (larger than 2 mm in size). The number of radioactive finds was higher than the previous period due to the increased performance this year of detecting low activity americium-241 finds. 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 2015 and March 2016, as part of the operator's routine environmental monitoring programme, and will also include an investigation of "inaccessible areas" on the beaches at Sellafield.

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 both 2013 and 2014. So far, only a single radioactive particle has been identified (in 2012) by these offshore surveys. No further campaigns have been programmed to take place in 2015/16.

In 2012, 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, PHE advice remained that no special precautionary actions were required to limit access to or use of the beaches. A more recent report by PHE describes the assessed health risks from the consumption of seafood (including those to commercial fishermen) from radioactive particles in the vicinity of the Sellafield Site (Oatway and Brown, 2015). Based on currently available information, it is concluded that the overall health risks to both seafood consumers and commercial fishermen are very low.

In June 2014, a single particle was found which was unusual in that its activity was predominantly from beta radiation. PHE has undertaken detailed dose measurements of this particle and established that the skin dose rate from this one particle exceeds the criterion recommended to prompt an urgent review of the risk assessment. PHE has provided advice that "While the retrieval of one particle cannot in itself be regarded as a substantial public health issue, this find should now lead to a reassessment of monitoring capabilities for particles with [a] high content of strontium-90, along with any other measures that may be considered appropriate, to support a reappraisal of the potential health risks." Work is ongoing to complete this reassessment of monitoring capability and regular updates of this reassessment work are provided to COMARE and the West Cumbria Site Stakeholder Group.

In relation to food safety, and following a previous assessment of the particles frequency and the activity concentrations, FSA'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

(SEPA, 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, FSA, NIEA and SEPA, 2010a).

Further detail on enhanced beach monitoring data compiled so far can be obtained from Sellafield Limited website:

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

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 2014 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 2014, 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 seaweed (Table 2.12) collected from sites in Cumbria were generally lower in comparison to those in 2013. At one specific location (Auchencairn, Scotland), known to have had fluctuating concentrations in previous years, activity concentrations in seaweed (*Fucus*) were also lower in 2014 compared with those in 2013. Variations in concentrations 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 1990's 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 has been previously monitored to determine the activity concentrations in a range of vegetables, and in grass and soil. Results are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014).

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2014; this pathway has therefore remained dormant. Samples of *Porphyra* were regularly collected from selected locations along UK shorelines of the Irish Sea in previous years. Results from surveys providing activity concentrations in *Porphyra*, and in samples of the major manufacturers' laverbread (that were regularly collected from markets in South Wales), are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014).

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 (MAFF and SEPA, 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, FSA and SEPA, 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. In 2014, samples of milk and livestock were collected and analysed, for radionuclides which were released in liquid effluent discharges from Sellafield. Results from surveys for activity concentrations in crops, fruit and environmental indicators are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014).

The results of measurements in 2014 are given in Table 2.13. Generally, the activity concentrations, where positively detected, showed lower concentrations than were found in the immediate vicinity of Sellafield (Table 2.4). As in previous years, the evidence for sea to

land transfer was very limited in 2014. Technetium-99 and plutonium-238 concentrations are reported as less than values. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. In recent years, 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} (FSA, 2003). Previous reported results (published in previous 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 2014 are included in Table 2.14. 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. As in 2013 and 2012, there was no evidence of tritium 100m downstream of the outfall in 2014 (Table 2.14). These waters are not potable and any low concentrations observed previously are of no radiological significance. Table 2.14 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 2014 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 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 2014 are included in Table 2.4. The maximum caesium-137 concentration in the muscle of wood pigeon (0.27 Bq kg^{-1}) in 2014 was detected just above the less than value, but generally similar to the maximum value reported in 2013 (< 0.07 Bq kg^{-1}). These 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 FSA 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 2014 are shown in Table 2.15, and were generally similar to those in recent years. 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. 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-1980's and these activities are continuing. The reactor decommissioning of the Windscale Advanced Gas Cooled Reactor (AGR) 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 FSA 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, 2014

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 adult inhabitant (0–0.25km)**	**0.17**[c]	**–**	**<0.005**	**–**	**–**	**<0.005**	**0.17**
Source specific doses	Infant inhabitants and consumer of locally grown food	<0.005[c]	–	<0.005	–	–	<0.005	–
	Children playing at Rivacre Brook	0.010[c]	–	–	0.009	<0.005	–	–
Springfields								
***Total dose* – all sources**	**Adult occupant on a houseboat**	**0.050**	**–**	**–**	**0.050**	**–**	**–**	**–**
Source specific doses	Seafood consumer	0.021[c]	<0.005	–	0.020	–	–	–
	Houseboat occupants	0.056	–	–	0.056	–	–	–
	Children playing at Lower Penwortham	<0.005[c]	–	–	<0.005	<0.005	–	–
	External in intertidal areas (farmers)	0.036	–	–	0.036	–	–	–
	Wildfowl consumer	0.006[c]	–	<0.005	0.006	–	–	–
	Inhabitant and consumer of locally grown food	<0.005[c]	–	<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
The representative person is an adult unless otherwise stated

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

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

Table 2.2(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2014

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										
Plaice	Liverpool Bay	1			0.44					
Shrimps	Wirral	1		0.27	0.79					
Mussels	Liverpool Bay	1			1.4	2.6				
Cockles	Dee Estuary	1		0.68	1.2	8.6				
Sediment	Rivacre Brook	2[E]		120	2.0	<36	93	3.6	45	<2.0
Sediment	Rivacre Brook (1.5 km downstream)	2[E]		51	2.2	<12	29	<1.5	20	<1.0
Sediment	Rossmore (3.1 km downstream)	2[E]		38	1.3	<14	18	<1.2	14	<1.0
Sediment	Rivacre Brook (4.3 km downstream)	2[E]		19	0.59	11	12.0	<1.3	8.6	<1.0
Freshwater	Rivacre Brook	2[E]	<4.8	<0.10			0.020	<0.0030	0.010	<0.040
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<3.1	<0.14			0.020	<0.0018	0.011	<0.040
Freshwater	Rossmore (3.1 km downstream)	2[E]	<3.2	<0.11			0.015	<0.0026	0.010	<0.040
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	<3.1	<0.079			0.015	<0.0015	0.010	<0.040

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									
Plaice	Liverpool Bay	1			<0.11				
Shrimps	Wirral	1	0.0010	0.0065	0.0097	*	*		
Mussels	Liverpool Bay	1			1.4				
Cockles	Dee Estuary	1	0.086	0.50	1.4	*	*		
Sediment	Rivacre Brook	2[E]						270	730
Sediment	Rivacre Brook (1.5 km downstream)	2[E]						<140	510
Sediment	Rossmore (3.1 km downstream)	2[E]						<180	430
Sediment	Rivacre Brook (4.3 km downstream)	2[E]						<110	290
Freshwater	Rivacre Brook	2[E]						<0.095	0.43
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]						<0.043	0.29
Freshwater	Rossmore (3.1 km downstream)	2[E]						<0.047	0.23
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]						<0.036	0.26

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		2	<2.1	<0.032	<0.00057	<0.00041	<0.00041
Milk	max		<2.2		<0.00076	<0.00044	<0.00044
Beetroot		1		<0.20	0.013	0.0015	0.010
Grass		1		<0.20	0.14	0.0049	0.14
Grass/herbage	North of Ledsham	1[E]		1.2	0.95	<0.086	1.1
Grass/herbage	South of Capenhurst	1[E]		1.2	<0.16	<0.12	<0.087
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<2.4	0.43	<0.16	0.34
Grass/herbage	East of station	1[E]		<0.27	0.34	<0.037	0.27
Soil	North of Ledsham	1[E]		3.4	21	0.92	22
Soil	South of Capenhurst	1[E]		7.0	18	<1.6	23
Soil	Off lane from Capenhurst to Dunkirk	1[E]		<12	22	<1.7	23
Soil	East of station	1[E]		<2.3	20	<1.3	22

* *Not detected by the method used*

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

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

[c] *In distillate fraction of sample*

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

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

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2014

Location	Ground type	No. of sampling observa-tions	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Grass and mud	2	0.092
Rivacre Brook 1.5 km downstream	Grass	2	0.082
Rossmore Road West 3.1 km downstream	Grass	1	0.079
Rossmore Road West 3.1 km downstream	Grass and vegetation	1	0.081
Rivacre Brook 4.3 km downstream	Grass	1	0.078
Rivacre Brook 4.3 km downstream	Grass and vegetation	1	0.079

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2014

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th
Marine samples												
Flounder	Ribble Estuary	1			<0.08				3.2			
Bass	Ribble Estuary	1			<0.09				3.4			
Shrimps[d]	Ribble Estuary	1		40	<0.06		<0.72		1.3	0.078	<0.00013	<0.00013
Mussels[d]	Ribble Estuary	1			<0.06				1.4	0.19	0.25	0.12
Wildfowl	Ribble Estuary	1	<4.7	33	<0.08	<0.043		<0.27	0.89		0.0042	0.0022
Samphire	Marshside Sands	1			<0.04		<0.31		0.37			
Sediment	River Ribble outfall	4[E]			<0.60				98	26	47	25
Sediment	Savick Brook	2[E]			<1.0				160	30	58	31
Sediment	Lea Gate	2[E]			<1.0				160	37	76	34
Sediment	Lower Penwortham Park	4[E]			<0.64				170	33	78	34
Sediment	Penwortham rail bridge	4[E]			<0.94				160	36	82	32
Sediment	Penwortham rail bridge - West bank	2[E]			<0.46				120	35	72	26
Sediment	Penwortham position 1	4[E]			<1.3				130	35	65	32
Sediment	Penwortham position 2	1[E]			<0.43				57	22	41	17
Sediment	Lytham Yacht Club	1[E]			<0.71				230	39	81	39
Sediment	Becconsall	4[E]			<0.52				110	28	54	28
Sediment	Freckleton	1[E]			<0.90				220	41	83	39
Sediment	Hutton Marsh	1[E]			<1.2				300	44	120	40
Sediment	Longton Marsh	1[E]			<0.55				450	57	300	52
Grass (washed)	Hutton Marsh	1[E]					1.9					
Grass (unwashed)	Hutton Marsh	1[E]					2.0					
Soil	Hutton Marsh	1[E]					40					

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples												
Flounder	Ribble Estuary	1								<0.20		
Bass	Ribble Estuary	1								<0.21		
Shrimps[d]	Ribble Estuary	1					0.00018	0.0019	0.013	0.022		
Mussels[d]	Ribble Estuary	1						0.096	0.54	1.1		
Wildfowl	Ribble Estuary	1						0.0013	0.0079	0.013		
Samphire	Marshside Sands	1								0.15		
Sediment	River Ribble outfall	4[E]	350	17	<1.1	18				88	420	970
Sediment	Savick Brook	2[E]	630	27	1.3	25				140	480	1800
Sediment	Lea Gate	2[E]	1800	31	<1.8	31				130	470	2900
Sediment	Lower Penwortham Park	4[E]	1600	26	<1.6	26				150	530	2300
Sediment	Penwortham rail bridge	4[E]	2400	27	<2.0	28				140	<480	3000
Sediment	Penwortham rail bridge - West bank	2[E]	1400	23	<1.1	23				110	480	1500
Sediment	Penwortham position 1	4[E]	930	25	<1.6	25				110	<420	1400
Sediment	Penwortham position 2	1[E]	590	17	<0.92	16				47	290	900
Sediment	Lytham Yacht Club	1[E]	170	26	1.4	27				190	690	1200
Sediment	Becconsall	4[E]	470	20	<1.3	20				99	450	1200
Sediment	Freckleton	1[E]	360	29	<1.8	27				190	500	1400
Sediment	Hutton Marsh	1[E]	<20	25	0.86	27				190	560	1400
Sediment	Longton Marsh	1[E]	49	31	1.4	32				290	880	1400

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{90}Sr	^{129}I	^{137}Cs	Total Cs
Terrestrial samples								
Beetroot		1	<2.0	12	0.044	<0.023	<0.05	0.043
Sediment	Deepdale Brook	2[E]					1.4	
Grass		1	<2.1	32	0.56	<0.016	0.28	
Freshwater[e]	Ulnes Walton	1[E]	<3.1				<0.26	

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		2				<0.00056	<0.00056	<0.00056
Milk	max				<0.00061	<0.00061	<0.00061	
Beetroot		1	0.00069	0.00049		0.0013	0.00021	0.0010
Sediment	Deepdale Brook	2[E]			81	61	2.6	55
Grass		1	0.011	0.0091		0.097	0.0032	0.073
Grass	Site fence	1[E]				<0.24	<0.066	<0.14
Grass	Opposite site entrance	1[E]				0.66	<0.080	0.65
Grass	Opposite windmill	1[E]				<0.15	<0.080	<0.26
Grass	Deepdale Brook	1[E]				<0.20	<0.093	<0.13
Grass	Lea Town	1[E]				<0.21	<0.17	<0.18
Grass	N of Lea Town	1[E]				<0.28	<0.26	<0.39
Soil	Site fence	1[E]				64	3.2	59
Soil	Opposite site entrance	1[E]				96	4.7	86
Soil	Opposite windmill	1[E]				110	4.7	110
Soil	Deepdale Brook	1[E]				83	3.7	77
Soil	Lea Town	1[E]				93	4.1	75
Soil	N of Lea Town	1[E]				29	<1.9	29
Freshwater	Deepdale Brook	4[E]				0.31	0.013	0.30
Freshwater[e]	Ulnes Walton	1[E]	<0.0069	<0.0034		0.067	<0.0032	0.061

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								
Beetroot		1	<0.000030	0.000090	<0.22	0.00011		
Sediment	Deepdale Brook	2[E]					290	450
Grass		1	0.00077	0.0067	<0.17	0.011		
Freshwater	Deepdale Brook	4[E]					0.45	0.71
Freshwater[e]	Ulnes Walton	1[E]					0.35	0.39

* *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*

[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] *^{242}Cm and $^{243+244}$Cm were not detected by the method used*

[e] *The concentration of ^{228}Th was <0.0010 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*

Table 2.3(b). Monitoring of radiation dose rates near Springfields, 2014

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	0.099
Warton Mud Marsh	Salt marsh	2	0.11
Warton Mud Marsh	Salt marsh[a]	2	0.12
Warton Salt Marsh	Salt marsh	2	0.10
Freckleton	Grass	1	0.089
Naze Point	Salt marsh	1	0.11
Naze Point	Grass	1	0.10
Banks Marsh	Salt marsh	1	0.12
Banks Marsh	Grass and salt marsh	1	0.12
Banks Marsh	Salt marsh[a]	1	0.12
Banks Marsh	Grass and salt marsh[a]	1	0.11
Hesketh Bank	Grass	2	0.10
Becconsall Boatyard	Grass and mud	3	0.088
Becconsall Boatyard	Mud and salt marsh	1	0.083
Becconsall Boatyard (beneath houseboat)	Mud	2	0.081
Becconsall (vicinity of houseboats)	Asphalt	2	0.079
Longton Marsh	Grass and salt marsh	1	0.11
Hutton Marsh	Grass	1	0.13
River Ribble outfall	Mud	4	0.092
Savick Brook, confluence with Ribble	Grass	2	0.087
Savick Brook, tidal limit	Salt marsh	1	0.095
Savick Brook, tidal limit	Grass and salt marsh	1	0.093
Savick Brook, Lea Gate	Grass	2	0.098
South bank opposite outfall	Grass	1	0.11
Penwortham Bridge cadet hut	Mud	1	0.088
Penwortham Bridge cadet hut	Mud and stones	1	0.085
Lower Penwortham Park	Grass	4	0.081
Lower Penwortham Railway Bridge	Grass	1	0.079
Lower Penwortham Railway Bridge	Mud	1	0.086
Lower Penwortham Railway Bridge	Mud and stones	2	0.095
River Darwen	Grass	4	0.085
Riverbank Angler location 1	Grass	4	0.080
Riverbank Angler location 2	Mud	1	0.082
Ulnes Walton, BNFL area survey	Grass	3	0.090
Mean beta dose rates			µSv h^{-1}
Lytham – Granny's Bay	Sand	1	0.052
Banks Marsh	Salt marsh	1	0.041
Banks Marsh	Grass and salt marsh	1	0.16
Warton Mud Marsh	Salt marsh	2	0.14
Warton Salt Marsh	Salt marsh	2	0.051

[a] *15cm above substrate*

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2014

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		9	<2.8	<2.9	15	<0.05	0.040	<0.038	<0.46	<0.13	<0.0073	<0.0026
Milk	max		<3.7	<4.1	17	<0.06	0.065	<0.044	<0.54	<0.15	0.019	<0.0031
Barley		1	<2.0	<2.0	89	<0.07	0.23		<0.63	<0.16	<0.046	
Beef kidney		1	<2.0	<2.0	30	<0.06	0.055	<0.11	<0.52	<0.15	<0.077	
Beef liver		1	<4.9	<4.9	36	<0.03	<0.040	<0.13	<0.23	<0.17	<0.027	
Beef muscle		1	<4.4	<4.4	35	<0.07	0.031	<0.12	<0.44	<0.18	<0.034	
Beetroot		1	<2.2	<2.2	13	<0.06	0.21	<0.21	<0.65	<0.14	<0.023	
Blackberries		1	<2.5	<2.5	23	<0.04	0.93	<0.20	<0.31	<0.09	<0.023	
Cabbage		1	<2.1	<2.1	6.7	<0.03	0.15		<0.68	<0.20	<0.029	
Duck		1	<2.0	<2.0	35	<0.07	<0.048	<0.21	<0.58	<0.13	<0.057	
Eggs		1	<2.1	<2.1	31	<0.05	<0.047		<0.54	<0.08	<0.040	
Honey		1	<2.0	<2.0	78	<0.02	<0.036		<0.31	<0.08	<0.019	
Mushrooms		1	<2.0	<2.0	21	<0.06	<0.032		<0.19	<0.11	<0.026	
Onions		1	<4.2	<4.2	14	<0.06	0.20		<0.29	<0.10	<0.040	
Potatoes		1	<3.7	<3.7	14	<0.05	<0.044		<0.32	<0.17	<0.019	
Rabbit		1	<2.4	<2.4	32	<0.03	0.034	<0.20	<0.30	<0.13	<0.031	
Sheep muscle		2	<4.3	<4.3	36	<0.05	<0.041	<0.11	<0.55	<0.15	<0.061	
Sheep muscle	max		<5.7	<5.7	42	<0.07	<0.044		<0.59	<0.17	0.11	
Sheep offal		2	<2.8	<2.8	35	<0.03	<0.041	<0.12	<0.52	<0.15	<0.068	
Sheep offal	max		<3.6	<3.6	41		<0.047	<0.13	<0.71	<0.22	0.093	
Wood pigeon muscle		2	<2.9	<2.9	36	<0.07	<0.053		<0.63	<0.12	<0.020	
Wood pigeon muscle	max		<3.1	<3.1	37	<0.08	<0.066		<0.72	<0.14	<0.022	
Soil[d]		1	<2.0	<2.0	12	<0.13	5.6	<3.0	<0.97	<0.31	<0.021	

Material	Selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{137}Cs	Total Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk		9	<0.11					<0.000031	<0.000031	<0.17	<0.000063
Milk	max		0.20					<0.000042	<0.000034	<0.20	<0.00011
Barley		1	<0.08	0.15				<0.00012	0.0013	<0.43	0.0025
Beef kidney		1	0.16		0.0024	<0.0014	0.0034	<0.00043	0.00018	<0.32	0.0013
Beef liver		1	0.17					0.00038	0.0017	<0.26	0.0022
Beef muscle		1	0.34					<0.000082	<0.00014	<0.26	<0.00044
Beetroot		1	0.12								<0.13
Blackberries		1	0.10					<0.00013	0.00056	<0.24	0.0011
Cabbage		1	<0.08	<0.040				0.000031	0.00013	<0.22	0.00027
Duck		1	<0.09					<0.00046	<0.00016	<0.34	0.000053
Eggs		1	<0.04					<0.000062	0.00011	<0.28	0.00016
Honey		1	<0.05	0.065				<0.00022	<0.00016	<0.26	0.000095
Mushrooms		1	0.31					0.0087	0.053	<0.25	0.099
Onions		1	0.07		0.00091	<0.00041	<0.00041				<0.06
Potatoes		1	0.77		0.0047	<0.00040	0.0052	<0.00017	0.00048	<0.29	0.00070
Rabbit		1	0.77					<0.00013	0.00034	<0.32	0.00033
Sheep muscle		2	1.5					<0.00035	<0.00027	<0.26	0.00011
Sheep muscle	max		1.9					<0.00049	<0.00038		0.00016
Sheep offal		2	0.59		0.0013	<0.00069	0.0017	0.00013	0.0016	<0.37	0.0011
Sheep offal	max		0.80		0.0016	<0.00081		0.00017	0.0017	<0.49	0.0013
Wood pigeon muscle		2	<0.17					<0.000090	<0.00010	<0.34	0.00011
Wood pigeon muscle	max		0.27					<0.00013	<0.00015	<0.46	0.0015
Soil[d]		1	47					0.52	13		4.7

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

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

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

[d] *The concentration of ^{226}Ra was 32 Bq kg^{-1}*

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2014

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										
Parton	Cod	2			64	<0.11	0.020	<0.21	<0.24	<0.57
Whitehaven	Cod	2			53	<0.07	0.013	<0.12	<0.15	<0.59
Whitehaven	Plaice[a]	2	25	28	71	<0.08	0.026	<0.13	<0.17	0.87
Ravenglass	Plaice[b]	2	64	49	98	<0.13	0.020	<0.35	<0.35	1.4
Ravenglass	Flounder	1			46					
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Flounder	2	<29	39	53	<0.09	0.028	<0.18	<0.20	<0.38
Ribble Estuary	Flounder	1				<0.08		<0.24	<0.24	
Ribble Estuary	Bass	1				<0.09		<0.19	<0.21	
Liverpool Bay	Plaice	1		<25		<0.04		<0.08	<0.10	
Scotland										
Shetland	Fish meal (salmon)	2[S]				<0.11		<0.27	<0.29	
Shetland	Fish oil (salmon)	2[S]				<0.10		<0.16	<0.21	
West of Scotland	Salmon	1[S]				<0.10			<1.1	
West of Scotland	Mackerel	1[S]				<0.10			<0.97	
Kirkcudbright	Plaice	2[S]				<0.11		<1.9	<1.7	1.3
Inner Solway	Flounder	2[S]			50	<0.12	<0.10	<0.46	<1.3	<0.15
Inner Solway	Salmon	1[S]		<5.0		<0.10			<0.47	
Inner Solway	Sea trout	1[S]		<5.0		<0.10		<3.1	<0.89	
Wales										
North Anglesey	Plaice	1	<25	<25	41	<0.06		<0.11	<0.14	
Northern Ireland										
North coast	Lesser spotted dogfish	4[N]				<0.12		<0.55	<0.42	
Ardglass	Herring	2[N]				<0.10		<0.63	<0.71	
Kilkeel	Cod	4[N]			34	<0.06		<0.15	<0.16	
Kilkeel	Plaice	4[N]				<0.05		<0.26	<0.19	
Kilkeel	Skates / rays	4[N]				<0.07		<0.34	<0.25	
Kilkeel	Haddock	4[N]				<0.06		<0.15	<0.16	
Further afield										
Norwegian Sea	Saithe	1				<0.09		<0.43	<0.33	

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									
Parton	Cod	2	<0.86	<0.25	<0.10	3.5	<0.46	<0.24	150
Whitehaven	Cod	2	<0.60	<0.17	<0.07	3.5	<0.35	<0.17	180
Whitehaven	Plaice[a]	2	<0.73	<0.19	<0.08	<1.8	<0.39	<0.19	130
Ravenglass	Plaice[b]	2	<0.99	<0.29	<0.13	2.2	<0.50	<0.22	160
Ravenglass	Flounder	1							
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Flounder	2	<0.79	<0.23	<0.08	5.4	<0.44	<0.22	
Ribble Estuary	Flounder	1	<0.67	<0.20	<0.08	3.2	<0.45	<0.20	
Ribble Estuary	Bass	1	<0.79	<0.24	<0.09	3.4	<0.49	<0.23	
Liverpool Bay	Plaice	1	<0.42	<0.11	<0.05	0.44	<0.23	<0.12	
Scotland									
Shetland	Fish meal (salmon)	2^{S}	<0.96	<0.28	<0.11	<0.17	<0.59	<0.28	
Shetland	Fish oil (salmon)	2^{S}	<0.82	<0.17	<0.10	<0.10	<0.52	<0.24	
West of Scotland	Salmon	1^{S}	<1.1	<0.26	<0.10	<0.10	<0.66	<0.21	
West of Scotland	Mackerel	1^{S}	<0.93	<0.23	<0.10	0.37	<0.70	<0.22	
Kirkcudbright	Plaice	2^{S}	<1.2	<0.29	<0.12	<0.11	<0.78	<0.24	
Inner Solway	Flounder	2^{S}	<0.97	<0.26	<0.12	9.4	<0.65	<0.21	
Inner Solway	Salmon	1^{S}	<0.48	<0.12	<0.10	0.30	<0.31	<0.11	
Inner Solway	Sea trout	1^{S}	<0.75	<0.18	<0.10	1.6	<0.56	<0.18	
Wales									
North Anglesey	Plaice	1	<0.60	<0.15	<0.06	0.68	<0.37	<0.17	
Northern Ireland									
North coast	Lesser spotted dogfish	4^{N}	<0.98	<0.25	<0.12	1.0	<0.49	<0.20	
Ardglass	Herring	2^{N}	<0.92	<0.25	<0.10	0.29	<0.62	<0.23	
Kilkeel	Cod	4^{N}	<0.46	<0.12	<0.06	0.92	<0.22	<0.10	
Kilkeel	Plaice	4^{N}	<0.47	<0.12	<0.05	0.26	<0.26	<0.11	
Kilkeel	Skates / rays	4^{N}	<0.61	<0.17	<0.07	0.72	<0.41	<0.18	
Kilkeel	Haddock	4^{N}	<0.51	<0.14	<0.06	0.34	<0.28	<0.14	
Further afield									
Norwegian Sea	Saithe	1	<0.78	<0.21	<0.09	0.23	<0.48	<0.22	

* *Not detected by the method used*

[a] *The concentrations of ^{129}I and ^{147}Pm were <0.27 and <0.022 Bq kg^{-1} respectively*

[b] *The concentrations of ^{129}I and ^{147}Pm were <0.25 and <0.026 Bq kg^{-1} respectively*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment 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											
Parton	Crabs	2			120	<0.12	0.057	<0.22	<0.26	1.8	<0.92
Parton	Lobsters	2			90	<0.10	0.025	<0.25	<0.26	28	<0.88
Parton	Winkles	2			69	0.61	1.3	<0.15	<0.21	34	<1.8
Whitehaven	*Nephrops*[a]	2	<25	<25	68	<0.08	0.038	<0.21	<0.23	15	<0.72
Whitehaven outer harbour	Mussels	2			67	0.31	0.38	<0.40	<0.26	14	<1.2
Nethertown	Winkles[b]	4	<25	<25	110	1.0	1.7	<0.38	<0.34	20	<4.5
Sellafield coastal area	Crabs[c]	2	42	59	140	0.30	0.15	<0.26	<0.26	3.2	<0.85
Sellafield coastal area	Lobsters	2	59	58	140	<0.19	0.046	<0.21	<0.22	96	<0.75
Ravenglass	Mussels	2			100	<0.71	0.28	<0.12	<0.15	49	<2.3
Seascale Area	Common prawns	2	<25	<25	99	<0.18	0.021	<1.4	<0.85	0.25	<1.6
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2	<43	<39	55	<0.08	<0.030	<0.21	<0.21	<0.75	<0.69
Morecambe Bay (Morecambe)	Mussels	2	34	59	50	<0.09	0.28	<0.19	<0.20	31	<0.65
Morecambe Bay (Middleton Sands)	Winkles	2	130	130	47	<0.09	0.17	<0.24	<0.24	8.1	<0.76
Ribble Estuary	Shrimps	1			40	<0.06		<0.15	<0.15	<0.72	<0.45
Ribble Estuary	Mussels	1				<0.06		<0.11	<0.14		<0.52
Liverpool Bay	Mussels	1		<25		<0.16		<0.26	<0.32		<1.5
Dee Estuary	Cockles	1		<25		<0.07		<0.13	<0.17	0.68	<0.52
Wirral	Shrimps	1		<25		<0.05		<0.08	<0.10	0.27	<0.40
Scotland											
Kinlochbervie	Crabs	2[S]				<0.10		<0.21	<0.16	0.19	<0.36
Lewis	Mussels	1[S]				<0.10		<0.43	<0.33		<0.70
Skye	Lobsters	1[S]				<0.10		<0.21	<0.23	4.1	<0.78
Skye	Mussels	1[S]				<0.10		<0.51	<0.34		<0.69
Islay	Crabs	1[S]				<0.10		<0.80	<0.46		<0.80
Islay	Scallops	1[S]				<0.10		<0.34	<0.22		<0.39
Kirkcudbright	Scallops	2[S]				<0.10		<0.32	<0.25	0.94	<0.59
Kirkcudbright	Queens	2[S]				<0.10		<0.18	<0.15	7.8	<0.41
Kirkcudbright	Crabs	2[S]			62	<0.10	<0.10	<0.15	<0.16	1.2	<0.58
Kirkcudbright	Lobsters	2[S]			94	<0.10	<0.10	<0.24	<0.19	46	<0.78
Kirkcudbright	Limpets	2[S]				<0.10		<0.65	<0.53		<1.3
Kirkcudbright	Winkles	2[S]				<0.13	0.34	<0.38	<0.28	29	<0.62
Cutters Pool	Winkles	1[S]				<0.10		<1.0	<0.69		<1.4
Southerness	Winkles	2[S]		<5.0		<0.10	<0.10	<0.51	<0.38	15	<0.81
North Solway coast	Cockles	1[S]		<5.0		<0.10		<0.16	<0.14		<0.37
North Solway coast	Mussels	2[S]		<5.0	49	<0.12	0.24	<0.40	<0.30	7.1	<0.59
Inner Solway	Shrimps	2[S]		<5.0		<0.10	0.10	<0.54	<0.80	0.47	<0.92
Wales											
North Anglesey	Crabs	1	<25	<25	50	<0.05		<0.10	<0.12		<0.41
North Anglesey	Lobsters	1	<25	<25	63	<0.08		<0.17	<0.19	24	<0.69
Northern Ireland											
Ballycastle	Lobsters	2[N]				<0.05		<0.26	<0.18	5.5	<0.41
County Down	Scallops	2[N]				<0.07		<0.13	<0.15		<0.56
Kilkeel	Crabs	4[N]				<0.07		<0.38	<0.27		<0.61
Kilkeel	Lobsters	4[N]				<0.06		<0.39	<0.27	11	<0.55
Kilkeel	Nephrops	4[N]				<0.07		<0.55	<0.36	1.5	<0.70
Minerstown	Winkles	4[N]				<0.08		<0.32	<0.27		<0.70
Carlingford Lough	Mussels	2[N]				<0.10		<0.37	<0.32	3.4	<0.87
Further afield											
Cromer	Crabs	2				<0.06		<0.07	<0.11		<0.50
Southern North Sea	Mussels	2				<0.04		<0.37	<0.33		<0.42

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										
Parton	Crabs	2	<0.16	<0.26	<0.10	0.78	<0.54		<0.25	110
Parton	Lobsters	2	<0.15	<0.24	<0.10	1.0	<0.50		<0.23	190
Parton	Winkles	2	<0.15	<0.25	<0.10	4.6	<0.41		<0.19	84
Whitehaven	*Nephrops*[a]	2	<0.13	<0.20	<0.09	2.4	<0.41	0.057	<0.21	110
Whitehaven outer harbour	Mussels	2	<0.10	<0.20	<0.07	1.4	<0.40		<0.18	110
Nethertown	Winkles[b]	4	<0.19	<0.32	<0.12	3.9	<0.52	1.0	<0.25	140
Sellafield coastal area	Crabs[c]	2	<0.13	<0.24	<0.09	0.80	<0.52	0.14	<0.23	130
Sellafield coastal area	Lobsters	2	<0.13	<0.20	<0.09	1.0	<0.34		<0.15	120
Ravenglass	Mussels	2	<0.10	0.49	<0.07	1.5	<0.35		<0.16	120
Seascale Area	Common prawns	2	<0.28	<0.43	<0.19	1.5	<0.83		<0.32	94
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Shrimps	2	<0.11	<0.23	<0.08	4.6	<0.46		<0.22	
Morecambe Bay (Morecambe)	Mussels	2	<0.10	<0.20	<0.09	2.5	<0.39		<0.18	120
Morecambe Bay (Middleton Sands)	Winkles	2	<0.11	<0.24	<0.09	3.2	<0.53		<0.24	110
Ribble Estuary	Shrimps	1	<0.07	<0.12	<0.05	1.3	<0.22		<0.10	
Ribble Estuary	Mussels	1	<0.08	<0.16	<0.06	1.4	<0.29		<0.14	
Liverpool Bay	Mussels	1	<0.25	<0.34	<0.16	1.4	<0.48		<0.22	
Dee Estuary	Cockles	1	<0.08	<0.17	<0.07	1.2	<0.31		<0.16	
Wirral	Shrimps	1	<0.07	<0.12	<0.05	0.79	<0.18		<0.08	
Scotland										
Kinlochbervie	Crabs	2[S]	<0.10	<0.11	<0.10	<0.10	<0.20		<0.10	
Lewis	Mussels	1[S]	<0.10	<0.19	<0.10	<0.10	<0.40		<0.16	
Skye	Lobsters	1[S]	<0.10	<0.22	<0.10	0.13	<0.47		<0.21	
Skye	Mussels	1[S]	<0.10	<0.18	<0.10	<0.10	<0.46		<0.17	
Islay	Crabs	1[S]	<0.10	<0.21	<0.10	0.15	<0.56		<0.19	
Islay	Scallops	1[S]	<0.10	<0.11	<0.10	<0.10	<0.27		<0.12	
Kirkcudbright	Scallops	2[S]	<0.10	<0.17	<0.10	<0.13	<0.36		<0.15	
Kirkcudbright	Queens	2[S]	<0.10	<0.12	<0.10	<0.10	<0.25		<0.11	
Kirkcudbright	Crabs	2[S]	<0.10	<0.18	<0.10	0.58	<0.35		<0.18	
Kirkcudbright	Lobsters	2[S]	<0.11	<0.23	<0.10	1.0	<0.46		<0.21	
Kirkcudbright	Limpets	2[S]	<0.26	<0.39	<0.16	2.0	<0.73		<0.28	
Kirkcudbright	Winkles	2[S]	<0.13	<0.18	<0.10	1.3	<0.41		<0.17	
Cutters Pool	Winkles	1[S]	<0.28	<0.40	<0.16	2.8	<0.83		<0.32	
Southerness	Winkles	2[S]	<0.12	<0.23	<0.10	0.68	<0.51		<0.21	
North Solway coast	Cockles	1[S]	<0.10	<0.11	<0.10	0.46	<0.23		<0.10	
North Solway coast	Mussels	2[S]	<0.12	<0.20	<0.10	1.8	<0.44		<0.18	
Inner Solway	Shrimps	2[S]	<0.17	<0.25	<0.10	3.6	<0.62		<0.21	
Wales										
North Anglesey	Crabs	1	<0.09	<0.10	<0.05	0.28	<0.14		<0.07	
North Anglesey	Lobsters	1	<0.15	<0.17	<0.08	0.41	<0.28		<0.13	110
Northern Ireland										
Ballycastle	Lobsters	2[N]	<0.07	<0.11	<0.05	0.07	<0.22		<0.09	
County Down	Scallops	2[N]	<0.12	<0.14	<0.07	0.20	<0.23		<0.11	
Kilkeel	Crabs	4[N]	<0.11	<0.16	<0.07	<0.09	<0.35		<0.15	
Kilkeel	Lobsters	4[N]	<0.09	<0.14	<0.06	0.14	<0.29		<0.12	
Kilkeel	Nephrops	4[N]	<0.13	<0.19	<0.08	0.37	<0.43		<0.17	
Minerstown	Winkles	4[N]	<0.12	<0.19	<0.09	<0.14	<0.34		<0.16	
Carlingford Lough	Mussels	2[N]	<0.15	<0.23	<0.10	0.26	<0.43		<0.19	
Further afield										
Cromer	Crabs	2	<0.08	<0.15	<0.06	<0.07	<0.29		<0.14	
Southern North Sea	Mussels	2	<0.07	<0.11	<0.05	<0.04	<0.29		<0.12	

[a] *The concentration of ^{129}I was <0.24 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <0.45 Bq kg^{-1}*
[c] *The concentration of ^{129}I was <0.29 Bq kg^{-1}*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 2.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2014

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									
Parton	Cod	2		0.00055	0.0034	<0.13	<0.0070	*	0.000035
Parton	Crabs	2		0.042	0.22	1.5	0.98	*	*
Parton	Lobsters	2		0.028	0.16	0.97	1.1	*	*
Parton	Winkles	2		1.2	7.4	41	15	*	0.026
Whitehaven	Cod	2		0.0013	0.0070	<0.15	0.014	*	0.000029
Whitehaven	Plaice	2	0.00010	0.0017	0.0099	<0.23	0.020	0.00011	0.000033
Whitehaven	Nephrops	2	0.0011	0.049	0.32	1.8	1.5	*	*
Whitehaven outer harbour	Mussels	2		0.49	3.0	18	6.7	*	0.014
Nethertown	Winkles	4	0.016	1.5	7.7	47	16	0.045	0.030
Sellafield coastal area	Crabs	2	0.0019	0.065	0.31	2.6	1.6	*	0.0045
Sellafield coastal area	Lobsters	2		0.060	0.28	2.1	5.3	*	*
Ravenglass	Flounder	1		0.00028	0.0013	<0.19	0.0031	*	*
Ravenglass	Plaice	1	0.00011	0.0017	0.0093	<0.21	0.017	*	*
Ravenglass	Mussels	2		1.0	5.2	34	13	*	0.029
Seascale	Prawns	2		0.0022	0.013	0.57	0.035	*	0.000065
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Flounder	2		0.00081	0.0039		0.0074	*	0.000026
Morecambe Bay (Morecambe)	Shrimps	2		0.0057	0.036		0.050	*	0.000057
Morecambe Bay (Morecambe)	Mussels	2		0.33	1.9	11	3.7	*	0.011
Morecambe Bay (Middleton Sands)	Winkles	2		0.28	1.6	8.9	3.2	*	*
Ribble Estuary	Flounder	1					<0.20		
Ribble Estuary	Bass	1					<0.21		
Ribble Estuary	Shrimps	1	0.00018	0.0019	0.013		0.022	*	*
Ribble Estuary	Mussels	1		0.096	0.54		1.1	*	*
Liverpool Bay	Mussels	1					1.4		
Liverpool Bay	Plaice	1					<0.11		
Dee Estuary	Cockles	1		0.086	0.50		1.4	*	*
Wirral	Shrimps	1		0.0010	0.0065		0.010	*	*
Scotland									
Shetland	Fish meal (salmon)	2[S]		<0.0082	0.037		0.016		
Shetland	Fish oil (salmon)	2[S]		<0.0027	<0.0072		0.024		
West of Scotland	Salmon	1[S]		<0.0054	<0.0054		0.022		
West of Scotland	Mackerel	1[S]		<0.0054	<0.0054		0.012		
Kinlochbervie	Crabs	1[S]		0.0038	0.016		<0.0028		
Lewis	Mussels	1[S]					<0.10		
Skye	Lobsters	1[S]					<0.13		
Skye	Mussels	1[S]					<0.10		
Islay	Crabs	1[S]					<0.12		
Islay	Scallops	1[S]					<0.10		
Kirkcudbright	Plaice	1[S]		<0.00060	<0.00060		0.0013		
Kirkcudbright	Scallops	1[S]		0.0087	0.060		0.023		
Kirkcudbright	Queens	1[S]		0.0060	0.032		0.062		
Kirkcudbright	Crabs	1[S]		0.16	0.83	3.1	3.7		
Kirkcudbright	Lobsters	1[S]		0.015	0.092	0.20	0.66		
Kirkcudbright	Winkles	1[S]		0.26	1.5		2.8		
Kirkcudbright	Limpets	2[S]					5.5		
Cutters Pool	Winkles	1[S]					7.6		
Southerness	Winkles	1[S]		0.18	1.4	5.1	3.5		
North Solway coast	Cockles	1[S]		0.080	0.29		2.7		
North Solway coast	Mussels	1[S]		0.28	2.0	<3.9	4.3		
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}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Wales									
North Anglesey	Plaice	1					<0.17		
North Anglesey	Crabs	1					0.07		
North Anglesey	Lobsters	1		0.0037	0.020	0.11	0.33	0.00018	0.00028
Northern Ireland									
North coast	Lesser spotted dogfish	4^{N}					<0.16		
Ballycastle	Lobsters	2^{N}					<0.10		
County Down	Scallops	2^{N}					<0.08		
Ardglass	Herring	2^{N}					<0.25		
Kilkeel	Cod	4^{N}					<0.09		
Kilkeel	Plaice	4^{N}					<0.09		
Kilkeel	Skates / rays	4^{N}					<0.18		
Kilkeel	Haddock	4^{N}					<0.14		
Kilkeel	Crabs	4^{N}					<0.17		
Kilkeel	Lobsters	4^{N}					<0.09		
Kilkeel	*Nephrops*	1^{N}		0.0030	0.019		0.049	*	*
Minerstown	Winkles	1^{N}		0.025	0.17		0.13	*	*
Carlingford Lough	Mussels	2^{N}					<0.15		
Further afield									
Norwegian Sea	Saithe	2					<0.24		
Cromer	Crabs	2					<0.12		
Southern North Sea	Mussels	1		0.0017	0.013		0.0060	*	*

* *Not detected by the method used*

^{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, 2014

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Cumbria											
Newton Arlosh	Sediment	4		<0.54		<1.5	<0.40	<4.1	<2.1	<0.58	160
Maryport Outer Harbour	Sediment	2		<0.65	<2.1	<0.88	<0.27	<2.5	<1.4	<0.34	48
Workington Harbour	Sediment	2		<0.33		<0.90	<0.35	<2.4	<1.3	<0.35	43
Harrington Harbour	Sediment	2		<0.38		<0.96	<0.34	<2.8	<1.4	<0.35	110
Whitehaven Outer Harbour	Sediment	4		<0.52	<2.6	<0.88	<0.29	<2.4	<1.3	<0.31	91
St Bees beach	Sediment	4		<0.80		<0.88	<0.23	<2.3	<1.2	<0.30	50
Sellafield beach, S of former pipeline	Sediment	2		<0.33		<0.71	<0.23	<2.1	<1.1	<0.27	53
River Calder – downstream	Sediment	2		<0.32		<0.79	<0.23	<2.2	<1.2	<0.30	79
River Calder – upstream	Sediment	2		<0.57		<1.3	<0.45	<3.3	<1.7	<0.50	38
Seascale beach	Sediment	4		<0.52		<0.97	<0.27	<2.4	<1.3	<0.34	33
Ravenglass – Carleton Marsh	Sediment	4		2.8		<1.6	<0.47	<11	<2.7	<0.63	370
River Mite Estuary (erosional)	Sediment	3		1.8	37	<0.97	<0.40	<5.1	<1.8	<0.42	220
Ravenglass – Raven Villa	Sediment	4		1.4		<1.4	<0.39	<5.4	<1.9	<0.48	94
Newbiggin (Eskmeals)	Sediment	4		4.7	52	<1.9	<0.54	<7.2	<2.8	<0.62	380
Haverigg	Sediment	2		<0.66		<0.88	<0.30	<2.6	<1.4	<0.36	47
Millom	Sediment	2		<1.1		<1.0	<0.36	<3.1	<1.6	<0.49	130
Low Shaw	Sediment	2		<0.49		<1.1	<0.30	<3.1	<1.6	<0.42	57
Walney Channel – N of discharge point	Sediment	2		<0.53		<1.3	<0.39	<3.5	<1.8	<0.46	76
Walney Channel – S of discharge point	Sediment	2		<0.51		<1.2	<0.38	<3.3	<1.6	<0.53	49
Sand Gate Marsh	Sediment	4		<0.43		<0.90	<0.32	<2.8	<1.5	<0.41	71
Kents Bank	Sediment	4		<0.47		<1.2	<0.38	<3.8	<2.0	<0.48	230
Lancashire											
Morecambe	Sediment	2		<0.28							13
Half Moon Bay	Sediment	2		<0.53							72
Red Nab Point	Sediment	2		<0.33							20
Potts Corner	Sediment	2		<0.34							15
Sunderland Point	Sediment	4		<0.45		<1.1	<0.42	<3.2	<1.7	<0.46	70
Conder Green	Sediment	4		<0.47		<1.1	<0.44	<3.2	<1.7	<0.47	62
Hambleton	Sediment	4		<0.50		<1.1	<0.42	<3.7	<1.9	<0.57	220
Skippool Creek	Sediment	4		<0.58		<1.3	<0.46	<4.2	<2.2	<0.60	210
Fleetwood	Sediment	4		<0.35		<0.78	<0.23	<2.1	<1.1	<0.34	10
Blackpool	Sediment	4		<0.28		<0.65	<0.18	<1.8	<0.89	<0.25	2.1
Crossens Marsh	Sediment	4		<1.4		<3.5	<1.1	<10	<5.2	<1.4	170
Ainsdale	Sediment	4		<0.28		<0.87	<0.20	<1.9	<0.93	<0.26	3.6
Rock Ferry	Sediment	4		<0.56		<1.4	<0.42	<3.9	<2.1	<0.56	62
New Brighton	Sediment	4		<0.28		<0.50	<0.19	<1.6	<0.89	<0.27	2.9
Scotland											
Campbeltown	Sediment	1[S]	<0.10	<0.10		<0.23	<0.25	<0.63	<0.20	<0.10	6.3
Garlieston	Sediment	1[S]	<0.10	<0.10		<0.24	<0.28	<0.63	<0.21	<0.10	22
Innerwell	Sediment	2[S]	<0.11	0.32		<1.4	<0.63	<1.4	<0.35	<0.17	62
Carsluith	Sediment	1[S]	<0.10	0.20		<0.20	<0.34	<0.74	<0.26	<0.11	34
Skyreburn	Sediment	2[S]	<0.10	<0.10		<0.36	<0.50	<0.75	<0.23	<0.10	17
Kirkcudbright	Sediment	2[S]	<0.10	0.31		<0.21	<0.27	<0.65	<0.15	<0.11	29
Balcary Bay	Sediment	1[S]	<0.10	0.31		<0.20	<0.37	<0.79	<0.27	<0.12	33
Palnackie Harbour	Sediment	2[S]	<0.11	0.36		<1.2	<0.78	<1.4	<0.43	<0.15	89
Gardenburn	Sediment	2[S]	<0.13	0.40		<2.3	<0.35	<1.7	<0.53	<0.17	160
Kippford Slipway	Sediment	2[S]	<0.11	0.94		<1.4	<0.84	<3.8	<0.43	<0.16	170
Kippford Merse	Sediment	1[S]	<0.13	0.40		<3.1		<2.5	<0.93	<0.19	560
Kirkconnell Merse	Sediment	1[S]	<0.10	0.16		<0.26	<0.53	<0.99	<0.37	<0.13	80
Southerness	Sediment	1[S]	0.23	<0.10		<0.24	<0.29	<0.61	<0.20	<0.10	11

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{144}Ce	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Cumbria											
Newton Arlosh	Sediment	4	<2.3	<1.3	<0.98				200	550	740
Maryport Outer Harbour	Sediment	2	<1.5	<0.94	<0.64	13	79	390	120	170	540
Workington Harbour	Sediment	2	<1.9	<0.81	<0.80				30	270	680
Harrington Harbour	Sediment	2	<2.0	<0.84	<0.85				60	340	740
Whitehaven Outer Harbour	Sediment	4	<1.7	<0.81	<0.73	14	81	440	130	230	570
St Bees beach	Sediment	4	<1.4	<0.81	<0.61				140	190	340
Sellafield beach, S of former pipeline	Sediment	2	<1.4	<0.74	<0.63				92	150	540
River Calder – downstream	Sediment	2	<1.7	<0.75	<0.70				82	<200	500
River Calder – upstream	Sediment	2	<2.0	<1.4	<2.2				<0.72	320	1300
Seascale beach	Sediment	4	<1.5	<0.93	<0.63				120	<200	450
Ravenglass – Carleton Marsh	Sediment	4	<3.4	3.3	<1.3				1200	1800	1300
River Mite Estuary (erosional)	Sediment	3	<2.3	2.1	<1.1	68	390	2200	760	1300	1100
Ravenglass – Raven Villa	Sediment	4	<2.0	<1.2	<0.87				360	670	760
Newbiggin (Eskmeals)	Sediment	4	<3.4	4.5	<1.5	130	720	4100	1600	2300	1100
Haverigg	Sediment	2	<1.6	<0.98	<0.67				180	350	530
Millom	Sediment	2	<2.1	<1.4	<0.92				360	790	790
Low Shaw	Sediment	2	<1.6	<1.2	<0.71				110	360	490
Walney Channel – N of discharge point	Sediment	2	<1.9	<1.3	<0.77				180	460	580
Walney Channel – S of discharge point	Sediment	2	<1.8	<1.2	<0.77				99	310	550
Sand Gate Marsh	Sediment	4	<1.6	<1.0	<0.73				52	<160	590
Kents Bank	Sediment	4	<2.5	<1.2	<2.3				130	480	850
Lancashire											
Morecambe	Sediment	2							12		
Half Moon Bay	Sediment	2				6.7	42		86		
Red Nab Point	Sediment	2							23		
Potts Corner	Sediment	2							13		
Sunderland Point	Sediment	4	<2.0	<1.1	<0.90				64	310	780
Conder Green	Sediment	4	<1.9	<1.2	<2.0				72	260	650
Hambleton	Sediment	4	<2.4	<1.2	<1.1				210	590	1000
Skippool Creek	Sediment	4	<2.5	<1.4	<1.1				210	500	1000
Fleetwood	Sediment	4	<1.2	<0.84	<0.54				17	<120	350
Blackpool	Sediment	4	<1.0	<0.65	<0.45				3.4	<130	<170
Crossens Marsh	Sediment	4	<4.3	<3.6	<1.9				150	470	1100
Ainsdale	Sediment	4	<1.2	<0.66	<0.47				2.9	<110	210
Rock Ferry	Sediment	4	<2.4	<1.3	<1.1				45	<220	760
New Brighton	Sediment	4	<1.0	<0.66	<0.47				3.0	<140	240
Scotland											
Campbeltown	Sediment	1[S]	<0.74	<0.17	<0.36				1.1		
Garlieston	Sediment	1[S]	<0.67	<0.16	<0.34	3.3	19		28		
Innerwell	Sediment	2[S]	<1.5	<0.18	1.2	9.3	56		100		
Carsluith	Sediment	1[S]	<0.72	0.41	0.81	14	8.0		180	220	1300
Skyreburn	Sediment	2[S]	<0.73	<0.17	0.70	2.5	16		23		
Kirkcudbright	Sediment	2[S]	<0.72	<0.15	1.8				68		
Balcary Bay	Sediment	1[S]	<0.75	0.46	0.49	11	67		110		
Palnackie Harbour	Sediment	2[S]	<1.6	<0.28	1.2	12	72		140		
Gardenburn	Sediment	2[S]	<1.6	<0.18	1.0	19	120		220		
Kippford Slipway	Sediment	2[S]	<1.9	0.88	1.1	22	130		260		
Kippford Merse	Sediment	1[S]	<2.7	1.5	0.96	34	200		380		
Kirkconnell Merse	Sediment	1[S]	<0.91	<0.12	0.80	6.9	44		82	170	1600
Southerness	Sediment	1[S]	<0.58	<0.14	0.82	2.2	14		25		

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{54}Mn	^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man											
Ramsey	Sediment	1		<0.32	<0.48	<0.22	<1.8	<0.99	<0.28	6.3	<1.3
Wales											
Rhyl	Sediment	2		<0.46	<1.0	<0.42	<3.0	<1.6	<0.44	48	<2.2
Llandudno	Sediment	2		<0.28	<0.43	<0.21	<1.6	<0.89	<0.26	2.3	<0.93
Caerhun	Sediment	2		<0.47	<1.0	<0.38	<2.9	<1.6	<0.44	33	<1.8
Llanfairfechan	Sediment	2		<0.41	<0.85	<0.28	<2.5	<1.4	<0.38	10	<1.3
Northern Ireland											
Carrichue	Mud	1^{N}	<0.22	<0.19	<0.59	<0.52	<1.7	<0.49	<0.26	2.70	<1.0
Carrichue	Mud and sand	1^{N}	<0.29	<0.23	<1.2	<2.0	<2.5	<0.71	<0.34	2.1	<2.1
Portrush	Sand	2^{N}		<0.22	<2.2	<0.89	<2.4	<0.65	<0.28	0.66	<2.1
Oldmill Bay	Mud	2^{N}	<0.45	<0.41	<2.0	<1.6	<3.4	<1.0	<0.51	18	<2.0
Ballymacormick	Mud	1^{N}	<0.29	<0.24	<0.71	<0.65	<2.3	<0.74	<0.32	11	<2.0
Ballymacormick	Mud and sand	1^{N}	<0.46	<0.39	<1.5	<1.5	<3.5	<1.0	<0.51	11	<2.0
Strangford Lough – Nicky's Point	Mud	2^{N}	<0.57	<0.50	<1.8	<2.2	<4.8	<1.5	<0.70	20	<3.2
Dundrum Bay	Mud	1^{N}	<0.48	<0.38	<1.3	<1.4	<3.9	<1.2	<0.59	23	<2.9
Dundrum Bay	Mud and sand	1^{N}	<0.55	<0.41	<2.1	<3.0	<3.9	<1.2	<0.62	4.2	<2.6
Carlingford Lough	Mud	2^{N}	<0.63	<0.56	<1.9	<1.9	<5.0	<1.5	<0.74	47	<3.0

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Isle of Man											
Ramsey	Sediment	1	<0.77	<0.58			1.5			<130	480
Wales											
Rhyl	Sediment	2	<1.1	<1.0			36			360	760
Llandudno	Sediment	2	<0.66	<0.45			1.7			<170	<190
Caerhun	Sediment	2	<1.1	<0.79			19			180	650
Llanfairfechan	Sediment	2	<1.0	<0.61			8.0			<160	310
Northern Ireland											
Carrichue	Mud	1^{N}	<0.65	<0.51	0.18	1.2	2.3	*	*		
Carrichue	Mud and sand	1^{N}	<0.70	<0.92			1.9				
Portrush	Sand	2^{N}	<0.66	<0.80			<2.2				
Oldmill Bay	Mud	2^{N}	<1.3	<0.96			<7.5				
Ballymacormick	Mud	1^{N}	<0.77	<0.97			12				
Ballymacormick	Mud and sand	1^{N}	<1.3	<0.94			8.7				
Strangford Lough – Nicky's Point	Mud	2^{N}	<1.7	<1.7			6.2				
Dundrum Bay	Mud	1^{N}	<1.3	<1.4			7.5				
Dundrum Bay	Mud and sand	1^{N}	<1.4	<1.1			2.4				
Carlingford Lough	Mud	2^{N}	<1.7	<1.4	1.9	13	9.8	*	*		

* *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, 2014

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Marsh	1	0.077
Rockcliffe Marsh	Grass	1	0.077
Burgh Marsh	Marsh	1	0.071
Burgh Marsh	Grass	1	0.077
Port Carlisle 1	Mud	3	0.084
Port Carlisle 1	Mud and sand	1	0.079
Port Carlisle 2	Grass	4	0.090
Greenend 1	Mud	2	0.082
Greenend 1	Mud and sand	1	0.085
Greenend 1	Sand	1	0.083
Greenend 2	Grass	4	0.087
Cardurnock Marsh	Marsh	1	0.072
Cardurnock Marsh	Grass	3	0.078
Newton Arlosh	Grass	4	0.093
Silloth harbour	Mud and pebbles	2	0.097
Silloth harbour	Sand and stones	2	0.10
Silloth silt pond	Grass	4	0.077
Allonby	Sand	4	0.082
Maryport harbour	Mud and sand	2	0.087
Workington harbour	Sand and shingle	1	0.11
Workington harbour	Sand and stones	1	0.11
Harrington harbour	Sand and stones	1	0.11
Harrington harbour	Pebbles and sand	1	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	4	0.091
St Bees	Sand	3	0.080
St Bees	Sand and shingle	1	0.078
Nethertown beach	Shingle	2	0.13
Braystones	Shingle	2	0.11
Sellafield dunes	Grass	2	0.11
North of former pipeline on foreshore	Sand	1	0.094
North of former pipeline on foreshore	Pebbles and sand	1	0.10
South of former pipeline on foreshore	Sand	1	0.088
South of former pipeline on foreshore	Pebbles and sand	1	0.096
River Calder downstream of site	Grass and sand	1	0.091
River Calder downstream of site	Grass	1	0.089
River Calder upstream of site	Stones	2	0.11
Seascale beach	Sand	1	0.078
Seascale beach	Sand and shingle	3	0.096
Seascale	Grass	4	0.082

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Grass and marsh	2	0.13
Ravenglass - Carleton Marsh	Grass	2	0.14
Ravenglass - River Mite estuary (erosional)	Salt marsh	2	0.14
Ravenglass - River Mite estuary (erosional)	Grass	1	0.14
Ravenglass - Raven Villa	Mud and salt marsh	1	0.14
Ravenglass - Raven Villa	Salt marsh	1	0.14
Ravenglass - Raven Villa	Grass and salt marsh	1	0.14
Ravenglass - Raven Villa	Pebbles and salt marsh	1	0.14
Ravenglass - boat area	Sand and shingle	1	0.11
Ravenglass - boat area	Pebbles and sand	2	0.10
Ravenglass - boat area	Sand and stones	1	0.11
Ravenglass - ford	Mud and sand	1	0.095
Ravenglass - ford	Sand	3	0.10
Muncaster Bridge	Grass	4	0.12
Ravenglass - salmon garth	Mud and sand	1	0.11
Ravenglass - salmon garth	Sand and shingle	1	0.11
Ravenglass - salmon garth	Pebbles and sand	1	0.10
Ravenglass - salmon garth	Sand and stones	1	0.11
Ravenglass - Eskmeals Nature Reserve	Mud and salt marsh	1	0.11
Ravenglass - Eskmeals Nature Reserve	Salt marsh	3	0.11
Newbiggin/Eskmeals viaduct	Mud and salt marsh	2	0.12
Newbiggin/Eskmeals viaduct	Salt marsh	2	0.11
Newbiggin/Eskmeals Bridge	Salt marsh	4	0.12
Tarn Bay	Sand	2	0.074
Silecroft	Shingle	2	0.11
Haverigg	Mud	1	0.093
Haverigg	Mud and sand	1	0.094
Millom	Sand and stones	1	0.10
Millom	Pebbles	1	0.096
Low Shaw	Grass	2	0.087
Askam	Sand	2	0.071
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	1	0.10
Walney Channel, N of discharge point	Mud and sand	1	0.086
Walney Channel, S of discharge point	Mud	1	0.085
Walney Channel, S of discharge point	Mud and sand	1	0.090
Tummer Hill Marsh	Salt marsh	2	0.11
Roa Island	Mud	1	0.087
Roa Island	Mud and sand	1	0.089
Greenodd Salt Marsh	Grass and mud	1	0.078
Greenodd Salt Marsh	Grass	1	0.078
Sand Gate Marsh	Grass	4	0.085
Kents Bank 2	Salt marsh	2	0.087
Kents Bank 2	Grass	2	0.090
High Foulshaw	Mud	1	0.076
High Foulshaw	Sand and mud	1	0.080
High Foulshaw	Grass and mud	1	0.077
High Foulshaw	Grass	1	0.078
Arnside 1	Mud	2	0.083
Arnside 1	Sand and mud	2	0.082
Arnside 2	Grass	4	0.090

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lancashire and Merseyside			
Morecambe Central Pier	Sand	2	0.075
Half Moon Bay	Sand and stones	1	0.082
Half Moon Bay	Stones	1	0.081
Red Nab Point	Sand	2	0.083
Middleton Sands	Sand	2	0.078
Sunderland Point	Mud	1	0.098
Sunderland Point	Mud and sand	3	0.10
Sunderland	Salt marsh	4	0.093
Colloway Marsh	Salt marsh	2	0.12
Colloway Marsh	Grass	1	0.12
Lancaster	Grass	4	0.082
Aldcliffe Marsh	Salt marsh	3	0.097
Aldcliffe Marsh	Grass	1	0.095
Conder Green	Mud	3	0.090
Conder Green	Mud and sand	1	0.090
Pilling Marsh	Salt marsh	2	0.096
Pilling Marsh	Grass	2	0.096
Knott End	Mud and sand	1	0.081
Knott End	Sand	1	0.073
Heads - River Wyre	Mud and salt marsh	1	0.10
Heads - River Wyre	Salt marsh	2	0.095
Heads - River Wyre	Grass	1	0.095
Height o' th' hill - River Wyre	Salt marsh	4	0.10
Hambleton	Salt marsh	1	0.10
Hambleton	Grass and mud	1	0.099
Hambleton	Grass	2	0.098
Skippool Creek 1	Salt marsh	4	0.11
Skippool Creek 2	Salt marsh	4	0.11
Skippool Creek (board walk)	Wood	4	0.093
Skippool Creek Bivand (board walk)	Wood	4	0.093
Skippool Creek Bivand 1	Mud	4	0.087
Fleetwood Marsh Nature Park	Salt marsh	4	0.11
Fleetwood shore 1	Sand	4	0.076
Blackpool	Sand	4	0.066
Crossens Marsh	Salt marsh	3	0.092
Crossens Marsh	Grass and marsh	1	0.093
Ainsdale	Sand	4	0.067
Rock Ferry	Mud and sand	4	0.091
New Brighton	Sand	4	0.068
West Kirby	Mud and sand	1	0.070
West Kirby	Sand	3	0.072
Little Neston Marsh 1	Grass	2	0.087
Little Neston Marsh 2	Salt marsh	1	0.079
Little Neston Marsh 2	Grass	1	0.074
Flint 1	Mud	2	0.092
Flint 2	Salt marsh	2	0.099
Scotland			
Piltanton Burn	Salt marsh	2^S	0.069
Garlieston	Sand	2^S	0.071
Innerwell	Sand and shells	2^S	0.085
Bladnoch	Mud	2^S	0.078
Carsluith	Sand	2^S	0.086
Skyreburn Bay (Water of Fleet)	Salt marsh	2^S	0.081
Kirkcudbright	Salt marsh	2^S	0.067
Cutters Pool	Winkle bed	4^S	0.081
Balcary Bay	Sand	2^S	0.099
Gardenburn	Mud	2^S	0.078
Palnackie Harbour	Mud	2^S	0.082
Kippford – Slipway	Mud	1^S	0.089
Kippford – Slipway	Sand	1^S	0.082
Kippford – Merse	Salt marsh	2^S	0.098
Kirkconnell Marsh	Mud	2^S	0.088

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Isle of Man			
Ramsey	Sand and stones	1	0.092
Wales			
Prestatyn	Sand	2	0.066
Rhyl	Salt marsh	2	0.085
Llandudno	Sand and shingle	2	0.089
Caerhun	Grass and salt marsh	1	0.093
Caerhun	Grass	1	0.087
Llanfairfechan	Sand and shells	1	0.076
Llanfairfechan	Shell and shingle	1	0.080
Northern Ireland			
Lisahally	Mud	1[N]	0.068
Donnybrewer	Shingle	1[N]	0.053
Carrichue	Mud	1[N]	0.067
Bellerena	Mud	1[N]	0.058
Benone	Sand	1[N]	0.060
Castlerock	Sand	1[N]	0.055
Portstewart	Sand	1[N]	0.057
Portrush, Blue Pool	Sand	1[N]	0.056
Portrush, White Rocks	Sand	1[N]	0.056
Portballintrae	Sand	1[N]	0.055
Giant's Causeway	Sand	1[N]	0.054
Ballycastle	Sand	1[N]	0.055
Cushendun	Sand	1[N]	0.063
Cushendall	Sand and stones	1[N]	0.062
Red Bay	Sand	1[N]	0.071
Carnlough	Sand	1[N]	0.060
Glenarm	Sand	1[N]	0.058
Half Way House	Sand	1[N]	0.058
Ballygally	Sand	1[N]	0.059
Drains Bay	Sand	1[N]	0.059
Larne	Sand	1[N]	0.061
Whitehead	Sand	1[N]	0.063
Carrickfergus	Sand	1[N]	0.061
Jordanstown	Sand	1[N]	0.062
Helen's Bay	Sand	1[N]	0.060
Groomsport	Sand	1[N]	0.061
Millisle	Sand	1[N]	0.071
Ballywalter	Sand	1[N]	0.068
Ballyhalbert	Sand	1[N]	0.067
Cloghy	Sand	1[N]	0.067
Portaferry	Shingle and stones	1[N]	0.091
Kircubbin	Sand	1[N]	0.080
Greyabbey	Sand	1[N]	0.080
Ards Maltings	Mud	1[N]	0.086
Island Hill	Mud	1[N]	0.070
Nicky's Point	Mud	1[N]	0.076
Strangford	Shingle and stones	1[N]	0.090
Kilclief	Sand	1[N]	0.074
Ardglass	Mud	1[N]	0.079
Killough	Mud	1[N]	0.080
Ringmore Point	Sand	1[N]	0.077
Tyrella	Sand	1[N]	0.079
Dundrum	Sand	1[N]	0.096
Newcastle	Sand	1[N]	0.11
Annalong	Sand	1[N]	0.11
Cranfield Bay	Sand	1[N]	0.081
Mill Bay	Sand	1[N]	0.11
Greencastle	Sand	1[N]	0.086
Rostrevor	Sand	1[N]	0.12
Narrow Water	Mud	1[N]	0.099

[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, 2014

Vessel or location	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
101	Nets	3	<0.061
102	Nets	1	<0.076
103	Nets	1	0.079
104	Nets	2	<0.068
105	Nets	1	<0.073
106	Nets	1	<0.041
107	Nets	1	0.071
108	Nets	2	0.070
109	Nets	1	0.084
110	Nets	2	<0.057
Saltcoats	Pots	3	<0.091

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2014

Location	Ground type	No. of sampling observations	Mean beta dose rate in tissue, mSv h^{-1}
Whitehaven – outer harbour	Sand	4	0.11
St Bees	Sand	4	0.074
St Bees	Sand and shingle	1	0.14
Sellafield pipeline	Sand	1	0.25
Sellafield pipeline	Pebbles and sand	1	0.16
Ravenglass – Raven Villa	Mud and salt marsh	1	0.23
Ravenglass – Raven Villa	Salt marsh	1	0.23
Ravenglass – Raven Villa	Grass and salt marsh	1	0.040
Ravenglass – Raven Villa	Pebbles and salt marsh	1	0.17
Tarn Bay	Sand	2	0.16

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2014

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag
Cumbria										
Silloth	Seaweed	2	<0.75			<0.96	<0.50	84	<5.1	<0.74
Harrington Harbour	Seaweed	2	<0.87			<1.2	<0.60	150	<5.1	<0.87
St Bees	Seaweed	2	<0.69		<0.76	<0.88	<0.47	200	<4.2	<0.67
Sellafield	Seaweed	2	<0.99		0.80	<1.2	<0.56	1400	<5.2	<0.85
Ravenglass	Samphire	1[F]	<0.08	<0.19		<0.22	<0.25	0.22	<0.60	<0.11
Ravenglass	Seaweed	2	<0.84			<1.2	<0.61	55	<5.4	<0.85
Lancashire										
Half Moon Bay	Seaweed	2	<0.76			<1.1	<0.51	120	<5.1	<0.76
Marshside Sands	Samphire	1[F]	<0.04	<0.09		<0.09	<0.07	<0.31	<0.30	<0.05
Scotland										
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10	<0.22		<0.71	<2.7	17	<0.56	<0.10
Lerwick	*Fucus vesiculosus*	1[S]	<0.10	<0.23		<0.77		4.1	<0.61	<0.10
Kinlochbervie	*Fucus vesiculosus*	2[S]	<0.10	<0.29		<0.52	<0.96	10	<0.84	<0.13
Lewis	*Fucus vesiculosus*	1[S]	<0.10	<0.20		<0.23	<0.26	8.2	<0.58	<0.10
Islay	*Fucus vesiculosus*	1[S]	<0.10	<0.17		<0.30	<0.52	29	<0.50	<0.10
Campbeltown	*Fucus vesiculosus*	1[S]	<0.10	<0.23		<0.30	<0.35	56	<0.68	<0.10
Port William	*Fucus vesiculosus*	4[S]	<0.10	<0.16		<0.24	<0.32	46	<0.54	<0.10
Garlieston	*Fucus vesiculosus*	4[S]	<0.10	<0.20		<0.39	<0.77	32	<0.57	<0.12
Auchencairn	*Fucus vesiculosus*	4[S]	<0.10	<0.18		<0.39	<0.31	110	<0.50	<0.12
Isle of Man	Seaweed	3	<0.91			<1.2	<0.62	41	<5.4	<0.90
Wales										
Cemaes Bay	Seaweed	2	<0.67			<0.88	<0.46	17	<4.2	<0.68
Porthmadog	Seaweed	2	<0.85			<1.1	<0.57	<1.6	<5.3	<0.85
Lavernock Point	Seaweed	2	<1.0			<1.4	<0.72	2.6	<6.1	<1.1
Fishguard	Seaweed	2	<0.40			<0.90	<0.27	<2.5	<2.9	<0.51
Northern Ireland										
Portrush	*Fucus* spp.	3[N]	<0.05	<0.13		<0.15	<0.16		<0.42	<0.07
Portrush	*Fucus serratus*	1[N]	<0.06	<0.17		<0.26	<0.39		<0.51	<0.12
Portaferry[a]	*Rhodymenia* spp.	4[N]	<0.09	<0.27		<0.44	<0.72	<0.26	<0.81	<0.14
Ardglass	*Fucus vesiculosus*	3[N]	<0.10	<0.28		<0.33	<0.41	12	<0.87	<0.17
Ardglass	*Ascophyllum nodosum*	1[N]	<0.11	<0.30		<0.27	<0.25		<0.81	<0.15
Carlingford Lough	*Fucus* spp.	1[N]	<0.05	<0.15		<0.13	<0.10	70	<0.47	<0.09
Carlingford Lough	*Fucus vesiculosus*	1[N]	<0.18	<0.45		<0.63	<0.87		<1.7	<0.28
Carlingford Lough	*Ascophyllum nodosum*	2[N]	<0.09	<0.24		<0.27	<0.26		<0.69	<0.12
Isles of Scilly	Seaweed	1	<1.3			<1.8	<0.84	<2.8	<8.3	<1.4

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	^{239}Pu + ^{240}Pu	^{241}Am
Cumbria										
Silloth	Seaweed	2	<2.9	<0.69	3.8	<2.3				3.2
Harrington Harbour	Seaweed	2	<3.1	<0.79	2.4	<2.2				2.9
St Bees	Seaweed	2	<2.5	<0.62	1.9	<2.0		1.0	4.7	2.5
Sellafield	Seaweed	2	<2.9	<0.78	4.2	<1.9		1.6	8.3	5.2
Ravenglass	Samphire	1^{F}	<0.16	<0.08	0.31	<0.24	<0.10			1.0
Ravenglass	Seaweed	2	<3.1	<0.76	4.9	<2.5				19
Lancashire										
Half Moon Bay	Seaweed	2	<2.9	<0.69	3.0	<2.0				<0.68
Marshside Sands	Samphire	1^{F}	<0.08	<0.04	0.37	<0.14	<0.07			0.15
Scotland										
Aberdeen	*Fucus vesiculosus*	1^{S}	<0.13	<0.10	0.11	<0.39	<0.12			<0.10
Lerwick	*Fucus vesiculosus*	1^{S}	<0.14	<0.10	<0.10	<0.40	<0.13			<0.10
Kinlochbervie	*Fucus vesiculosus*	2^{S}	<0.23	<0.10	0.50	<0.56	<0.21			<0.14
Lewis	*Fucus vesiculosus*	1^{S}	<0.16	<0.10	0.28	<0.38	<0.17			<0.13
Islay	*Fucus vesiculosus*	1^{S}	<0.13	<0.10	0.11	<0.30	<0.12			<0.10
Campbeltown	*Fucus vesiculosus*	1^{S}	<0.20	<0.10	<0.10	<0.47	<0.20			<0.13
Port William	*Fucus vesiculosus*	4^{S}	<0.16	<0.10	0.43	<0.36	<0.15			0.69
Garlieston	*Fucus vesiculosus*	4^{S}	<0.16	<0.10	2.5	<0.42	<0.16			5.7
Auchencairn	*Fucus vesiculosus*	4^{S}	<0.15	<0.10	1.5	<0.35	<0.15			3.1
Isle of Man	Seaweed	3	<3.3	<0.82	<0.71	<2.2	<1.1			<0.77
Wales										
Cemaes Bay	Seaweed	2	<2.4	<0.64	<0.97	<1.8				<0.63
Porthmadog	Seaweed	2	<2.9	<0.77	<0.63	<2.0				<0.68
Lavernock Point	Seaweed	2	<3.6	<0.93	<0.67	<2.5	<1.2			<0.80
Fishguard	Seaweed	2	<1.5	<0.36	<0.29	<1.1				<0.30
Northern Ireland										
Portrush	*Fucus* spp.	3^{N}	<0.12	<0.05	0.10	<0.27	<0.13			<0.18
Portrush	*Fucus serratus*	1^{N}	<0.12	<0.06	<0.53	<0.28	<0.13			0.30
Portaferry[a]	*Rhodymenia* spp.	4^{N}	<0.21	<0.09	<0.28	<0.41	<0.16	0.032	0.21	0.41
Ardglass	*Fucus vesiculosus*	3^{N}	<0.19	<0.10	0.35	<0.33	<0.15			<0.23
Ardglass	*Ascophyllum nodosum*	1^{N}	<0.22	<0.11	0.27	<0.39	<0.18			<0.12
Carlingford Lough	*Fucus* spp.	1^{N}	<0.11	<0.06	0.39	<0.23	<0.13			<0.16
Carlingford Lough	*Fucus vesiculosus*	1^{N}	<0.32	<0.18	0.32	<0.53	<0.23			<0.12
Carlingford Lough	*Ascophyllum nodosum*	2^{N}	<0.19	<0.09	0.26	<0.42	<0.21			<0.24
Isles of Scilly	Seaweed	1	<4.4	<1.2	<0.94	<2.6	<1.3			<0.84

[a] *^{242}Cm and $^{243+244}$Cm were not detected by the method used*

^{F} *Measurements labelled "F" are made on behalf of the Food Standards Agency*

^{N} *Measurements labelled "N" are made on behalf of the 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 terrestrial food and the environment near Ravenglass, 2014

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		3	<2.4	16	<0.05	<0.037	<0.99	<0.41	<0.032	<0.48	<0.14	<0.0088	<0.06
Milk	max				<0.06	<0.039	<2.8	<0.69		<0.53	<0.15	0.013	<0.07
Beef kidney		1	<2.0	22	<0.04	0.075	<0.05	<0.10	<0.12	<0.27	<0.09	<0.036	<0.05
Beef liver		1	<2.0	37	<0.07	<0.039	<0.06	<0.22	<0.11	<0.62	<0.12	<0.036	<0.10
Beef muscle		1	<2.0	34	<0.08	0.021	<0.16	<0.17	<0.14	<0.62	<0.09	<0.023	<0.08
Sheep muscle		2	<2.1	31	<0.06	<0.034	<0.10	<0.14	<0.11	<0.58	<0.13	<0.026	<0.08
Sheep muscle	max					<0.042		<0.17		<0.78	<0.14	<0.032	<0.11
Sheep offal		2	<4.4	33	<0.05	0.067	<0.11	<0.13	<0.11	<0.52	<0.11	<0.016	<0.04
Sheep offal	max		<6.9	34	<0.06	0.070	<0.12	<0.15	<0.12	<0.54	<0.15	<0.018	<0.07

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		3	<0.10	<0.35				<0.000027	<0.000029	<0.12	<0.000061
Milk	max		<0.12	<0.38				<0.000047	<0.000042	<0.14	<0.00016
Beef kidney		1	0.49	<0.27	0.0086	0.00053	0.0076	<0.00017	<0.000077	<0.43	0.00019
Beef liver		1	0.38	<0.46				<0.000031	0.00025	<0.30	0.00018
Beef muscle		1	0.76	<0.40				<0.00013	<0.00013	<0.26	0.000055
Sheep muscle		2	1.3	<0.38				<0.00012	<0.00013	<0.29	<0.000079
Sheep muscle	max		1.4	<0.41					<0.00016	<0.32	<0.000094
Sheep offal		2	0.89	<0.26				<0.00018	0.0014	<0.26	0.0011
Sheep offal	max		1.0	<0.36				<0.00026	0.0026	<0.28	0.0019

[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 2.14. Concentrations of radionuclides in surface waters from West Cumbria, 2014

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	170	<0.30	<0.050	<0.31	<0.26	<0.0043	<0.0043	<3.1	11
River Ehen (100m downstream of sewer outfall)	4	<3.5	<0.31	<0.085	<0.32	<0.27	<0.0028	<0.0018	<0.035	0.45
River Calder (downstream)	4	<3.2	<0.28	<0.040	<0.29	<0.23	<0.0037	<0.0022	<0.058	0.11
River Calder (upstream)	4	<3.0	<0.26	<0.053	<0.26	<0.21	<0.0037	<0.0015	<0.026	0.046
Wast Water	1	<3.2	<0.21			<0.18			<0.011	0.037
Ennerdale Water	1	<3.2	<0.14		<0.16	<0.12			<0.018	0.039
Devoke Water	1	<3.1	<0.11		<0.13	<0.09			<0.025	<0.022
Thirlmere	1	<3.3	<0.37			<0.32			<0.022	<0.028

[a] *The concentration of ^{99}Tc was <0.37 Bq l^{-1}*

Table 2.15. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2014

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	<0.51	<2.0	<0.51	270	4.7	30	43
Seascale SS 233	1	<1.8	<2.0	<1.7	180	2.1	21	23
Seascale SS 209	1	<0.58	<2.0	<0.52	17	0.73	7.6	9.7
Seascale SS 232	1	<0.37	<2.0	<0.49	90	2.6	14	24
Seascale SS 231	1	<1.8	<2.0	<1.8	43	4.5	26	40
Whitehaven SS 201	1	<1.7	<2.0	<1.7	22	<0.92	<0.58	<1.6

Table 2.16. Doses from artificial radionuclides in the Irish Sea, 2007-2014

	Exposure, mSv per year							
Group	2007	2008	2009	2010	2011	2012	2013	2014
Northern Ireland	0.015	0.017	0.012	0.010	0.010	0.011	0.010	0.009
Dumfries and Galloway	0.060	0.047	0.047	0.040	0.040	0.046	0.044	0.045
Whitehaven	0.009	0.009	0.011	0.010	0.010	0.013	0.010	0.012
Sellafield (5 year average consumption)	0.24	0.23	0.20	0.18	0.15	0.14	0.12	0.089
Morecambe Bay	0.037	0.042	0.041	0.046	0.034	0.034	0.036	0.032
North Wales	0.014	0.018	0.015	0.013	0.014	0.014	0.013	0.018

Table 2.17. Individual radiation exposures, Sellafield, 2014

Representative person[a]	Exposure, mSv per year							
	Total	Seafood (nuclear industry discharges)[h]	Seafood (other discharges)[i]	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 mollusc consumer	**0.22**[e]	**0.052**	**0.15**	**–**	**0.017**	**–**	**–**	**–**
***Total dose* – maximum effect of gaseous release and direct radiation sources**								
Local adult inhabitants (0–0.25km)	**0.009**[b]	**–**	**–**	**<0.005**	**<0.005**	**–**	**<0.005**	**0.005**
***Total dose* – maximum effect of liquid release source**								
Adult mollusc consumer	**0.22**[e]	**0.052**	**0.15**	**–**	**0.017**	**–**	**–**	**–**
Source specific doses								
Seafood consumer								
Local seafood consumer (habits averaged 2010–14)	0.22[f]	0.057	0.13	–	0.032	–	–	–
Local seafood consumer (habits for 2014)	0.27[g]	0.053	0.18	–	0.040	–	–	–
Whitehaven – seafood consumer	0.012	0.012	–	–	–	–	–	–
Dumfries and Galloway – seafood and wildfowl consumer	0.045	0.034	–	–	0.011	–	–	–
Morecambe Bay – seafood consumer	0.032	0.013	–	–	0.018	–	–	–
Northern Ireland – seafood consumer	0.009	0.007	–	–	<0.005	–	–	–
North Wales – seafood consumer	0.018	0.011	–	–	0.007	–	–	–
Other groups								
Ravenglass Estuary, marsh users	0.012	–	–	–	0.009	<0.005	–	–
Fishermen – handling nets or pots[c]	0.077	–	–	–	0.077	–	–	–
Bait diggers and shellfish collectors[c]	0.069	–	–	–	0.069	–	–	–
Ribble Estuary – houseboats	0.056	–	–	–	0.056	–	–	–
Barrow Houseboats	0.053	–	–	–	0.053	–	–	–
Local infant consumers of locally grown food at Ravenglass	0.017[b]	–	–	0.017	–	–	–	–
Local infant consumers of locally grown food at LLWR near Drigg	0.007[b]	–	–	0.007	–	–	–	–
Infant inhabitants and consumers of locally grown food	0.012[b]	–	–	0.012	–	–	<0.005	–
Groups with average consumption or exposure								
Average seafood consumer in Cumbria	<0.005	<0.005	–	–	–	–	–	–
Average consumer of locally grown food[d]	<0.005	–	–	<0.005	–	–	–	–
Typical visitor to Cumbria	<0.005	<0.005	<0.005	–	<0.005	–	–	–
Recreational user of beaches								
Dumfries and Galloway	0.009	–	–	–	0.009	–	–	–
North Cumbria	0.012	–	–	–	0.012	–	–	–
Sellafield	0.011	–	–	–	0.011	–	–	–
Lancashire	0.007	–	–	–	0.007	–	–	–
North Wales	0.007	–	–	–	0.007	–	–	–
Isle of Man	0.011	–	–	–	0.011	–	–	–
Recreational user of mud/saltmarsh areas								
Dumfries and Galloway	<0.005	–	–	–	<0.005	–	–	–
North Cumbria	<0.005	–	–	–	<0.005	–	–	–
Sellafield	0.015	–	–	–	0.015	–	–	–
Lancashire	0.007	–	–	–	0.007	–	–	–
North Wales	0.006	–	–	–	0.006	–	–	–

[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. The representative person is an adult unless otherwise stated*

[b] *Includes a component due to natural sources of radionucludies*

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

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

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

[f] *The dose due to nuclear industry discharges was 0.089 mSv*

[g] *The dose due to nuclear industry discharges was 0.094 mSv*

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

[i] *Enhanced naturally occurring radionuclides from Whitehaven*

3. Research establishments

This section considers the results of monitoring by the Environment Agency, FSA and SEPA near research establishments that hold nuclear site licences.

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 (PBO) competition.

In 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. In September 2014, NDA formally appointed Cavendish Fluor Partnership (CFP) as the new PBO for RSRL (and Magnox Limited).

In November 2014, ONR received an application to relicense the Harwell and Winfrith sites into a single site licence company alongside the ten Magnox sites. As of 1st April 2015, Harwell and Winfrith sites, previously operated by RSRL, merged to be part of Magnox Limited.

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.

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 have been considered in a summary report (Environment Agency, FSA, NIEA and SEPA, 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, for sites that were assessed
- Doses, discharges, environmental concentrations and dose rates in 2014 were broadly similar to those in 2013

Dounreay, Highland

- There were small changes in public radiation doses in 2014
- A new authorisation was issued for liquid, gaseous and solid radioactive waste disposals in 2014

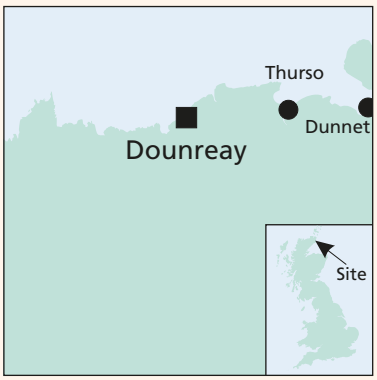
Harwell, Oxfordshire

- *Total dose* for the representative person increased in 2014
- Gaseous discharges of alpha and beta radionuclides decreased, and liquid discharges to Lydebank Brook increased, in 2014

Winfrith, Dorset

- *Total dose* for the representative person continued to be very low
- Gaseous and liquid discharges generally decreased in 2014; liquid discharges of tritium and alpha-emitting radionuclides were the lowest reported value in 2014

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 2029 (NDA, 2015).

From 2005, NDA became responsible for the UK's civil nuclear liabilities which included those at UKAEA

Dounreay, and UKAEA became a contractor to NDA. In common with other NDA sites, UKAEA prepared a long term decommissioning plan known as the Lifetime Plan. NDA's Strategy includes a summary of the PBO 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 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.

In April 2014, SEPA issued a new authorisation to DSRL in relation to the decommissioning work at Dounreay. The new authorisation replaced the three existing authorisations which individually covered liquid, gaseous and solid radioactive waste disposals. The new authorisation contains annual authorised site limits for the disposals of gaseous and liquid waste and sub-limits for disposals of gaseous waste based on stack height groupings. The annual authorised limits for the disposals of gaseous and liquid waste from the site have either been reduced or kept at the same level, compared to the previous authorisations. Discharge limits effective during 2014 (January to April; May to December) are given in Appendix 2.

In 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, was completed in 2014. SEPA provided DSRL with written agreement for disposal operations to begin at the disposal facility in March 2015. That agreement was subject to a number of requirements which came out of SEPA's review of DSRL's readiness to begin disposal operations. The facility began accepting waste for disposal in April 2015.

In December 2014, DSRL completed the shipment of cemented radioactive waste to Belgium. The waste, which arose from historical reprocessing operations, was returned to its country of origin (Belgium) as part of the site's decommissioning process.

During 2014, DSRL notified SEPA of several issues relating to compliance reporting with respect to the monthly disposal reports which are submitted to SEPA. As a result SEPA has written to DSRL conveying its expectation that DSRL will undertake a detailed review of the site's arrangements for the compilation and checking of the monthly disposal reports as part of DSRL's Environmental Improvement Programme.

In 2014, 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 2013 (Appendix 2).

The most recent habits survey was conducted in 2013 (Papworth *et al.*, 2014).

Doses to the public

In 2014, 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, and unchanged from 2013. The representative person was an adult consuming wild fruit and nuts at high-rates and was a change from that in 2013 (an adult consuming local green vegetables). The larger change in total dose from 0.017 mSv in 2012, and the most exposed age group (1-year-old infant), was mostly due to the contribution of goats' milk not being included in the assessment (which has been assessed prior to 2013), as milk samples were not available in 2013 and 2014. 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.

The trend in *total dose* over the period 2004 – 2014 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 2014 (Table 3.1). In 2014, the dose to a consumer of terrestrial foodstuffs was 0.016 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 (as in 2013). The small increase in dose from 0.014 mSv (in 2013) was mostly due to including a caesium-137 concentration value from the honey sample in the 2014 assessment (honey was not sampled in recent years). The dose to a consumer of fish and shellfish, including external exposure from occupancy over local beaches, was less than 0.005 mSv. The decrease in dose from 0.012 mSv (in 2013) was mostly due to lower gamma dose rates over sand in 2014.

Gaseous discharges and terrestrial monitoring

DSRL is authorised by SEPA to discharge radioactive gaseous wastes to the local environment via stacks to the atmosphere. As a result of the gaseous discharges arising from fuel repackaging work that was being undertaken in the Prototype Fast Reactor (PFR) facility (see Table A2.4 for further information), the reported discharges of tritium in May and June exceeded a sub-limit for gaseous disposals from the site. The assessed tritium discharges arising from the fuel were well below the annual authorised site limit.

Monitoring conducted in 2014 included the sampling of air, freshwater, grass, soil and locally grown terrestrial

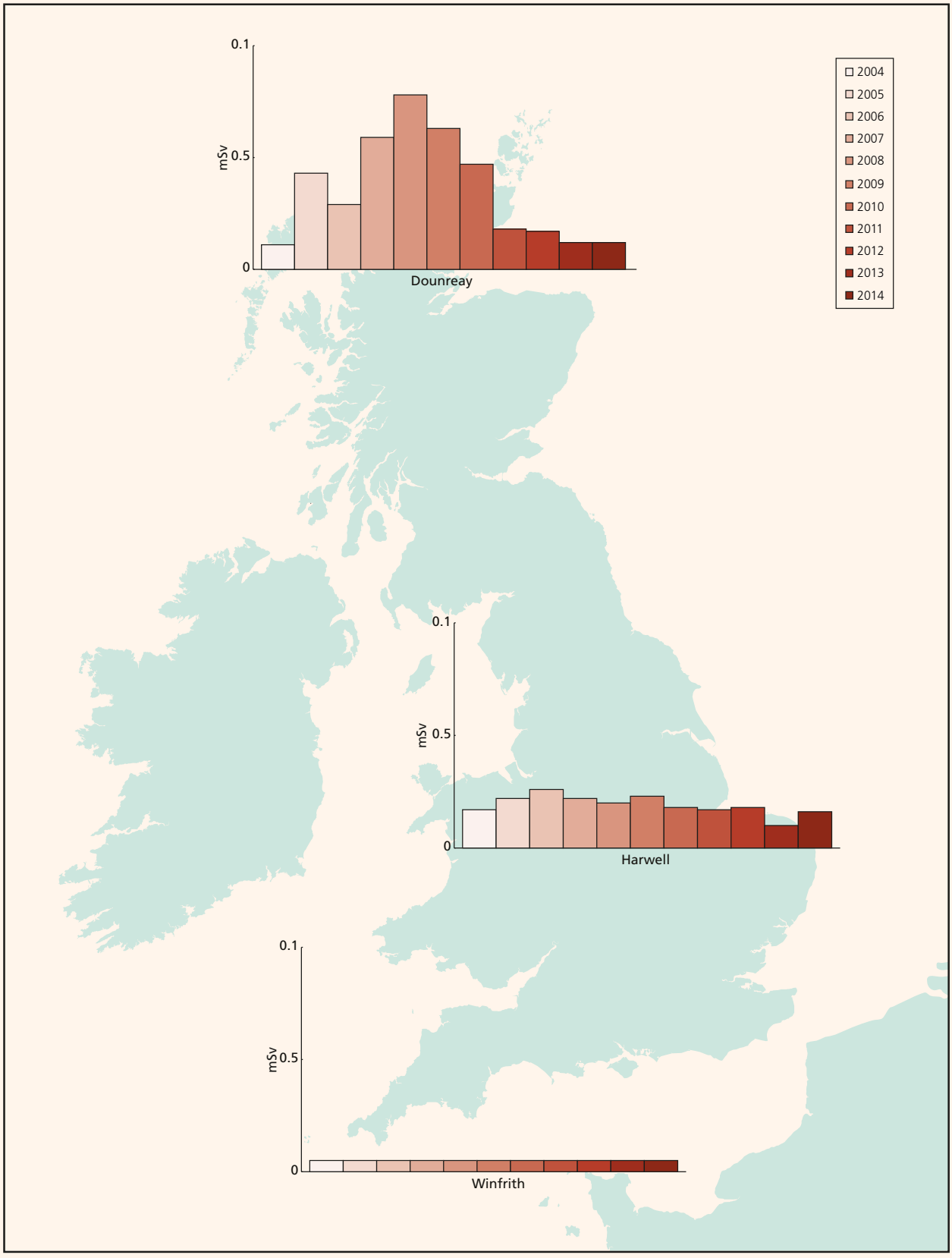


Figure 3.1. *Total dose* at research establishments, 2004–2014
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

foods including meat and vegetables 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 2014. 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 2014, low concentrations of caesium-137, strontium-90, cobalt-60, europium-155, uranium, plutonium and americium-241 are reported in most samples (many reported as less than values). Caesium-137 concentration in honey and wild mushrooms were elevated (33 and 18 Bq kg^{-1}, respectively) in 2014. Activity concentrations in air samples at locations near to the site are reported as less than values.

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 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 2014 and generally similar to those in recent years. In 2014, plutonium radionuclide concentrations were elevated in crab and winkle samples (collected from the pipeline and Brims Ness, respectively) and americium-241 concentrations were also elevated in winkle samples (from Sandside Bay), in comparison to those in 2013. Overall gamma dose rates were lower in 2014 (in comparison to 2013), especially over sand and soil (but with increased rates over sand at Sandside Bay). Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were generally lower 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 are reported as less than values (Table 3.2(b)).

During 2014, DSRL continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. In 2014, 12 fragments were recovered from Sandside Bay and 11 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 9.9 kBq and 92 kBq (similar to ranges observed in 2013).

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 (DPAG, 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 (PRAG (D), 2010; 2011; *in press*).

In 2007, FSA reviewed the Dounreay FEPA Order. A risk assessment, that was peer-reviewed by PHE, indicated that the food chain risk was very small (FSA, 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. The Harwell nuclear licensed site forms

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

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

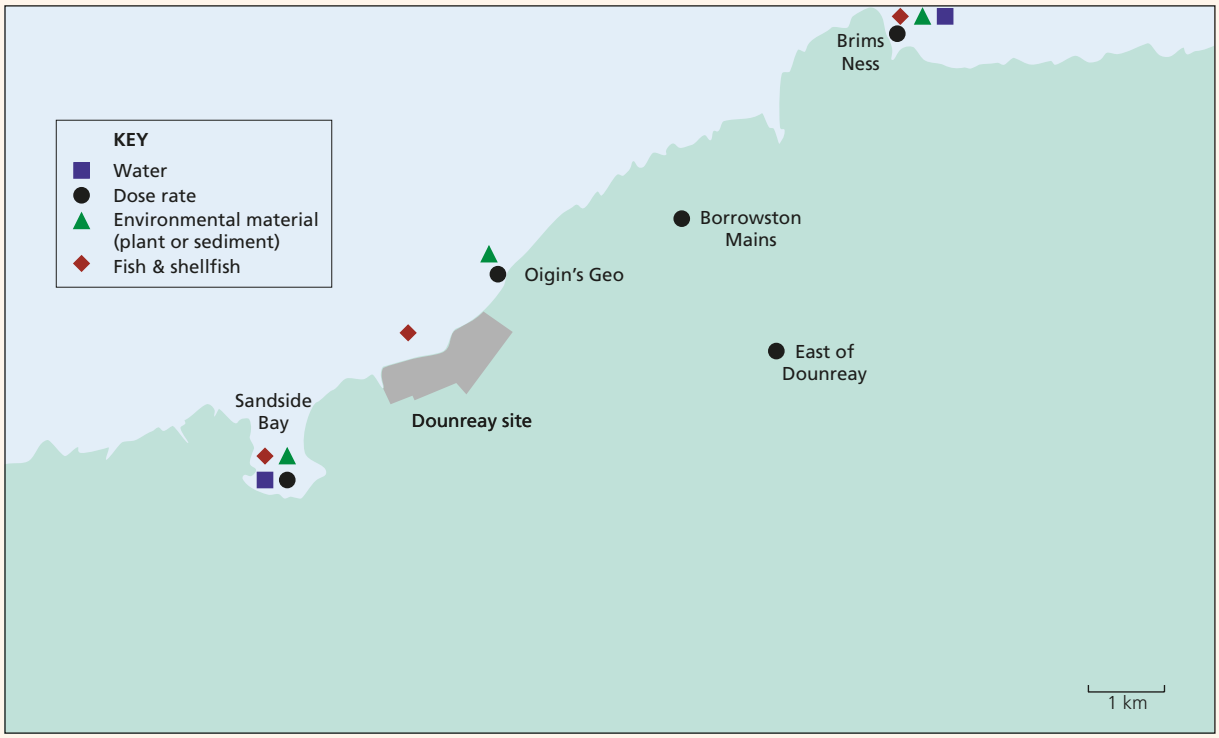


Figure 3.2. Monitoring locations at Dounreay, 2014 (not including farms)

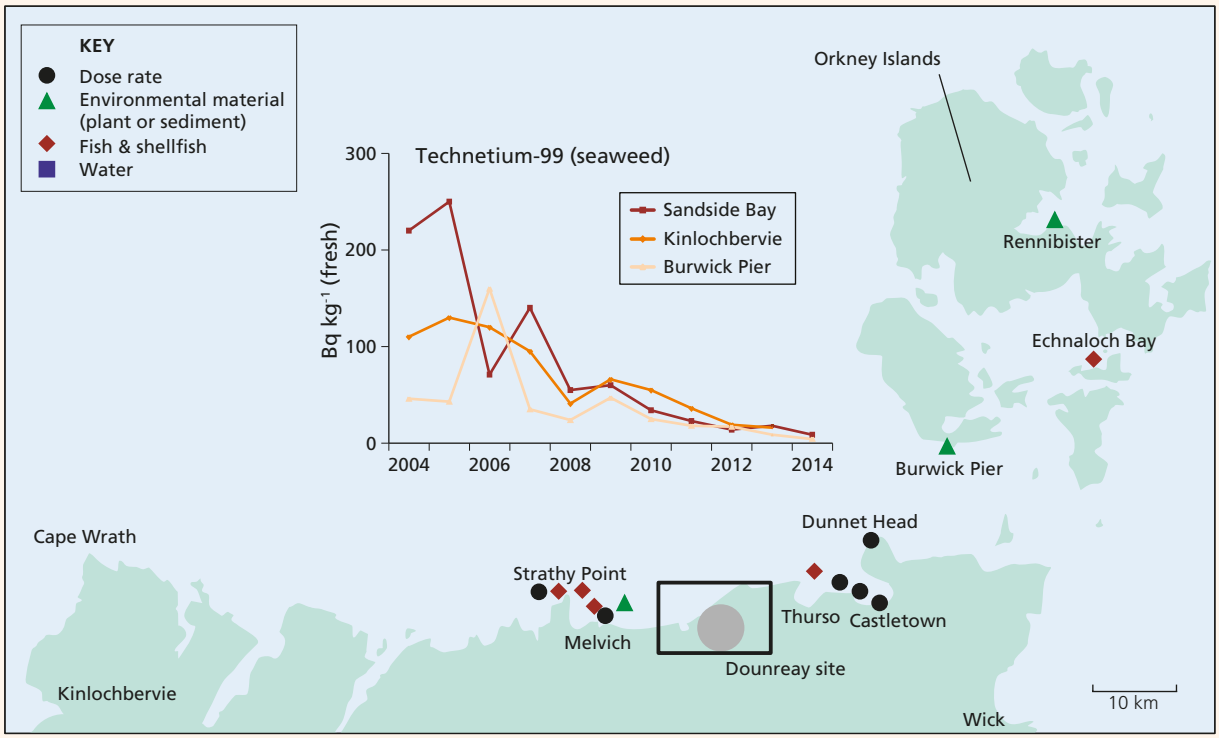


Figure 3.3. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2014 (not including farms)

part of Harwell Oxford, a science, innovation and business campus. The nuclear licensed site originally accommodated five research reactors of various types. Two of the reactors have been completely removed, and the fuel has been removed from the remaining three reactors. Decommissioning at the Harwell site is well underway. It is expected that decommissioning of all redundant buildings on the site will be completed by 2027 (DECC and NDA, 2014). Final site clearance is expected to be achieved by 2064 (NDA, 2015). The most recent habits survey was conducted in 2007 (Garrod *et al.*, 2008).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.016 mSv in 2014 (Table 3.1), which was less than 2 per cent of the dose limit, and up from 0.010 mSv in 2013. The dominant contribution to this dose was direct radiation from the site and the representative person was a prenatal child of local inhabitants. The trend in *total dose* over the period 2004 – 2014 is given in Figure 3.1. The *total doses* remained broadly similar from year to year, and were 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).

Gaseous discharges and terrestrial monitoring

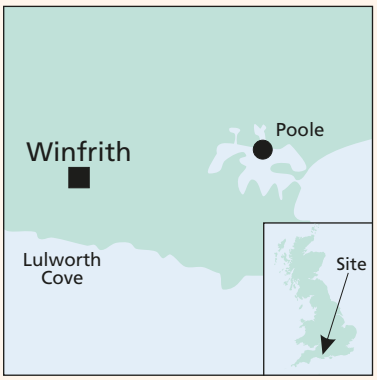
Gaseous wastes are discharged via stacks to the local environment. Discharges of alpha and beta radionuclides decreased, in comparison to releases in 2013. The monitoring programme sampled milk and fruit. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.4. The results of the terrestrial monitoring programme are shown in Table 3.3(a). The results for tritium analyses in terrestrial samples are reported as less than values.

Liquid waste discharges and aquatic monitoring

Regulated discharges from Harwell to the River Thames at Sutton Courtenay ceased in 2013 and these wastes are now discharged to sewers serving the Didcot STW; 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. Discharges of surface water effluent from the Harwell site are made via the Lydebank Brook, north of the site, which is a permitted route. In 2014, the overall total of discharges to the Lydebank Brook increased, in comparison to those in 2013. This was due to record levels of rainfall during winter 2013-14. From April to December 2014, discharges were generally similar to previous years. Discharges to the sewer were generally similar to the combined discharges to the River Thames and the sewer in 2013. Figure 3.5 shows trends of discharges over time (2000 – 2014) 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 concentrations in fish and freshwater, are reported as less than values. The concentrations of all radionuclides in flounder from the lower reaches of the Thames (from Beckton) are reported as less than values. Caesium-137 concentrations in sediments continued to be enhanced above background levels (including those close to Sutton Courtenay) in 2014, but were small in terms of any radiological effect. Concentrations of transuranic elements in sediments are mostly reported as less than values. Overall, gamma dose rates were generally similar to those in recent years.

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 commenced in 2014, with the aim to be completed by 2021 (NDA, 2015). The most recent habits survey undertaken for Winfrith was in 2003 (McTaggart *et al.*, 2004b).

Doses to the public

In 2014, 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. In 2014, the representative person was an adult consuming fish at high-rates (as opposed to a 1-year-old infant consuming milk in 2013). 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 2014 (Table 3.1).

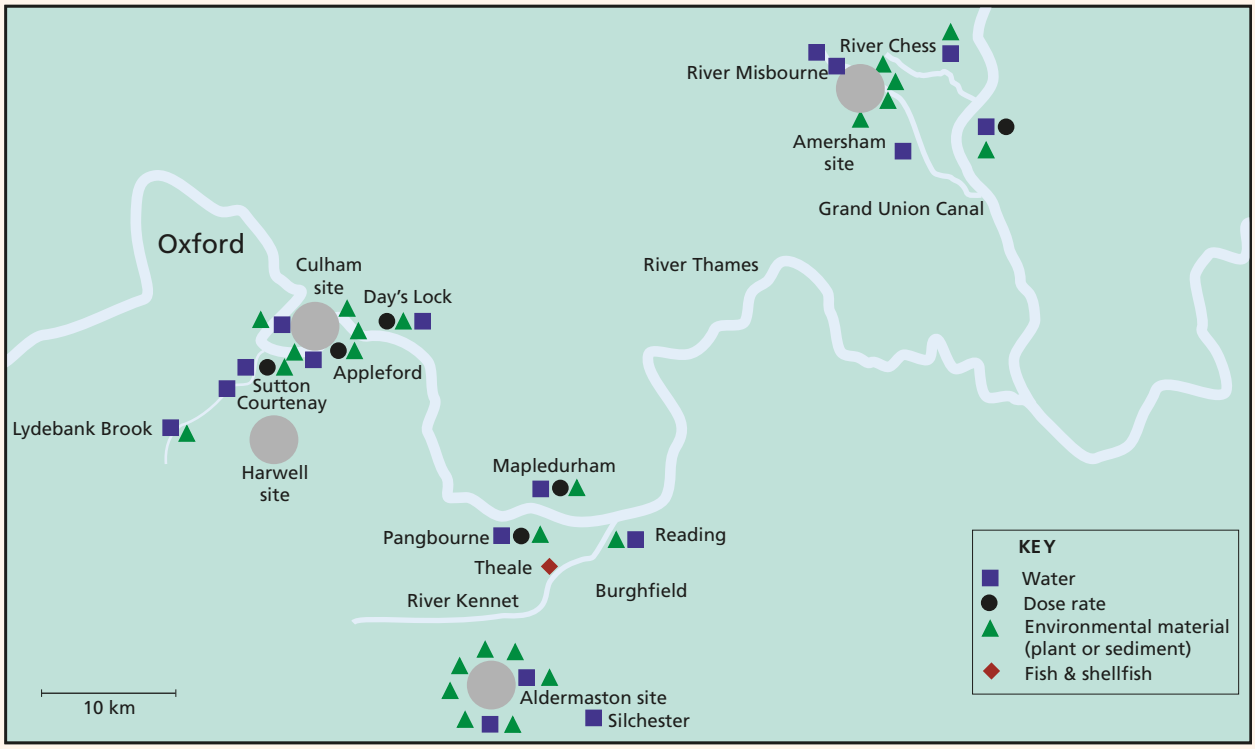


Figure 3.4. Monitoring locations at Thames sites, 2014 (not including farms)

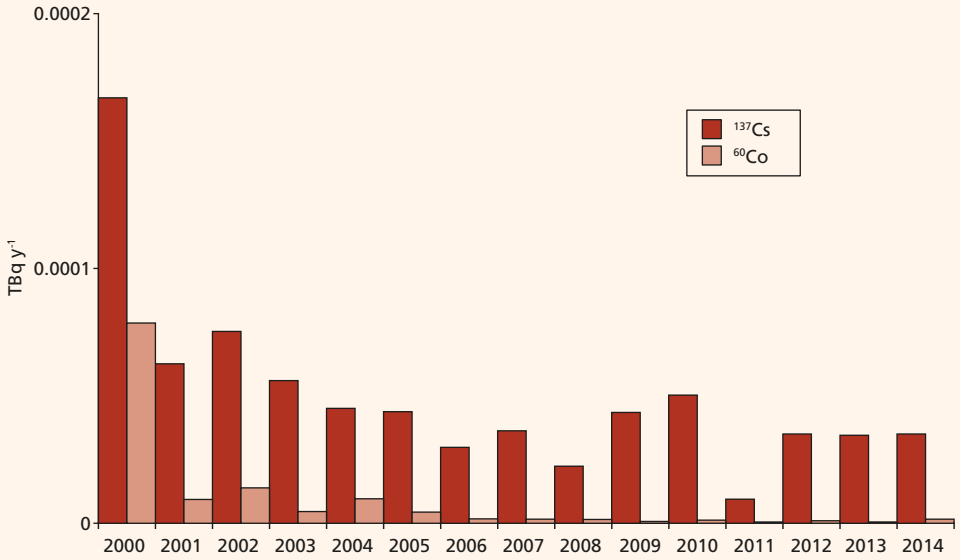


Figure 3.5. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2014

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 2014 at very low rates; tritium discharges decreased, and carbon-14 discharges reduced to almost nil, from Winfrith (Tradebe Inutec) in comparison to those in 2013. The focus of the terrestrial sampling was for the content of tritium and carbon-14 in milk and crops. Local freshwater samples were also analysed. Sampling locations at Winfrith are shown in Figure 3.6. Data for 2014 are given in Table 3.4(a). Results for terrestrial samples provide little indication of an effect due to gaseous discharges. Carbon-14 was detected in locally produced milk, at expected background concentrations, and decreased by small amounts in comparison to those in 2013 (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

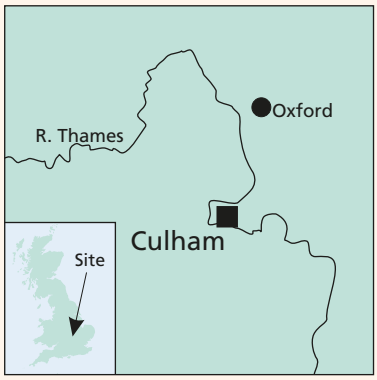
Liquid wastes are disposed via a pipeline to deep water in Weymouth Bay. Tritium, alpha-emitting radionuclides and "other radionuclides" discharges decreased from Winfrith (inner pipeline), in comparison to those in 2013. Figure 3.7 shows trends of liquid discharges over time (2000 – 2014) for tritium and alpha emitting radionuclides. Over the period, alpha-emitting 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). Both alpha-emitting radionuclides and tritium discharges were the lowest releases in 2014.

Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Data for 2014 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 2014 due to operation of these sites.

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 UKAEA (under contract from Euratom). Although not currently designated, NDA understands that the intention of Government is to designate that part of the Culham Site occupied by JET facilities as an NDA site at an appropriate time after JET operation ceases. 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 (DECC and NDA, 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 2014, 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 2014. 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 2014, measurements of tritium in all samples are reported as less than values. Unlike in recent years, sulphur-35 was detected at very low concentration in the soil sample. 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 was de-fuelled in the summer of 2014. The aim is that the reactor will be dismantled over a period of ten years with eventual de-licensing of the site by 2023 (DECC and NDA, 2014).

In 2014, gaseous and aqueous discharges were very low (Appendix 2). Monitoring of the environmental effects involved the analysis of grass and crop (potato) samples by gamma-ray spectrometry. Activity concentrations in both samples, from radioactive discharges, are reported as less than values.

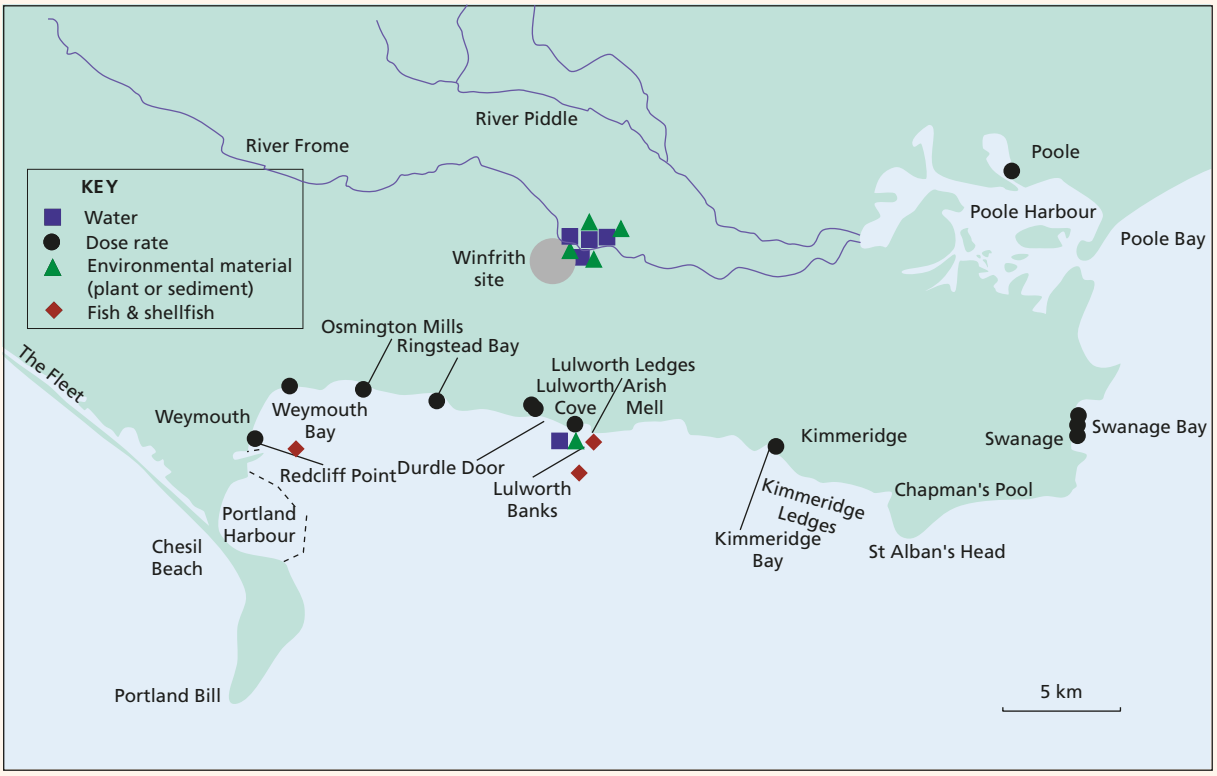


Figure 3.6. Monitoring locations at Winfrith, 2014 (not including farms)

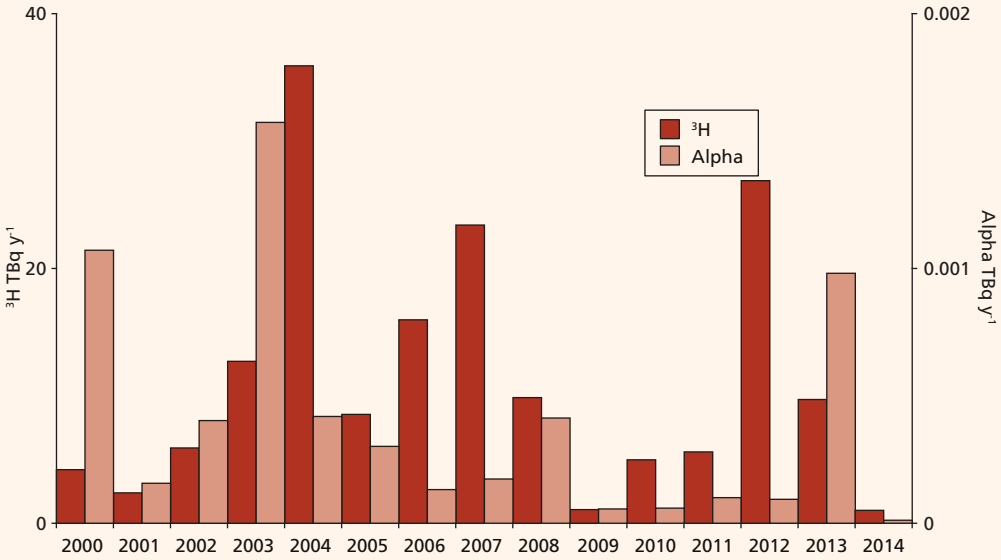


Figure 3.7. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2014

Table 3.1. Individual doses – research sites, 2014

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	Drinkers of river water	<0.005	–	–	–	<0.005	–	–
Dounreay								
***Total dose* – all sources**	**Adult wild fruit and nut consumer**	**0.012**	**–**	**0.005**	**–**	**–**	**<0.005**	**0.007**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–	–
	Geo occupants[b]	<0.005	–	–	<0.005	–	–	–
	Inhabitants and consumers of locally grown food	0.016	–	0.016	–	–	<0.005	–
Harwell								
***Total dose* – all sources**	**Prenatal child of local inhabitants (0–0.25km)**	**0.016[c]**	**–**	**<0.005**	**–**	**–**	**<0.005**	**0.016**
Source specific doses	Anglers	<0.005	<0.005	–	<0.005	–	–	–
	Infant inhabitants and consumers of locally grown food	<0.005[c]	–	<0.005	–	–	<0.005	–
Winfrith								
***Total dose* – all sources**	**Adult fish consumer**	**<0.005**	**<0.005**	**<0.005**	**–**	**–**	**<0.005**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	–	<0.005	–

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

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

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

Table 3.2(a). Concentrations of radionuclides in food and the environment near Dounreay, 2014

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	<0.23		<0.52		0.32
Crabs	Pipeline	2		<0.10	<0.28	<0.10	<1.1	2.9	<0.10
Crabs	Strathy	2		<0.10	<0.22		<1.0		<0.10
Crabs	Melvich Bay	2		<0.10	<0.12		<0.60	1.1	<0.10
Winkles	Brims Ness	4		<0.12	<0.33	<0.10	<0.84		<0.12
Winkles	Sandside Bay	4		<0.10	<0.21	<0.10	<0.62	1.9	<0.10
Mussels	Echnaloch Bay	4		<0.11	<0.33		<1.1	13	<0.11
Fucus vesiculosus	Brims Ness	4		<0.10	<0.14		<0.56		<0.11
Fucus vesiculosus	Sandside Bay	4		<0.10	<0.16		<0.65	8.5	<0.12
Fucus vesiculosus	Burwick Pier	4		<0.10	<0.21		<0.46	4.2	<0.11
Sediment	Oigin's Geo	2		<0.10	<0.35		<0.35		3.2
Sediment	Brims Ness	1		<0.10	<0.22		<0.15		0.93
Sediment	Sandside Bay	1		<0.10	<0.20		<0.13		2.1
Sediment	Melvich Bay	1		<0.10	<0.22		<0.26		1.5
Sediment	Strathy	1		<0.10	<0.18		<0.21		1.0
Sediment	Rennibister	1		<0.10	<0.34		<0.27		9.2
Seawater	Brims Ness	2	<1.0	<0.10	<0.16		<0.36		<0.10
Seawater	Sandside Bay	2	<1.0	<0.10	<0.20		<0.33		<0.10
Spume	Oigin's Geo	2		<0.15	<0.41		<0.28		<5.5

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	<0.11	<0.18	<0.0040	0.00060	0.0054		
Crabs	Pipeline	2	<0.10	<0.18	0.0076	0.024	0.34	<1.2	160
Crabs	Strathy	2	<0.11	<0.17	0.0020	<0.013	<0.0017		
Crabs	Melvich Bay	2	<0.10	<0.10	0.0021	0.012	0.0083		
Winkles	Brims Ness	4	<0.13	<0.23	0.070	0.35	<0.17		
Winkles	Sandside Bay	4	<0.11	<0.17	0.023	0.094	0.20		
Mussels	Echnaloch Bay	4	<0.13	<0.23	0.0086	0.042	0.027		
Fucus vesiculosus	Brims Ness	4	<0.10	<0.11			<0.10	1.8	300
Fucus vesiculosus	Sandside Bay	4	<0.10	<0.13			<0.19	1.7	360
Fucus vesiculosus	Burwick Pier	4	<0.10	<0.16			<0.11	<1.1	270
Sediment	Oigin's Geo	2	<0.19	1.10	2.7	12	6.8	3.0	
Sediment	Brims Ness	1	<0.11	<0.25	2.2	10	13	8.0	
Sediment	Sandside Bay	1	0.26	<0.21	3.5	12	13	8.7	
Sediment	Melvich Bay	1	<0.12	<0.23	<0.79	2.4	1.9	0.72	
Sediment	Strathy	1	<0.12	<0.25	<0.26	2.8	7.0	0.85	
Sediment	Rennibister	1	<0.21	0.73	<0.17	0.84	<1.5	<0.37	
Seawater	Brims Ness	2	<0.10	<0.15			<0.10		
Seawater	Sandside Bay	2	<0.12	<0.19			<0.11		
Spume	Oigin's Geo	2	<0.37	<0.60	0.66	3.6	4.5	<12	

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		<0.10	<0.11	<0.32	<0.05	<0.05	0.06	<0.23
Beef offal		1	<5.0		<0.10	<0.80	<0.41	<0.05	<0.05	0.27	<0.35
Cabbage		1	<5.0		0.11	<0.75	<0.47	<0.05	<0.05	0.10	<0.33
Carrots		1	<5.0		<0.10	<0.33	<0.42	<0.05	<0.05	<0.05	<0.28
Cauliflower		1	<5.0		<0.10	<0.05	<0.27	<0.05	<0.05	<0.05	<0.18
Eggs		1	<5.0		<0.10	<0.18	<0.49	<0.05	<0.05	<0.05	<0.33
Honey		1	<5.0		<0.10	<0.09	<0.51	<0.05	<0.05	33	<0.34
Lamb muscle		1	<5.0		<0.10	<0.09	<0.28	<0.05	<0.05	0.49	<0.23
Parsnips		1	<5.0		<0.10	<0.05	<0.21	<0.05	<0.05	<0.05	<0.16
Pheasant		1	<5.0		<0.10	<0.75	<0.60	<0.05	<0.06	0.20	<0.39
Potatoes		1	<5.0		<0.10	<0.68	<0.48	<0.05	<0.05	0.05	<0.33
Rosehips		1	<5.0		0.25	<0.71	<0.49	<0.05	<0.05	0.16	<0.34
Turnips		1	<5.0		0.14	<0.45	<0.34	<0.05	<0.05	<0.05	<0.23
Wild mushrooms		1	<5.0		<0.10		<0.71	<0.05	<0.07	18	<0.47
Grass		6	<5.0		0.57	<0.72	<0.51	<0.05	<0.06	0.33	<0.34
Grass	max				0.87	<1.8	<0.97		<0.09	0.58	<0.59
Soil		6	<5.0		1.3	<0.24	<0.43	<0.05	<0.06	14	<0.47
Soil	max				2.0	<0.46	<0.52			15	<0.57
Freshwater	Loch Calder	1	<1.0	<0.01		<0.01	<0.03		<0.01	<0.01	<0.02
Freshwater	Loch Shurrery	1	<1.0	<0.01		<0.01	<0.06		<0.01	<0.01	<0.03
Freshwater	Loch Baligill	1	<1.0	<0.05		<0.05	<0.08		<0.05	<0.05	<0.05
Freshwater	Heldale Water	1	<1.0	<0.05		<0.05	<0.07		<0.05	<0.05	<0.05

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		
Cabbage		1					<0.050	<0.050	<0.050		
Carrots		1					<0.050	<0.050	<0.050		
Cauliflower		1					<0.050	<0.050	<0.050		
Eggs		1					<0.050	<0.050	<0.050		
Honey		1					<0.050	<0.050	<0.050		
Lamb muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Parsnips		1					<0.050	<0.050	<0.050		
Pheasant		1					<0.050	<0.050	<0.050		
Potatoes		1					<0.050	<0.050	<0.050		
Rosehips		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		0.42	<0.032	0.44	<0.050	<0.053	<0.052		
Grass	max			1.3	0.056	1.4		0.070	0.060		
Soil		6	1.8	28	1.8	27	<0.040	<0.28	0.27		
Soil	max		2.1	46	4.7	41	<0.050	0.39	0.77		
Freshwater	Loch Calder	1							<0.01	<0.010	0.041
Freshwater	Loch Shurrery	1							<0.01	<0.010	0.041
Freshwater	Loch Baligill	1							<0.05	0.014	0.076
Freshwater	Heldale Water	1							<0.05	<0.011	0.079

[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*

Table 3.2(b). Monitoring of radiation dose rates near Dounreay, 2014

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	0.049
Sandside Bay	Winkle bed	2	0.12
Oigin's Geo	Shingle and rocks	2	0.13
Brims Ness	Shingle and rocks	2	0.095
Melvich	Salt marsh	2	0.067
Melvich	Sand	2	0.051
Strathy	Sand	2	0.049
Thurso riverbank	Sediment	2	0.078
Achvarasdal	Grass	2	0.077
Thurso Park	Grass	2	0.071
Borrowston Mains	Grass	2	0.077
East of Dounreay	Grass	2	0.080
Castletown Harbour	Sand	2	0.066
Dunnet Bay	Sand	2	0.052
Mean beta dose rates			μSv h^{-1}
Sandside Bay	Sediment	2	<1.0
Oigin's Geo	Shingle and rocks	2	<1.0
Thurso riverbank	Sediment	2	<1.0
Castletown Harbour	Sand	2	<1.0

Table 3.2(c). Radioactivity in air near Dounreay, 2014

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	12	<0.010	<0.0079	<0.19
Reay	11	<0.010	0.012	<0.19
Balmore	12	<0.010	<0.0084	<0.19

Table 3.3(a). Concentrations of radionuclides in food and the environment near Harwell, 2014

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	<0.06	<1.0	<0.06	
Sediment	Appleford	3[E]		<0.66		7.5	<0.33
Sediment	Outfall (Sutton Courtenay)	4[E]		<0.79		11	<0.30
Sediment	Day's Lock	4[E]		<0.27		11	<0.31
Sediment	Lydebank Brook	4[E]		<0.89		7.7	<0.30
Freshwater	Day's Lock	4[E]	<3.0	<0.27		<0.22	
Freshwater	Lydebank Brook	4[E]	<3.1	<0.29		<0.25	
Freshwater	R Thames (above discharge point)	4[E]	<3.1	<0.22		<0.20	
Freshwater	R Thames (below discharge point)	4[E]	<3.1	<0.23		<0.20	

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		<0.06		
Sediment	Appleford	3[E]	<0.16	0.74	<130	220
Sediment	Outfall (Sutton Courtenay)	4[E]	0.71	<0.50	<130	270
Sediment	Day's Lock	4[E]	0.49	0.52	<130	210
Sediment	Lydebank Brook	4[E]	0.38	<0.45	<210	340
Freshwater	Day's Lock	4[E]			<0.056	0.24
Freshwater	Lydebank Brook	4[E]			<0.050	0.18
Freshwater	R Thames (above discharge point)	4[E]			<0.038	0.18
Freshwater	R Thames (below discharge point)	4[E]			<0.041	0.22

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}	
			Organic ^{3}H	^{3}H
Terrestrial samples				
Milk		2	<2.0	<2.0
Milk	max		<2.1	<2.1
Raspberries		1	<2.0	<2.0
Grass		1	<2.0	<2.0

[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, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Grass and mud	1	0.057
Appleford	Grass	1	0.066
Sutton Courtenay	Mud	1	0.059
Sutton Courtenay	Grass	1	0.072
Day's Lock	Grass	2	0.056

Table 3.4(a). Concentrations of radionuclides in food and the environment near Winfrith, 2014

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	1		<0.06		<0.07	
Crabs	Lulworth Banks	1	26	<0.06		<0.06	
Scallops	Lulworth Ledges	1		<0.06		<0.05	0.00033
Seaweed	Lulworth Cove	1[E]		<1.1	2.6	<0.78	
Seaweed	Bognor Rock	2[E]		<0.77	3.3	<0.63	
Seawater	Lulworth Cove	1[E]		<0.23		<0.20	

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	1		<0.18				
Crabs	Lulworth Banks	1		<0.16				
Scallops	Lulworth Ledges	1	0.0032	0.00081	*	*		
Seaweed	Lulworth Cove	1[E]		<0.69				
Seaweed	Bognor Rock	2[E]		<0.80				
Seawater	Lulworth Cove	1[E]		<0.30			<5.4	15

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		2	<2.0	<2.0	14	<0.06		
Milk	max							
Carrot		1	<2.0	<2.0	9.9	<0.08		
Grass		1	<2.0	<2.0	32	<0.09		
Sediment	North of site (Stream A)	1[E]				0.94	<140	<110
Sediment	R Frome (upstream)	1[E]				0.59	<110	<140
Sediment	R Frome (downstream)	1[E]				0.89	<140	<84
Sediment	R Win, East of site	1[E]				0.48	260	<120
Freshwater	North of site (Stream A)	2[E]		14		<0.22	<0.054	0.26
Freshwater	R Frome (upstream)	2[E]		<3.0		<0.23	<0.12	0.11
Freshwater	R Frome (downstream)	3[E]		<3.2		<0.20	<0.035	0.10
Freshwater	R Win, East of site	2[E]		<3.2		<0.27	<0.038	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, 2014

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand and shingle	1	0.055
Red Cliffe Point to Black Head	Shingle	1	0.048
Osmington Mills	Pebbles	1	0.053
Ringstead Bay	Sand	1	0.050
Durdle Door	Shingle	1	0.046
St Oswald's Head	Sand and shingle	1	0.048
Lulworth Cove	Sand	1	0.053
Kimmeridge Bay	Pebbles and sand	1	0.067
Swanage Bay 1	Sand	1	0.043
Swanage Bay 2	Sand	1	0.054
Swanage Bay 3	Sand and mud	1	0.048
Poole Harbour	Sand and shingle	1	0.046

Table 3.5. Concentrations of radionuclides in the environment near Culham, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Freshwater	River Thames (upstream)	2	<3.1				<0.18	<0.040	0.21
Freshwater	River Thames (downstream)	2	<3.1				<0.25	<0.052	0.21
Grass	1 km East of site perimeter	1	<9.5	11	<3.0	<0.24	<1.3		160
Sediment	River Thames (upstream)	2					14		
Sediment	River Thames (downstream)	2					16		
Soil	1 km East of site perimeter	1	<3.8	<3.7	16	<2.0	2.7		360

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

4. Nuclear power stations

Key points

- *Total doses* for the representative person were less than 3 per cent of the dose limit for all sites assessed
- Electricity production continued at one Magnox station (Wylfa), one PWR station (Sizewell B) and seven AGR stations in 2014
- Discharges, environmental concentrations and dose rates in 2014 were broadly similar to those in 2013
- Concentrations of radiocaesium and transuranic elements were enhanced around some sites. These were mainly due to discharges from Sellafield

Berkeley, Gloucestershire and Oldbury, South Gloucestershire

- *Total dose* for the representative person decreased in 2014
- New source specific assessment undertaken to determine dose to houseboat dwellers

Bradwell, Essex

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

Chapelcross, Dumfries and Galloway

- *Total dose* for the representative person decreased in 2014
- Gaseous discharges of tritium decreased in 2014

Dungeness, Kent

- Gaseous discharges of carbon-14, sulphur-35, and argon-41 increased, and liquid discharges of tritium decreased, from Dungeness B in 2014

Hartlepool, County Durham

- *Total dose* for the representative person increased in 2014
- Gaseous discharges of carbon-14 and sulphur-35 decreased and cobalt-60 increased, liquid discharges of tritium and sulphur-35 decreased, in 2014
- Environmental concentrations of a natural radionuclide were enhanced, though not related to power station operation

Heysham, Lancashire

- *Total dose* for the representative person decreased in 2014
- Gaseous discharges of carbon-14 decreased from Heysham 1. Liquid discharges decreased from Heysham 1, and tritium increased from Heysham 2, in 2014

Hinkley Point, Somerset

- Gaseous discharges of carbon-14 and argon-41 increased from Hinkley Point B, and liquid discharges of tritium and 'other radionuclides' decreased from Hinkley A, in 2014

Hunterston, North Ayrshire

- Gaseous discharges of tritium decreased from Hunterston B in 2014

Sizewell, Suffolk

- Gaseous discharges of carbon-14 decreased at Sizewell A, and liquid discharges of tritium increased from Sizewell B, in 2014

Torness, East Lothian

- Liquid discharges of tritium and "other radionuclides" increased, and caesium-137 decreased, in 2014

Trawsfynydd, Gwynedd

- *Total dose* for the representative person decreased in 2014
- Liquid discharges of tritium decreased in 2014

Wylfa, Isle of Anglesey

- *Total dose* for the representative person increased in 2014
- Power generation from the Magnox station is to continue beyond 2014
- Gaseous discharges of carbon-14 and sulphur-35 decreased and tritium increased in 2014

This section considers the results of environment and food monitoring by the Environment Agency, FSA and SEPA from nuclear power stations. There is a total of 19 nuclear power stations at 14 locations, nine in England (Berkeley, Oldbury, Bradwell, Calder Hall, Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell), three in Scotland (Chapelcross, Hunterston and Torness) and two in Wales (Trawsfynydd and Wylfa). Some of these stations are being decommissioned.

Eleven of the 19 nuclear power stations are older Magnox power stations, owned by NDA. NDA (set up under the Energy Act 2004) is a non-departmental public body, with a remit to secure the decommissioning and clean-up of

the UK's civil public sector nuclear licensed sites. Only one Magnox station (Wylfa) continued to generate electricity, others are in the process of de-fuelling or decommissioning. In March 2015, NDA published a business plan which summarises the programme of work at each of the sites during 2015/18 (NDA, 2015).

In 2012, NDA announced its competition for the PBO contracts for Magnox Limited. In March 2014, NDA announced that the Cavendish Fluor Partnership, a joint venture between Cavendish Nuclear (a wholly-owned subsidiary of Babcock International Group plc) and Fluor Corporation, had been selected as the preferred bidder in the competition to take ownership of Magnox Limited. In 2013, Magnox Limited managed ten nuclear sites and was owned and operated by Energy Solutions on behalf of NDA.

In September 2014, NDA formally appointed the Cavendish Fluor Partnership (CFP) as the new PBO for Magnox Limited (and RSRL). In November 2014, ONR received an application to relicense the ten Magnox sites into a single site licence company alongside the Harwell and Winfrith sites. As of 1st April 2015, Harwell and Winfrith sites, previously operated by RSRL, merged to be part of Magnox Limited. Concurrently the EPR 2010 radioactive substances permits for each site were also transferred to Magnox Limited.

Calder Hall is being decommissioned; it is operated by Sellafield Limited and discharges from this Magnox power station are considered in Section 2 because it is located at Sellafield.

Seven AGR power stations and one Pressurised Water Reactor (PWR) power station were owned and operated by EDF Energy Nuclear Generation Limited in 2014; these are Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B and Sizewell B Power Stations in England, and Hunterston B and Torness Power Stations in Scotland. All of these were generating electricity during 2014.

Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency and NRW in England and Wales, respectively and by SEPA in Scotland. In 2014, gaseous and liquid discharges were below regulated limits for each of the power stations (see Appendix 2). Independent monitoring of the environment around each of the power stations is conducted by the FSA and the Environment Agency in England and Wales, and by SEPA in Scotland. In Wales, this is conducted on behalf of NRW and the Welsh Government.

The medium-term trends in dose, discharges and environmental concentrations at these sites have been considered in a summary report (Environment Agency, FSA, NIEA and SEPA, 2010b).

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

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station is situated on the eastern bank of the River Severn and was powered by two Magnox reactors. Berkeley was the first commercial power station in the UK to enter into decommissioning. It ceased electricity generation in 1989 and de-fuelling was completed in 1992. Decommissioning is still in progress and radioactive wastes are still generated by these operations. The Berkeley site will enter the Care and Maintenance phase by the year 2021. Thereafter, the current plan is to de-license the Berkeley site (released from regulatory control). Final site clearance is expected to be achieved by 2079 (NDA, 2015).

The Oldbury Power Station is located on the south bank of the River Severn close to the village of Oldbury-on-Severn and has two Magnox reactors. Oldbury Power Station ceased electricity generation in 2012 and de-fuelling began in early 2013. The Oldbury site will enter the Care and Maintenance phase by the year 2027. Thereafter, the current plan is to de-license the Oldbury site (released from regulatory control). Final site clearance is expected to be achieved by 2101 (NDA, 2015). The radioactive substances permit (issued in January 2013) was varied by the Environment Agency in early 2014 to remove the use of the site's incinerator/oil burner as a permitted activity.

Berkeley and Oldbury sites are considered together for the purposes of environmental monitoring because the effects from both sites contribute to the same area. In August 2014, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al.*, 2015). A decrease in both the fish and crustacean consumption rates has been observed, together with a decrease in the occupancy rate, in comparison with those of the previous survey in 2007. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been less than 0.005 mSv in 2014 (Table 4.1), which was less than 0.5 per cent of the dose limit, and down from 0.010 mSv in 2013. The lower value

in 2014 was due to a combination of the revised habits information (a reduction in the occupancy rate and a revision of occupancy areas) and a decrease in the external exposure over intertidal areas. In 2014, the representative person was a 1-year-old infant consuming milk at high-rates (as opposed to an adult spending a large amount of time over sediments in 2013). The trend in the *total dose* over the period 2004 – 2014 is given in Figure 4.1. Any longer-term variations in *total doses* with time are attributable to changes in the contribution from direct radiation from the site.

Source specific assessments for a high-rate consumer of locally grown foods, and of fish and shellfish, give exposures that were also less than 0.005 mSv in 2014 (Table 4.1). The decrease in dose to a high-rate consumer of locally grown foods from 0.008 mSv (in 2013) was due to lower carbon-14 concentrations in milk in 2014. The dose to a consumer of fish and shellfish includes external radiation, a component due to the tritium historically originating from GE Healthcare Limited at Cardiff, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The reason for the decrease in this dose in 2014, from 0.018 mSv (in 2013), is the same as that for the *total dose*. In 2014, a new assessment was undertaken to determine the external exposure for houseboat dwellers in the vicinity of the Berkeley and Oldbury sites (as identified in the recent habits survey). The estimated dose was 0.022 mSv for this activity (Table 4.1). This estimate is determined as a cautious value (and therefore not included in the *total dose* assessment), because gamma dose rate measurements used were not necessarily representative of the type of ground type and houseboat location (as identified in the habits survey).

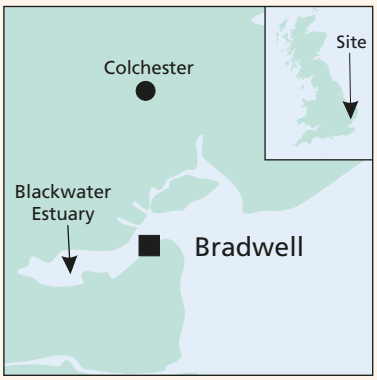
Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. A revised permit became effective on 1 May 2014, with the removal of the annual limits of sulphur-35 and argon-41 at Oldbury. The focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk and crops. Local freshwater samples were also analysed. Data for 2014 are given in Table 4.2(a). As in previous years, sulphur-35 was detected at very low levels in terrestrial food samples. Carbon-14 was detected in locally produced foods at concentrations close to background values. Carbon-14 concentrations in foodstuffs (milk) decreased by small amounts in comparison to those in 2013. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Liquid radioactive wastes are discharged to the Severn Estuary. Analyses of seafood and marine indicator materials and measurements of external radiation were conducted over muddy intertidal areas. Measurements of tritium in seafood were made in order to monitor the additional local effects of historical discharges from the GE Healthcare Limited radiopharmaceutical plant in Cardiff (see Section 6). Data for 2014 are given in Tables 4.2(a) and (b). Most of the artificial radioactivity detected was due to caesium-137, representing the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. There is now limited evidence to suggest that caesium-137 concentrations in sediment have been generally decreasing over the last decade (Figure 4.2). As in recent years, the tritium concentration in fish is reported as a less than value. In previous years, the levels of tritium in seafood have been relatively high and were likely to be mainly due to historical discharges from GE Healthcare Limited, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance. Gamma dose rates were generally lower in comparison to those in 2013.

4.2 Bradwell, Essex



The Bradwell site is located on the south side of the Blackwater Estuary. This Magnox power station ceased electricity production in 2002 after 40 years of operation, and de-fuelling was completed in 2006. The focus for the site is the completion of decommissioning projects. Bradwell will be the first Magnox site in England to enter the Care and Maintenance phase in 2018. The Care and Maintenance phase is expected to last for around 70 years. Thereafter, the plan is for final site clearance to be achieved by 2092 (NDA, 2015).

During 2014, the Environment Agency carried out a review of their own environmental monitoring programme, which concluded that the Bradwell programme was consistent with the published technical guidance (Environment Agency, FSA and SEPA, 2010). However, in response to requests from local stakeholders to enhance the environmental monitoring, whilst treatment of ILW (FED) was being carried out, the Environment Agency expanded the size of their environmental monitoring programme.

These enhancements to the environmental monitoring started at the beginning of 2015 and are only planned to remain in place whilst the ILW treatment is being carried out; thereafter it will then revert to the baseline requirements. This monitoring will therefore be reported first in RIFE 21. A habits survey is being carried out in 2015. Until the information from the 2015 habits survey becomes available (published), the previous habits survey will be used, which was undertaken in 2007 (Tipple *et al.*, 2008).

Doses to the public

The *total dose* from all pathways and sources of radiation was less than 0.005 mSv in 2014 (Table 4.1), which was less than 0.5 per cent of the dose limit for members of the public of 1 mSv, and unchanged from 2013. In 2014, adults were identified as the most exposed age group (prenatal child in 2013). The majority of the dose was received from the consumption of fish. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. Any significant variations in *total dose* with time were attributed to changes in the estimate of direct radiation.

The source specific assessments for a high-rate consumer of locally grown foods, and of fish and shellfish give an exposure that was also less than 0.005 mSv in 2014 (Table 4.1). The decrease in dose to a high-rate consumer of locally grown foods, from 0.005 mSv (in 2013) was due to lower carbon-14 concentrations in milk in 2014.

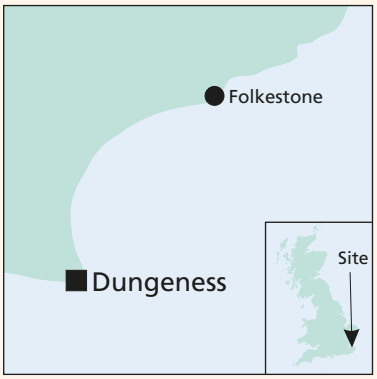
Gaseous discharges and terrestrial monitoring

This power station is permitted to discharge gaseous wastes to the local environment via stacks to the atmosphere. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch and public supplies. Data for 2014 are given in Table 4.3(a). Activity concentrations were low in terrestrial food samples, although some small enhancements of carbon-14 concentrations in terrestrial samples (including milk) were apparent. The gross alpha and beta activities in freshwater (public supplies) were less than the WHO screening levels for drinking water. As in previous years, the gross beta activities in water from the coastal ditch continued to be enhanced above background levels, and these were in excess of the WHO screening level for drinking water (1 Bq l^{-1}). Tritium concentrations in coastal ditches were similar to those in recent years, with positively detected values substantially below the EU reference level for tritium of 100 Bq l^{-1}. The water in the ditches is not known to be used as a source of drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged into the River Blackwater estuary. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Seaweeds were also analysed as an environmental indicator material. Data for 2014 are given in Tables 4.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source; however concentrations were generally similar to those in recent years. There is an overall decline in caesium-137 concentrations in sediments over the last decade (Figure 4.2), and the reported activity concentration is the lowest value in 2014. The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity. Gamma dose rates on beaches were difficult to distinguish from natural background.

4.3 Dungeness, Kent



The Dungeness power stations are located on the south Kent coast between Folkestone and Rye. There are two separate A and B nuclear power stations on neighbouring sites; the A station was powered by two Magnox reactors and the B station has two AGRs. Discharges are made via separate and adjacent outfalls and stacks, but for the purposes of environmental monitoring these are considered together. Dungeness A ceased generating electricity in 2006. De-fuelling of both Magnox reactors was completed in 2012, with the spent fuel being dispatched to Sellafield (Cumbria) for reprocessing. The Dungeness A site will enter the Care and Maintenance phase by the year 2027. Final site clearance is expected to be achieved by 2097 (NDA, 2015). Following an application to the NDA by EDF Energy, Dungeness B is now expected to continue electricity generation until 2028 (previously scheduled for cessation in 2018). EDF Energy must continue to demonstrate that the station complies with the Safety Cases which are reviewed by ONR to enable continued operation to 2028. The most recent habits survey was undertaken in 2010 (Clyne *et al.*, 2011b).

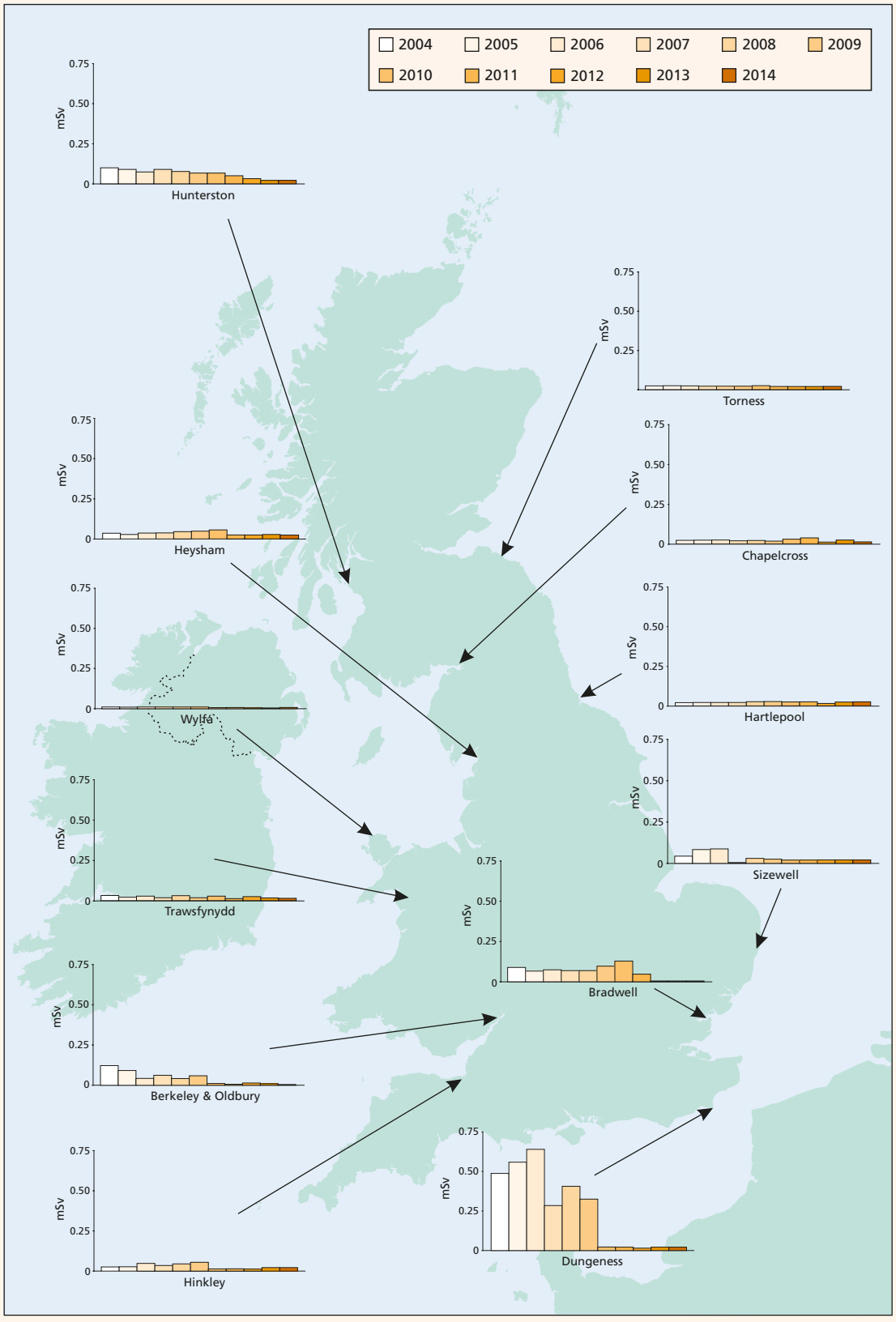


Figure 4.1. *Total dose* at nuclear power stations, 2004-2014
(Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was 0.021 mSv (Table 4.1), or approximately 2 per cent of the dose limit of 1 mSv, and unchanged from 2013. As in recent years, this is almost entirely due to direct radiation from the site. An adult living near to the site was the representative person. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total doses* ranged between 0.015 and 0.63 mSv over the time period and were dominated by direct radiation. Following the shut-down of the Magnox reactors in 2006, this dose has significantly declined.

Source specific assessments for a high-rate consumer of locally grown foodstuffs, for a local bait digger (who consumes large quantities of fish and shellfish and spends long periods of time in the location being assessed), and for a houseboat occupant give exposures that were less than the *total dose* (Table 4.1). The dose to a high-rate consumer of locally grown foods was estimated to be less than 0.005 mSv. The decrease in dose from 0.009 mSv (in 2013) was due to lower carbon-14 concentrations in milk in 2014. The dose to a houseboat dweller from external exposure was 0.005 mSv and the decrease from 0.017 mSv (in 2013) was because gamma dose rates were measured on different types of ground type (at Rye Bay) in 2014. In 2013 the ground type comprised of sand and mud, whereas in 2014 it comprised of sand and shingle.

Gaseous discharges and terrestrial monitoring

Discharges of carbon-14, sulphur-35 and argon-41 increased, by a small amount, from Dungeness B, in comparison to releases in 2013. The focus of the terrestrial sampling was analyses of tritium, carbon-14 and sulphur-35 in milk and crops. The results of monitoring for 2014 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods are reported as less than values (or close to). As in previous years, low concentrations of sulphur-35 were positively detected in some samples and carbon-14 was detected in locally produced foods at concentrations above background values; carbon-14 concentrations in milk decreased by small amounts in comparison to those in 2013. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium from Dungeness B decreased, in comparison to releases in 2013. Marine monitoring included gamma dose rate measurements, and analysis of seafood and sediments. The results of monitoring for 2014 are given in Tables 4.4(a) and (b). Caesium-137 concentrations in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield and La Hague. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. The low concentrations of transuranic nuclides in scallops were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood in 2014. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2); the apparent increase in 2010 was due to the inclusion of a value (<5.8 Bq kg^{-1}) which was reported as a less than value. Gamma dose rates were generally difficult to distinguish from the natural background.

4.4 Hartlepool, County Durham

Hartlepool Power Station is situated on the mouth of the Tees estuary, on the north east coast of England, and is powered by twin AGRs. It is estimated that its power generation will continue until at least 2019. In June 2014, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Garrod *et al.*, 2015b). An increase in the fish, crustacean and mollusc consumption rates has been observed, and an increase in the occupancy rate over sand, in comparison with those of the previous survey in 2008. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 1 (Table X2.2).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.027 mSv in 2014 (Table 4.1), which was less than 3 per cent of the dose limit, and up from 0.024 mSv in 2013. The small increase in *total dose* (from 2013) was due to an increase in the occupancy rate over sand, from the revision of the habits information in 2014. The representative person was an adult spending time living near to the site whose dose was from direct radiation (from the site) and, to a lesser extent, external exposure from activity in sand and sediment on local beaches. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both high-rate consumers of locally grown foodstuffs, and of fish and shellfish, give exposures that were less than the *total dose* (Table 4.1). The dose to a consumer of locally grown

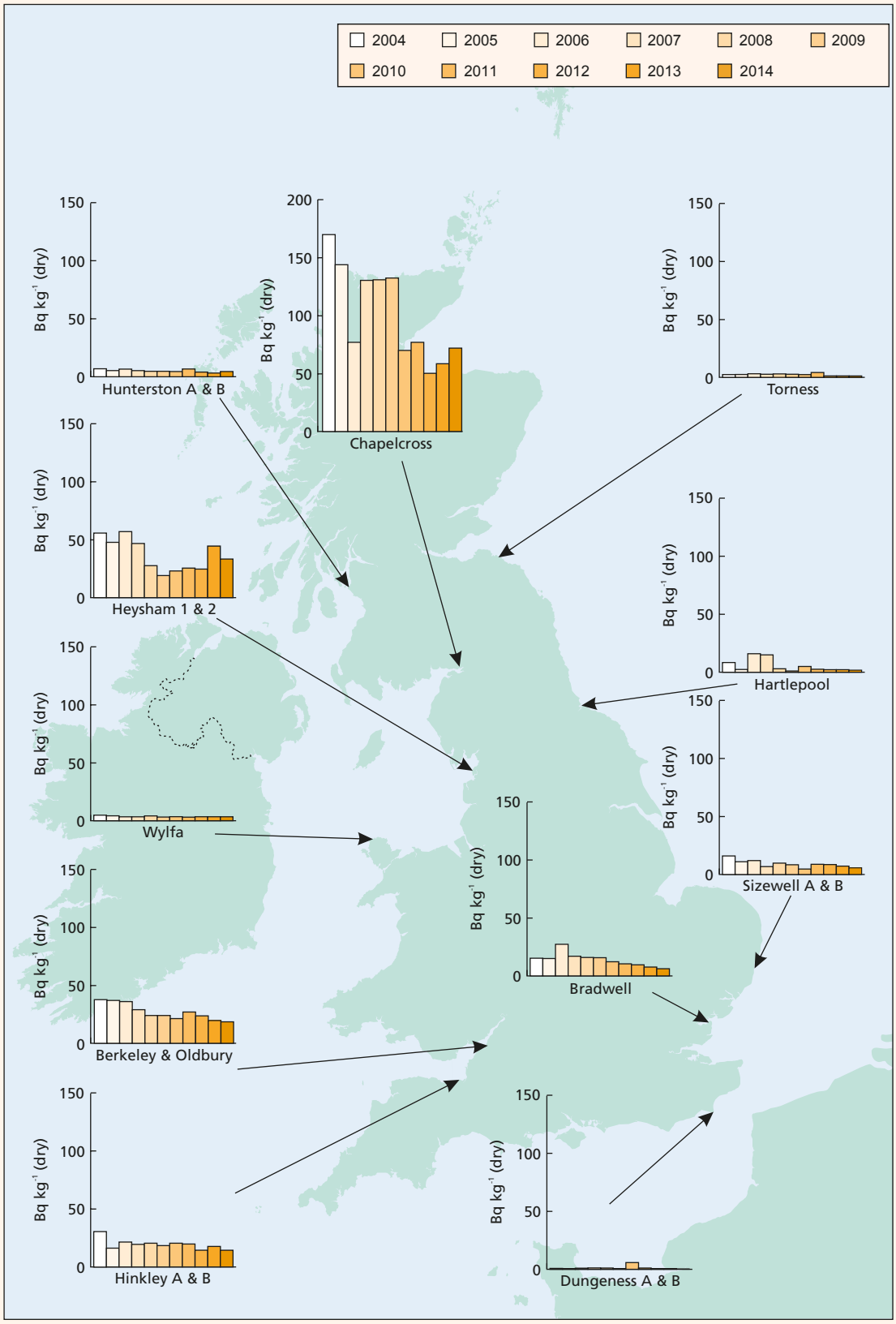


Figure 4.2. Caesium-137 concentration in marine sediments near nuclear power stations between 2004-2014

foods was less than 0.005 mSv. The dose in 2013 was 0.007 mSv, the decrease was mostly due to lower carbon-14 concentrations in milk in 2014. The dose to a local fish and shellfish consumer, including external radiation but excluding naturally occurring radionuclides, was 0.012 mSv. The dose in 2013 was 0.007 mSv, and the reason for the increase in 2014 is the same as that contributing to the maximum *total dose*. The dose received from collecting sea coal at Carr House was not assessed separately in 2014 due to revision of habits information (the occupancy rate for coal collecting was combined with the pathway for seafood consumers).

As in 2013 and 2012, a source specific assessment was undertaken in 2014 to determine the exposure from naturally occurring radionuclides, as a consequence of the reported polonium-210 concentrations in mollusc samples. In 2014, winkle samples collected for South Gare (inside the Tees Estuary entrance) consisted of a mixture including some winkles from the estuary entrance near Paddy's Hole. The area in the close proximity of Paddy's Hole was unlikely to sustain a high-rate consumption of winkles, as it is an extremely localised area which contains oil and other wastes. In addition, the habits survey undertaken in 2008 did not identify any consumption of molluscs from Paddy's Hole. However, in the event that some of these molluscs were a constituent of the diet of a high-rate consumer of fish and shellfish, the dose from naturally occurring radionuclides was assessed to be 0.068 mSv, in addition to that from artificial radionuclides. This estimate assumes that the median concentrations for naturally occurring radionuclides at background (Appendix 1, Table X4.1) be subtracted from the total concentrations as measured in 2014.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Discharges of carbon-14 and sulphur-35 decreased, and cobalt-60 increased, in comparison to releases in 2013. Analyses of tritium, carbon-14, sulphur-35 and gamma emitters were made in milk and crop samples. Samples of water are also taken from a borehole and public water supplies. Data for 2014 are given in Table 4.5(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, although small enhancements of sulphur-35 concentrations (reported as just above the less than value) were measured in food samples (excluding milk). Carbon-14 was detected in locally produced milk but has decreased in 2014 to expected background concentrations. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

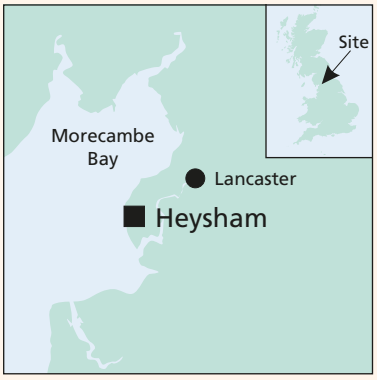
Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Discharges of tritium and sulphur-35 decreased in 2014, in comparison to those in 2013. Results of the aquatic monitoring programme conducted in 2014 are shown in Tables 4.5(a) and (b). Small enhancements of carbon-14 concentrations, above expected background, were observed in seafood samples. Enhancements are most likely to be due to carbon-14 discharges from a nearby non-nuclear site since carbon-14 discharges from the power station are low. Technetium-99 analysis in seaweed is used as a specific indication of the far-field effects of disposals to sea from Sellafield.

Concentrations in seaweed were low and much less than the peak observed in 1998 (see also Figure 2.9). They are less than 1 per cent of the equivalent concentrations near Sellafield. Iodine-131 was again positively detected in seaweed samples collected around the mouth of the River Tees Estuary in 2014. The detected values, as in previous years, are believed to originate from the therapeutic use of this radionuclide in a local hospital. Detectable concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. However, caesium-137 concentrations in sediment have remained low over the last 7 years (Figure 4.2). Overall, gamma dose rates in 2014 were generally similar to those in 2013.

In 2014, the reported polonium-210 concentration in winkles from South Gare was 18 Bq kg^{-1} and enhanced above the value expected due to natural sources. These samples (collected inside the Tees Estuary entrance) consisted of a mixture including some winkles collected from the estuary entrance near Paddy's Hole. The polonium-210 concentration is consistent with previously reported values in winkles from Paddy's Hole, obtained from sampling and analysis undertaken between in 2004 and 2006. The enhanced levels of polonium-210 were believed to be due to a combination of waste slag from local iron and steel industries, used in sea defences, and/or the build-up of naturally occurring gamma-emitting radionuclides in sediments at this location as the result of degradation of the sea defence materials over time.

4.5 Heysham, Lancashire



Heysham Power Station is situated on the Lancashire coast to the south of Morecambe and near the port of Heysham. This establishment comprises two separate nuclear power stations, both powered by two AGRs. It is estimated that Heysham 1 and 2 will continue to generate electricity until at least 2019 and 2023, respectively. Disposals of radioactive waste from both stations are made under permit via separate outfalls to Morecambe Bay and via stacks, but for the purposes of environmental monitoring both stations are considered together. The most recent habits survey was undertaken in 2011 (Garrod *et al.*, 2012).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.023 mSv in 2014 (Table 4.1), or approximately 2 per cent of the dose limit for members of the public, and down from 0.028 mSv in 2013. The lower value in 2014 was mostly due to a small decrease in the americium-241 concentrations in molluscs. The representative person was an adult who was a high-rate consumer of molluscs. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. Any changes in *total doses* from 2004 – 2010 were attributable to environmental variability (in measurements of gamma dose rates); thereafter (2011-2013) relatively lower *total doses* were estimated due to a lower occupancy rate over local beaches.

Source specific assessments for high-rate terrestrial food consumption, and from external exposure for turf cutting over salt marsh, give exposures that were less than the *total dose* (Table 4.1). The estimated dose from terrestrial food consumption in 2014 less than 0.005 mSv. The decrease in dose from 0.012 mSv (in 2013), was mostly due to lower carbon-14 concentrations in milk in 2014. The dose to a local fisherman, who was considered to consume a large amount of seafood and was exposed to external radiation over intertidal areas, was 0.032 mSv in 2014, which was approximately 3 per cent of the dose limit for members of the public of 1 mSv (Table 4.1), and slightly down compared to that in 2013 (0.036 mSv). The reason for the small increase in dose in 2014 is the same as that contributing to maximum *total dose*.

Gaseous discharges and terrestrial monitoring

Discharges of carbon-14 decreased at Heysham 1 in 2014, compared with 2013; other discharges of radionuclides were broadly comparable (including those from Heysham 2). The monitoring programme for the effects of gaseous disposals was similar to that for other power stations. Data for 2014 are given in Table 4.6(a). The effects of gaseous disposals were difficult to detect in 2014. Carbon-14 was detected in locally produced milk but has decreased in 2014 to expected background concentrations. Small enhancements of concentrations of sulphur-35 were measured in some samples (reported as just above the less than value), but activities of cobalt-60 are all reported as less than values.

Liquid waste discharges and aquatic monitoring

All permitted discharges decreased from Heysham 1 and tritium increased from Heysham 2, compared with those in 2013. The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates and for completeness the data considered in this section include all of those for Morecambe Bay. A substantial part of the programme is in place in order to monitor the effects of Sellafield disposals. The results for 2014 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2013 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in flounder, shrimps and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham, although relatively higher concentrations were measured in winkle and seawater samples (detected when sampling coincides with the periodic discharges). Concentrations of technetium-99 in marine samples remained at levels typical of recent years, caused by discharges from Sellafield, but concentrations of americium-241 were slightly lower (compared to those in 2013). In 2014, strontium-90 concentrations were detected at low levels (close to, or just above, the less than value) in food samples. Gamma dose rates over intertidal sediment were generally similar to measurements in recent years.

4.6 Hinkley Point, Somerset

The Hinkley Point Power Station sites are situated on the Somerset coast, west of the River Parrett estuary. There are two separate A and B stations that include two Magnox reactors and two AGRs, respectively. Hinkley Point A started electricity generation in 1965 and ceased in 2000. This station completed de-fuelling in 2004 and is undergoing decommissioning. The Hinkley Point A site will enter the Care and Maintenance phase by the year 2025. Final site clearance is expected to be achieved by 2090 (NDA, 2015). It is estimated that power generation will continue at Hinkley Point B until at least 2023. A single environmental monitoring programme covers the effects of the two power stations.

In 2013, the Secretary of State for Energy and Climate Change granted a planning consent order to EDF Energy to build and operate Hinkley Point C and associated development. The decision follows the submission of EDF Energy's application to the Infrastructure Planning Commission (now the Planning Inspectorate) in 2011. More information concerning decisions on environmental permit applications for the proposed nuclear power plant can be found at: https://www.gov.uk/government/collections/hinkley-point. In March 2014, ONR published its assessment of a Pre-Construction Safety Report submitted by NNB GenCo Limited for the Hinkley Point C

licensed site: http://www.onr.org.uk/hinkley-point-c/assessment-reports.htm#preconstruction.

In 2013, Hinkley A commenced draining and cleaning of fuel pond of Reactor 1 and this work was concluded with the complete draining and stabilisation of the pond in early 2014. The most recent habits survey was conducted in 2010 (Clyne *et al.*, 2011a).

Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was 0.022 mSv (Table 4.1), or approximately 2 per cent of the dose limit, and unchanged from 2013. An adult who spent a large amount of time over sediments was the representative person. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. In 2010, the decrease in *total dose* (and continued thereafter) was attributed to relatively lower gamma dose rates over local beaches.

A source specific assessment for a high-rate consumer of locally grown food gives an exposure that was less than the *total dose* (Table 4.1). The dose to this consumer was 0.010 mSv in 2014. The decrease in dose (from 0.015 mSv in 2013) was mostly due to lower carbon-14 concentrations in milk, but also because the contribution of domestic fruit (containing carbon-14 activity) not being sampled in the assessment, in 2014. The samples collected can vary between years. For example, in 2014 domestic fruit was not collected in Hinkley. FSA will adapt their sampling schedule in future to account for potential dose contributors. This is in line with the risk-based review of the FSA's monitoring programme. The dose to a local fisherman, who consumed a large amount of seafood and was exposed to external radiation over intertidal areas, was 0.032 mSv in 2014, which was approximately 3 per cent of the dose limit for members of the public of 1 mSv, and generally similar to that in 2013 (0.031 mSv). This estimate also includes the effects of discharges (current and historical) of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1).

Gaseous discharges and terrestrial monitoring

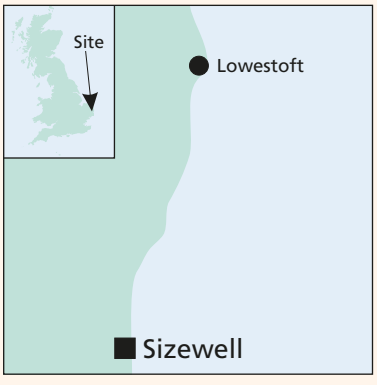
Gaseous radioactive waste is discharged via separate stacks to the local environment. Discharges of carbon-14 and argon-41 from Hinkley Pont B increased by a small amount, in comparison to releases in 2013. Analyses of milk and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. Data for 2014 are given in Table 4.7(a). Activity concentrations of tritium and gamma emitters (including caesium-137) in terrestrial materials are reported as less than values. Sulphur-35 from Hinkley Point B was detected at low concentrations in some of the food samples (excluding milk). Carbon-14 concentrations in all foods were higher than the default values used to represent background levels. Some carbon-14 concentrations in foodstuffs decreased by small amounts (milk and honey), in comparison to those in 2013. Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent from both power stations are made via separate outfalls into the Bristol Channel. Discharges of tritium and 'other radionuclides' from Hinkley Point A decreased in 2014, in comparison to those in 2013. Analyses of seafood and marine indicator materials and measurements of external radiation were conducted over intertidal areas. Measurements of tritium and carbon-14 are made primarily to establish the local effects of historical discharges from the GE Healthcare Limited plant at Cardiff.

The environmental results for 2014 are given in Tables 4.7 (a) and (b). Where results can be compared, the concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in recent years (see also Figure 4.2). Concentrations of tritium in shellfish in 2014 were similar in comparison to those in recent years. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors to the aquatic environment are Sellafield, GE Healthcare Limited at Cardiff, weapons tests and Chernobyl fallout. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Overall, gamma dose rates over intertidal sediment in 2014 were generally similar to measurements in recent years.

4.7 Sizewell, Suffolk



The two Sizewell Power Stations are located on the Suffolk coast, near Leiston. Sizewell A is a Magnox twin reactor site. Sizewell B, powered by one reactor, is the only commercial PWR power station in the UK. The B station began operation in 1995 and it is estimated that it will end power generation by 2035. Sizewell A power station ceased to be an

electricity generator in 2006 and de-fuelling completed with the final flask of spent fuel leaving the site in August 2014. The Sizewell A site will enter the Care and Maintenance phase by the year 2027. Final site clearance is expected to be achieved by 2097 (NDA, 2015). The radioactive substances permit for Sizewell A (issued in January 2013) was varied by the Environment Agency in early 2014, to remove the use of site's incinerator/oil burner as a permitted activity. The most recent habits survey was conducted in 2010 (Garrod *et al.*, 2011).

Doses to the public

The *total dose* from all pathways and sources was 0.020 mSv in 2014 (Table 4.1) or 2 per cent of the dose limit, and similar to the value of 0.021 mSv in 2013. As in recent years, the dominant contribution to *total dose* was from direct radiation and the representative person was an adult living in the vicinity of the site. Dose from this pathway has reduced by a factor of three since Sizewell A ceased generation in 2006. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. The *total dose* declined at the end of 2006, following the closure of the Magnox reactors at Sizewell A, thereafter any variations were due to the change in the contribution from direct radiation from the site.

Source specific assessments for both a high-rate consumer of locally grown foodstuffs, and of fish and shellfish, and of external exposure for houseboat occupancy, give exposures that were less than the *total dose* in 2014 (Table 4.1). The dose to a consumer of locally grown foods was less than 0.005 mSv. The dose in 2013 was 0.008 mSv, the decrease was mostly due to lower carbon-14 concentrations in milk in 2014. The dose to a houseboat dweller from external exposure was less than 0.005 mSv. The decrease from 0.018 mSv in 2013 was due to lower dose rates from mud at Southwold Harbour in 2014.

Gaseous discharges and terrestrial monitoring

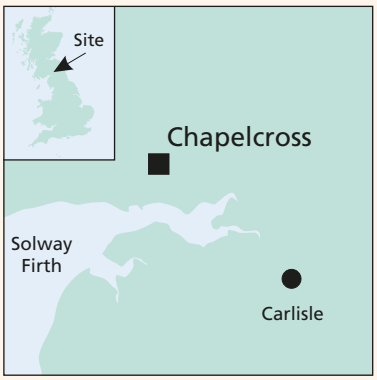
Gaseous wastes are discharged via separate stacks to the local environment. Discharges of carbon-14 at Sizewell A decreased in 2014, compared with 2013; other discharges of radionuclides were similar (including those from Sizewell B). The results of the terrestrial monitoring in 2014 are shown in Table 4.8 (a). Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk and crops generally showed very low concentrations of artificial radionuclides near the power stations in 2014. Carbon-14 concentrations were detected in locally produced milk, above background concentrations, and these decreased by small amounts, in comparison to those in 2013. Tritium concentrations in local freshwater were all low, although those measured at the Leisure Park were positively detected above the less than value (previously observed in 2010). Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made via outfalls to the North Sea. Tritium discharges increased from Sizewell B in comparison to those in 2013. In the aquatic programme, analysis of seafood, sediment, and seawater, and measurements of gamma dose rates were conducted in intertidal areas. Data for 2014 are given in Tables 4.8(a) and (b). Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium concentrations in seafood are all reported as less than values. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Overall, gamma radiation dose rates over intertidal areas were difficult to distinguish from the natural background, although the dose rates at Southwold Harbour decreased in comparison to those in 2013, most likely due to natural variation.

SCOTLAND

4.8 Chapelcross, Dumfries and Galloway



Chapelcross was Scotland's first commercial nuclear power station and has four Magnox reactors located near the town of Annan in Dumfries and Galloway. After 45 years of continuous operation, electricity generation ceased in 2004 and the station has been preparing for decommissioning. De-fuelling of the reactors began in 2008 and was completed during 2013. The major hazards on the site will now be addressed early during decommissioning, by 2017. Current plans are for the site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2095 (NDA, 2015).

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2010 (Clyne *et al.*, 2013a). In 2012, a habits survey was also conducted to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast (Garrod *et al.*, 2013a). The results of this survey are used to determine the potential exposure pathways

relating to permitted liquid discharges from the Sellafield nuclear licensed site in Cumbria (see Section 2.3.1).

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.014 mSv in 2014 (Table 4.1), which was less than 2 per cent of the dose limit, and down from 0.024 mSv in 2013. In 2014, an adult who spent a large amount of time over sediments was the representative person, and was a change from that in 2013 (an infant consuming milk). The decrease in *total dose,* and change in the representative person, (from 2013) was mostly attributed to the exclusion of a less than value for americium-241 activity in food in the 2014 assessment. In line with the rules on use of the results for dose calculations, americium-241 was excluded because detectable activity was not observed in other samples from the terrestrial environment (unlike in 2013) in 2014. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for a high-rate consumer of locally grown food and seafood (crustaceans), and for a salmon and wildfowl consumer, give exposures that were less than the *total dose* in 2014 (Table 4.1). The dose for the terrestrial food consumer was estimated to be 0.008 mSv in 2014. The reason for the decrease in dose (from 0.018 mSv in 2013) in 2014 is the same as that contributing to the maximum *total dose*. The dose for the salmon and wildfowl consumer was 0.010 mSv in 2014. The increase, from less than 0.005 mSv in 2013, was mostly due to higher dose rates over salt marsh at the pipeline and Dornoch Brow in 2014.

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

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. In 2014, discharges of tritium decreased by a small amount, in comparison to releases in 2013. As a result of an unscheduled increase in gaseous tritium discharges from a number of outlets (see Table A2.4 for further information), the reported discharges of tritium exceeded a sub-limit for gaseous disposals from the site. The assessed tritium discharges arising from unscheduled increase are well below the annual authorised site limit.

Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit, crops and game, as well as grass, soil and freshwater samples, for a range of radionuclides. Air samples at three locations were also monitored to investigate the inhalation pathway.

The results of terrestrial food and air monitoring in 2014 are given in Tables 4.9(a) and (c). The activity concentrations of radionuclides in milk and grass were generally similar to those observed in previous years. As in 2013, carbon-14 concentrations in milk were similar to the default values used to represent background levels. Americium-241 concentrations in all terrestrial food samples are reported as less than values in 2014. The results for terrestrial foods show the effects of discharges from Chapelcross in the concentrations of tritium in a range of foods, and these were mostly reported as just above or as the less than value. As in recent years, the level of tritium was measured well above the detection limit in one freshwater sample (Gullielands Burn). Activity concentrations in air samples at locations near to the site are reported as less than values (Table 4.9(c)).

Liquid waste discharges and aquatic monitoring

Radioactive liquid effluents are discharged to the Solway Firth. Samples of seawater and *Fucus vesiculosus*, as environmental indicators, were collected in addition to seafood, sediments and dose rates. Data for 2014 are given in Tables 4.9(a) and (b). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years. Low concentrations of cobalt-60 and europium-155 were positively detected (just above the less than value) in sediment samples. As in recent years concentrations of caesium-137, plutonium radionuclides and americium-241 were enhanced in sediment taken close to the pipeline in 2014. Concentrations of technetium-99 in biota were generally similar to those observed in recent years. Concentrations of caesium-137 in sediments, largely due to Sellafield, are generally in decline over the last decade (Figure 4.2). In 2014, gamma dose rates (where comparisons can be made) were generally higher than those in in 2013. Measurements of the contact beta dose rate on stake nets are reported as less than values in 2014.

Between 1992 and 2009, a number of particles were found at the end of the discharge outfall consisting of lime-scale originating from deposits within the pipeline. Magnox Limited continues to monitor this area frequently and no particles were found during 2014 (as for the interim years). The relining of the pipeline and grouting at strategic points, which was undertaken in 2009/2010, has reduced the potential for particles to be released.

4.9 Hunterston, North Ayrshire

Hunterston Power Station is located on the Ayrshire coast near West Kilbride. At this location there are two separate nuclear power stations - Hunterston A and Hunterston B.

Hunterston A was powered by twin Magnox reactors until it ceased electricity production in 1990 and is now being decommissioned by Magnox Limited. Decommissioning activities have continued throughout 2014 at Hunterston A. The decommissioning activities include the ongoing draining and cleaning of the cartridge (nuclear fuel) cooling pond and the construction and commissioning of new facilities for the retrieval, conditioning and long term storage of legacy higher activity waste. The transfer of higher activity waste into the new Intermediate Level Radioactive Waste Store (ILWS) commenced during 2014. This represents a significant milestone in the decommissioning of the site and makes progress towards ensuring that all higher activity waste is stored in a passively safe manner. Current plans are for the Hunterston A site to be de-licensed (released from regulatory control) with final site clearance to be achieved by 2080 (NDA, 2015).

In 2014, SEPA issued a new authorisation to Magnox Limited in relation to decommissioning work at Hunterston A. The new authorisation took effect on 1st July 2014 and replaced the previous three authorisations that were individually applied to liquid, gaseous and solid radioactive waste disposals. The discharge limits in the new authorisation have been significantly reduced compared to the previous authorisations. This reduction reflects the actual discharges that were being made whilst still providing Magnox Limited with sufficient flexibility to undertake its decommissioning activities. Discharge limits effective during 2014 (January to June; July to December) are given in Appendix 2.

Hunterston B is powered by a pair of AGRs. Due to issues with the boiler tubes a number of years ago, the station is limited to approximately 80 per cent of its design output. The life of the station has been extended twice, and the current end of generation is set for 2023.

In 2013, EDF Energy applied to SEPA to vary Hunterston B's authorisation in order to allow radioactive waste to be disposed of by transfer to any waste permitted person, both within the UK and overseas, and to be able to accept radioactive waste from other EDF Energy stations for the purposes of bulking up low volume wastes before final disposal. The proposed variation does not include any changes to the station's authorised limits for discharges to the environment. During 2014, the application went out for statutory and public consultation and is still being determined by SEPA.

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

Doses to the public

The *total dose* from all pathways and sources of radiation is assessed to have been 0.021 mSv in 2014 (Table 4.1), which was approximately 2 per cent of the dose limit, and unchanged from 2013. The dose was mainly from direct radiation from the site, and the representative person was a prenatal child of local inhabitants. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. The decrease in *total dose* in recent years reflected a downward trend in the reported direct radiation.

Source specific assessments for both a high-rate consumer of locally grown food and of local seafood give exposures that were unchanged to those in 2013 and less than the *total dose* in 2013 (Table 4.1). The estimated dose to a terrestrial food consumer was 0.009 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv. The dose to a fish and shellfish consumer was less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. Discharges of tritium decreased by small amounts from Hunterston B, in comparison to those releases in 2013. There is a substantial terrestrial monitoring programme which includes the analyses of a comprehensive range of wild and locally produced foods. In addition, air, freshwater, grass and soil are sampled to provide background information. The results of terrestrial food and air monitoring in 2013 are given in Tables 4.10(a) and (c). The concentrations of radionuclides in air, milk, crops and fruit were generally low and, where comparisons can be drawn, similar to those in previous years. Some carbon-14 concentrations in foodstuffs were higher than the default values used to represent background levels (apples, turnips and wild fruit). Activity concentrations in air at locations near to the site are reported as less than values (or close to) (Table 4.10(c)).

Liquid waste discharges and aquatic monitoring

Authorised liquid discharges from both Hunterston stations are made to the Firth of Clyde via the Hunterston B station's cooling water outfall. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials.

The results of aquatic monitoring in 2014 are shown in Tables 4.10(a) and (b). The concentrations of artificial radionuclides in the marine environment are predominantly due to Sellafield discharges, the general values being consistent with those to be expected at this distance from Sellafield. The reported concentrations of technetium-99 from Sellafield in crabs around Hunterston were very low (just above the less than value). In lobsters, technetium-99 concentrations continued to remain low in 2014 and were lower to those reported in 2013. Small concentrations (above the less than value) of activation products (silver-110m) were also detected in some foodstuffs, which were likely to have originated from the site, but these were of negligible radiological significance. Gamma dose rates were generally similar to those in 2013. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2).

4.10 Torness, East Lothian

Torness Power Station is located near Dunbar on the east coast of Scotland. This station, which is powered by two AGRs, began operation at the end of 1987 and it is currently scheduled to cease generation in 2023. Disposals and discharges of radioactive waste from the site are made in accordance with the RSA 93 authorisation issued to the site by SEPA in 2007.

In December 2013, EDF Energy applied to SEPA to vary the authorisation for Torness in order to allow radioactive waste to be disposed of by transfer to any waste permitted person, both within the UK and overseas, and to be able to accept radioactive waste from other EDF Energy stations for the purposes of bulking up low volume wastes before final disposal. The proposed variation does not include any changes to the site's authorised limited for discharges to the local environment. During 2014, the application was subject to statutory and public consultation and is still being determined by SEPA.

EDF Energy is continuing with its programme to reduce carbon deposition within the reactor and has continued to inject carbonyl sulphide (COS) into both reactors during 2014. This process was started in 2011 and after the initial expected increase in sulphur-35 levels discharged to the local environment, via the liquid and gaseous routes, the levels have stabilised. In 2014, the sulphur-35 discharged to the local environment was similar to that discharged in 2013 and remained within the authorised limits. The gaseous and liquid discharges from the site are given in Appendix 2.

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

Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was 0.020 mSv (Table 4.1) or 2 per cent of the dose limit, and unchanged from the previous 3 years. Direct radiation was the dominant contributor to the dose and the representative person was an adult. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both a high-rate consumer of locally grown foods and of local fish and shellfish give exposures that were less than the *total dose* in 2014 (Table 4.1). The estimated dose to a terrestrial food consumer was 0.006 mSv, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv, and unchanged from recent years. The dose to a fish and shellfish consumer was less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops, fruit, and game as well as grass, soil and freshwater samples, were measured for a range of radionuclides. Air sampling at three locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2014 are given in Tables 4.11(a) and (c). As in recent years, the effects of discharges from the power station were not observed for concentrations of sulphur-35, which are reported as less than values in terrestrial foods and environmental indicator materials. In 2014, americium-241 concentrations, measured by gamma–ray spectrometry, are reported as less than values. Measured concentrations of radioactivity in air at locations near to the site are reported as less than values (or close to) (Table 4.11(c)).

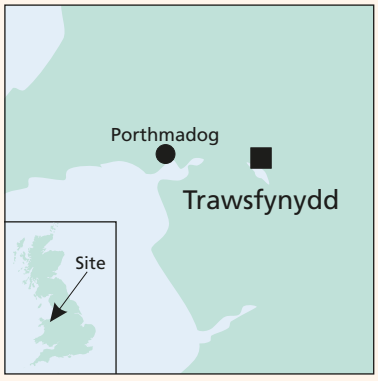
Liquid waste discharges and aquatic monitoring

Discharges of tritium decreased by a small amount, in comparison to those releases in 2013. Samples of seawater and *Fucus vesiculosus*, as useful environmental indicators, were collected in addition to seafood. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

The results of the aquatic monitoring in 2014 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout. In 2014, an americium-241 concentration was elevated in a *nephrops* sample (from Dunbar Bay). As in recent years, a few very low concentrations of activation products were detected in environmental indicator samples. These were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2013. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Beta radiation from fishermen's pots are reported as less than values. Gamma dose rates over intertidal areas were generally indistinguishable from natural background and were similar to those measured in recent years.

WALES

4.11 Trawsfynydd, Gwynedd



Trawsfynydd Power Station is located inland, on the northern bank of a lake in the heart of Snowdonia National Park, North Wales and was powered by twin Magnox reactors. Trawsfynydd ceased to generate electricity in 1991. De-fuelling of the reactors was completed in 1995 and the station is being decommissioned. The focus for the site is now the completion of decommissioning projects. The Trawsfynydd site will enter the Care and Maintenance phase in 2016. Final site clearance is expected to be achieved by 2083 (NDA, 2015). The most recent habits survey was undertaken in 2005 (Tipple *et al.,* 2006).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.013 mSv in 2014 (Table 4.1), which was approximately 1 per cent of the dose limit, and down from 0.017 mSv in 2013. The decrease in *total dose* was mostly due to lower carbon-14 concentrations in milk in 2014. The representative person was an infant living near to the site. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments were undertaken for a high-rate consumer of locally grown foods and for an angler (Table 4.1). The dose to an angler (who consumes large quantities of fish and spends long periods of time in the location being assessed) was 0.007 mSv in 2014, which was less than 1 per cent of the dose limit for members of the public of 1 mSv. The observed activity concentrations in lake sediments are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels. The decrease from the estimate of 0.013 mSv in 2013 was mostly due to lower caesium-137 concentrations in lake sediments in 2014. The dose to an infant consuming terrestrial food was 0.025 mSv, or less than 3 percent of the dose limit. The dose in 2013 was 0.035 mSv, and the reason for the decrease in dose in 2014 was the same as that for the *total dose*.

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, for local milk, crop and grass samples in 2014, are shown in Table 4.12(a). Results from surveys, for activity concentrations in sheep samples, are available in earlier RIFE reports (e.g. Environment Agency, FSA, NIEA, NRW and SEPA, 2014). Concentrations of activity in all terrestrial samples were low. Carbon-14 was detected in locally produced milk but has decreased in 2014 to expected background concentrations. As in previous years, measured activities for caesium-137 are mostly reported as less than values (or close to). The most likely source of small amounts of caesium-137 is fallout from Chernobyl and weapon tests, though it is conceivable that a small contribution may be made by re-suspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also conducted in crop samples (and in animal samples in previous years). In 2014, detected activities in crops were low and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was no evidence of re-suspension of activity in sediment from the lake shore contributing to increased exposure from transuranic radionuclides in 2014.

Liquid waste discharges and aquatic monitoring

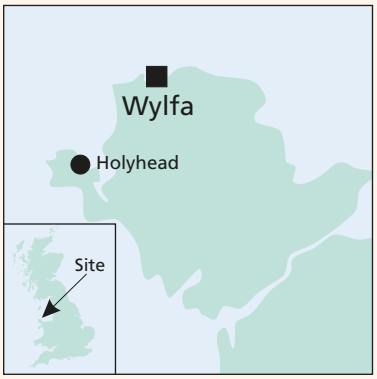
Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK

terms. Discharges of tritium and "other radionuclides" increased, and caesium-137 decreased, by small amounts in comparison to those in 2013. The aquatic monitoring programme was directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. Freshwater and sediment samples are also analysed. Habits surveys have established that the species of fish regularly consumed are brown and rainbow trout. Most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than indigenous fish.

Data for 2014 are given in Tables 4.12(a) and (b). The majority of activity concentrations in fish and sediments result from historical discharges. Concentrations of radiocaesium in fish in 2014 were similar to those in recent years. Concentrations in the water column are predominantly maintained by processes that release activity (such as remobilisation) from near surface sediments. Low concentrations of other radionuclides including transuranics were also detected, particularly in lake sediments; in previous years' monitoring, it has been demonstrated that these concentrations increase with depth beneath the sediment surface. Caesium-137 concentrations in the lake sediments decreased overall in comparison to those in 2013 (and similar to those in earlier years). In 2014, sediment concentrations of strontium-90, americium-241 and plutonium radionuclide at one location (fish farm) were lower than those in 2013 (and similar to those in earlier years), but overall, sediment activity concentrations in 2014 were similar to those in other recent years. Strontium-90 and transuranic concentrations in fish continued to be very low in 2014 and it is the effects of caesium-137 that dominate the fish consumption and external radiation pathways.

In the lake itself, there remains clear evidence of activity concentrations from the site's liquid discharges. However, gamma dose rates found on the shoreline where anglers fish were difficult to distinguish from background levels, although there is limited evidence to suggest that rates were slightly higher in 2014 (and in most recent years). The predominant radionuclide was caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.3. A substantial decline in levels was observed in the late 1990's in line with reducing discharges. In the earlier part of the last decade, the observed concentrations were mainly affected by sample variability. In the latter part of the last decade, with sustained reductions in discharges of caesium-137, there was a general progressive decrease in these concentrations in sediments, with the lowest concentrations reported in 2010. In years thereafter, there has been an overall small increase in activity concentrations, but activities generally decreasing again from the small peak in discharge in 2012.

4.12 Wylfa, Isle of Anglesey



Wylfa Power Station is the only Magnox site still generating electricity. The site is located on the north coast of Anglesey and has two Magnox reactors (Reactor 1 and 2). It was the last and largest power station of its type to be built in the UK and commenced electricity generation in 1971. Reactor 2 at the Wylfa site ceased generating electricity in 2012. In 2013, a decision report was published by ONR, issuing consent for Magnox Limited to start decommissioning Wylfa power station within the next five years (ONR, 2013). In September 2014, consent was given to continue electricity generation from Reactor 1 until the end of December 2015; following the submission of a Periodic Safety Review (PSR) by the operator and its subsequent review by the ONR. The operator will continue the programme (approved by ONR) of transferring partially used fuel from Reactor 2 to Reactor 1, enabling electricity generation to be maintained.

The most recent habits survey was undertaken in 2013 (Garrod *et al.*, 2014).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.007 mSv in 2014 (Table 4.1), which was approximately 0.5 per cent of the dose limit, and up from less than 0.005 mSv in 2013. In 2014, the representative person was a local adult who spends a large amount of time over sediments. The increase in *total dose* (from 2013) was because gamma dose rates were measured on different types of ground type from one year to the next. The trend in *total dose* over the period 2004 – 2014 is given in Figure 4.1. *Total dose*s remained broadly similar from year to year, and were low.

Source specific assessment for a high-rate consumer of both locally grown foods gives an exposure that was less than the *total dose* in 2014 (Table 4.1). The dose to a consumer of locally grown foods was less than 0.005 mSv. The dose in 2013 was 0.010 mSv, the decrease was mostly due to lower carbon-14 concentrations in milk (~0.005 mSv), and to a lesser extent, sulphur-35 concentrations in milk (~0.001 mSv) in 2014. The dose to a high-rate consumer of fish and shellfish (including external radiation) was 0.010 mSv. The reason for the small increase in dose in 2014 (from 0.007 mSv in 2013) was because gamma dose rates were measured on different types of ground type from one year to the next.

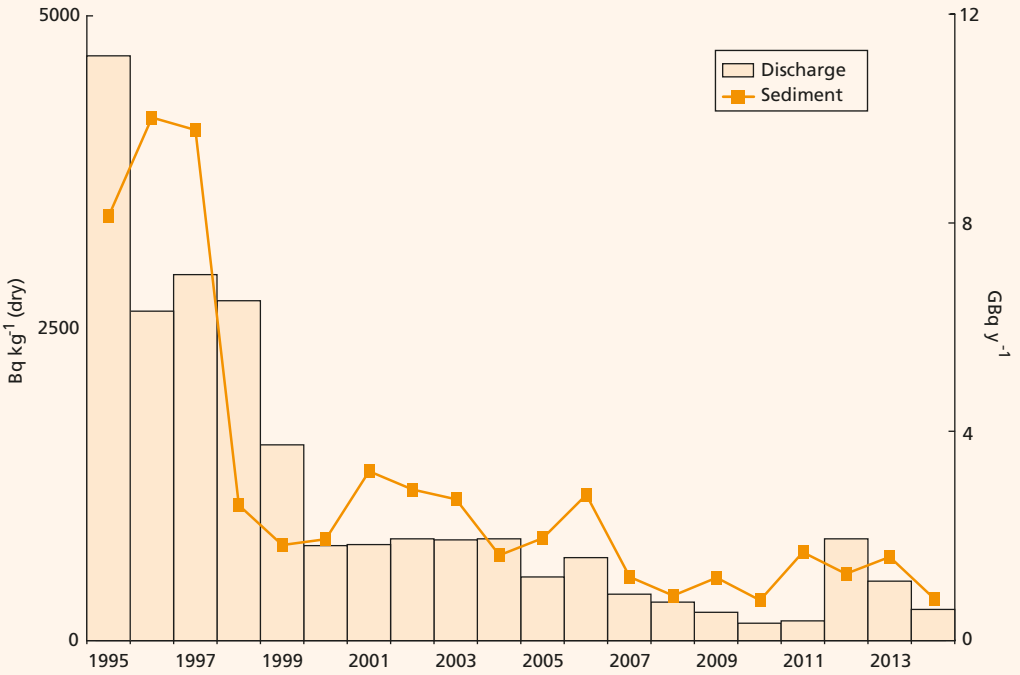


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2014

Gaseous discharges and terrestrial monitoring

Discharges of carbon-14 and sulphur-35 decreased and tritium increased by a small amount, in comparison to releases in 2013. The focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk and crops. Data for 2014 are given in Table 4.13(a). Sulphur-35 was detected at a very low concentration in one food sample (wheat). Carbon-14 was detected in locally produced milk, above expected background concentrations, but decreased by small amounts in comparison to those in 2013. Overall the effects of discharges were low. Gross alpha and beta activities in surface water (public supply) were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

The monitoring programme for the effects of liquid disposals included sampling of seafood, sediment, seawater and measurements of gamma dose rates. The results of the programme in 2014 are given in Tables 4.13 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges. The activity concentrations in 2014 were similar to those in 2013, including technetium-99 derived from Sellafield. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Where comparisons can be made (from similar ground types and locations), gamma dose rates were generally similar in comparison to those in recent years.

Table 4.1. Individual doses – nuclear power stations, 2014

Site	Representative person[a]	Exposure, mSv per year					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or the shoreline	Gaseous plume related pathways	Direct radiation from site
England							
Berkeley and Oldbury							
***Total dose* – all sources**	**Infant milk consumer**	**<0.005**	**–**	**<0.005**	**–**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupants	0.022	–	–	0.022	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–
Bradwell							
***Total dose* – all sources**	**Adult sea fish consumer**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	
Dungeness							
***Total dose* – all sources**	**Local adult inhabitants (0–0.25km)**	**0.021**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupants	0.005	–	–	0.005	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–
Hartlepool							
***Total dose* – all sources**	**Local adult inhabitants (0–0.25km)**	**0.027**	**–**	**–**	**0.007**	**<0.005**	**0.020**
Source specific doses	Seafood consumer[b]	0.012	<0.005	–	0.010	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–
Heysham							
***Total dose* – all sources**	**Adult mollusc consumer**	**0.023**	**0.013**	**–**	**0.010**	–	–
Source specific doses	Seafood consumer	0.032	0.013	–	0.018	–	–
	Turf cutters	0.016	–	–	0.016	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–
Hinkley Point							
***Total dose* – all sources**	**Adult occupants over sediment**	**0.022**	**<0.005**	**<0.005**	**0.021**	**<0.005**	**<0.005**
Source specific doses	Seafood consumer	0.032	<0.005	–	0.031	–	–
	Infant inhabitants and consumers of locally grown food	0.010	–	0.010	–	<0.005	–
Sizewell							
***Total dose* – all sources**	**Local adult inhabitants (0–0.25km)**	**0.020**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupants	<0.005	–	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–

Table 4.1. continued

Site	Representative person[a]	Exposure, mSv per year					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or the shoreline	Gaseous plume related pathways	Direct radiation from site
Scotland							
Chapelcross							
***Total dose* – all sources**	**Adult occupants over sediment**	**0.014**	**<0.005**	**<0.005**	**0.013**	**–**	**–**
Source specific doses	Salmon and wildfowl consumer	0.010	<0.005	<0.005	0.008	–	–
	Crustacean consumer	<0.005	<0.005	–	–	–	–
	Infant inhabitants and consumers of locally grown food	0.008	–	0.008	–	<0.005	–
Hunterston							
***Total dose* – all sources**	**Prenatal children of local inhabitants (0.25–0.5km)**	**0.021**	**–**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	0.009	–	0.008	–	<0.005	–
Torness							
***Total dose* – all sources**	**Local adult inhabitants (0.5–1km)**	**0.020**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	0.006	–	0.006	–	<0.005	–
Wales							
Trawsfynydd							
***Total dose* – all sources**	**Infant local inhabitants (0.25–0.5km)**	**0.013**	**–**	**0.013**	**–**	**<0.005**	**–**
Source specific doses	Anglers	0.007	<0.005	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	0.025	–	0.025	–	<0.005	–
Wylfa							
***Total dose* – all sources**	**Adult occupants over sediment**	**0.007**	**<0.005**	**<0.005**	**0.007**	**–**	**–**
Source specific doses	Seafood consumer	0.010	<0.005	–	0.007	–	–
	Infant inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	<0.005	–

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

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

Table 4.2(a). Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu
Marine samples								
Salmon	Beachley	1				0.11		
Mullet	River Severn	1	<25			0.29		
Elvers	River Severn	1				<0.13		
Shrimps	Guscar	2	67	27		0.43	0.00012	0.00042
Seaweed	Pipeline	2[E]			<1.3	<0.90		
Sediment	Hills Flats	2[E]				9.3		
Sediment	1 km south of Oldbury	2[E]				23		
Sediment	2 km south west of Berkeley	2[E]				19		
Sediment	Sharpness	2[E]				16		
Seawater	Local beach	2[E]				<0.21		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Salmon	Beachley	1	<0.07				
Mullet	River Severn	1	<0.06				
Elvers	River Severn	1	<0.10				
Shrimps	Guscar	2	0.0005	*	*		
Seaweed	Pipeline	2[E]	<0.64				
Sediment	Hills Flats	2[E]	<0.62				
Sediment	1 km south of Oldbury	2[E]	<0.78				
Sediment	2 km south west of Berkeley	2[E]	<0.77				
Sediment	Sharpness	2[E]	<0.81				
Seawater	Local beach	2[E]	<0.36			<1.6	7.0

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		4	<2.8	18	<0.28	<0.07		
Milk	max		<3.0	20	0.40	<0.08		
Beetroot		1	<2.0	16	0.40	<0.06		
Wheat		1	<2.0	84	0.40	<0.02		
Freshwater	Gloucester and Sharpness Canal	2[E]	<3.3		<1.4	<0.24	<0.061	0.17
Freshwater	Public supply	2[E]	<3.3		<0.61	<0.26	<0.046	0.18

* *Not detected by the method used*

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

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

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

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

Table 4.2(b). Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud and salt marsh	2	0.083
2 km south west of Oldbury	Mud and salt marsh	2	0.073
Guscar Rocks	Mud and salt marsh	2	0.081
Lydney Rocks	Mud	1	0.10
Lydney Rocks	Mud and salt marsh	1	0.099
Sharpness	Mud and salt marsh	2	0.077
Hills Flats	Mud and salt marsh	2	0.075

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2014

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu
Marine samples							
Bass	Pipeline	1			0.23		
Lobsters	West Mersea	1			0.07		
Native oysters	Blackwater Estuary	1			<0.05	0.00032	0.0019
Seaweed	Waterside	2[E]		3.6	<0.66		
Samphire	Tollesbury	1		<0.29	0.13		
Sediment	Pipeline	2[E]	<2.0		<0.15		
Sediment	Waterside	2[E]	<2.0		7.3		
Sediment	West Mersea Beach Huts	2[E]	<2.0		<0.51		
Sediment	West Mersea Boatyard	2[E]	<2.0		1.7		
Sediment	Maldon	2[E]	<2.0		20		
Sediment	N side Blackwater Estuary	2[E]	<2.3		7.2		
Seawater	Bradwell	2[E]			<0.24		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Bass	Pipeline	1	<0.11				
Lobsters	West Mersea	1	<0.19				
Native oysters	Blackwater Estuary	1	0.0048	*	0.000093		
Seaweed	Waterside	2[E]	<0.70				
Samphire	Tollesbury	1	<0.04				
Sediment	Pipeline	2[E]	<0.28				
Sediment	Waterside	2[E]	<1.1				
Sediment	West Mersea Beach Huts	2[E]	<0.53				
Sediment	West Mersea Boatyard	2[E]	<0.36				
Sediment	Maldon	2[E]	<1.2				
Sediment	N side Blackwater Estuary	2[E]	<0.75				
Seawater	Bradwell	2[E]	<0.28			<3.3	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		2	<2.3	18				
Milk	max		<2.6	20				
Cabbage		1	<2.0	8.8				
Lucerne		1	<2.9	20				
Freshwater	Public supply, N side Estuary	1[E]	<3.0		<1.4	<0.22	<0.040	0.34
Freshwater	Public supply, S side Estuary	1[E]	<3.4		<0.20	<0.19	<0.048	0.21
Freshwater	Coastal ditch 1	1[E]	<3.7		<0.32	<0.18	<0.52	3.0
Freshwater	Coastal ditch 2	1[E]	<5.3		<0.24	<0.20	<0.62	3.2
Freshwater	Coastal ditch 3	2[E]	6.5		<0.30	<0.22	<0.58	18
Freshwater	Coastal ditch 4	2[E]	6.7		<1.5	<0.29	<0.78	11

* *Not detected by the method used*

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

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

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

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

Table 4.3(b). Monitoring of radiation dose rates near Bradwell, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Sand and shells	2	0.073
Beach opposite power station, N side of estuary	Mud	1	0.066
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.070
Waterside	Mud and salt marsh	1	0.060
Waterside	Mud and pebbles	1	0.064
Maldon	Mud and salt marsh	2	0.062
West Mersea Beach Huts	Sand and shells	1	0.050
West Mersea Beach Huts	Sand and shingle	1	0.051
West Mersea	Sand and shells	1	0.048
West Mersea	Mud and shells	1	0.054

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Whiting	Pipeline	1	<25	<25		<0.05			<0.05
Sole	Pipeline	1	<25	<25		<0.06			<0.06
Shrimps	Pipeline	1	<25	<25		<0.09			<0.09
Scallops	Pipeline	1	<25	<25	27	<0.05	<0.030		<0.04
Sea kale	Dungeness Beach	1				<0.04			0.04
Seaweed	Folkestone	2[E]				<0.71		<0.69	<0.51
Sediment	Rye Harbour 1	2[E]				<0.39			0.72
Sediment	Camber Sands	2[E]				<0.27			<0.19
Sediment	Pilot Sands	2[E]				<0.40			<0.29
Seawater	Dungeness South	2[E]		<3.1		<0.30			<0.25

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									
Whiting	Pipeline	1			<0.14				
Sole	Pipeline	1			<0.16				
Shrimps	Pipeline	1			<0.25				
Scallops	Pipeline	1	0.00047	0.0024	0.00083	*	0.000022		
Sea kale	Dungeness Beach	1			<0.09				
Seaweed	Folkestone	2[E]			<0.58				
Sediment	Rye Harbour 1	2[E]	<0.35	0.33	<0.92				610
Sediment	Camber Sands	2[E]			<0.33				
Sediment	Pilot Sands	2[E]			<0.43				
Seawater	Dungeness South	2[E]			<0.34			<3.7	13

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<2.9	17	<0.21	<0.05	<0.06		
Milk	max		<3.4	20	<0.25	<0.07			
Potatoes		1	<2.0	24	0.40	<0.12	<0.09		
Rape oil		1	<3.6	90	7.4	<0.13	<0.11		
Freshwater	Long Pits	2[E]	<2.7		<0.60	<0.25	<0.22	<0.028	0.16
Freshwater	Pumping station Well number 1	1[E]	<3.1		<0.18	<0.30	<0.26	<0.018	0.092
Freshwater	Pumping station Well number 2	1[E]	<3.0		<2.1	<0.26	<0.22	<0.023	0.14
Freshwater	Reservoir	1[E]	<3.1			<0.26	<0.23	<0.027	0.10

* *Not detected by the method used*

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

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

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

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

Table 4.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	2	0.051
Greatstone-on-Sea	Sand	1	0.060
Greatstone-on-Sea	Sand and shingle	1	0.050
Dungeness East	Sand and shingle	2	0.052
Dungeness South	Shingle	2	0.047
Jurys Gap	Sand and shingle	2	0.056
Rye Bay	Sand and shingle	2	0.053

Table 4.5(a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{210}Pb
Marine samples										
Plaice	Pipeline	1	<25	<25	24	<0.06		*	0.15	
Crabs	Pipeline	1	<25	<25	34	<0.06		*	<0.06	
Winkles	South Gare	2	<26	<25		<0.05		<0.52	0.18	1.8
Seaweed	Pilot Station	2[E]				<0.98	4.2	11	<0.69	
Sediment	Old Town Basin	2[E]				<0.45			2.1	
Sediment	Seaton Carew	2[E]				<0.29			<0.22	
Sediment	Paddy's Hole	2[E]				<0.40			1.8	
Sediment	North Gare	2[E]				<0.25			<0.20	
Sediment	Greatham Creek	2[E]				<0.45			3.0	
Sea coal	Old Town Basin	2[E]				<0.39			<0.73	
Sea coal	Carr House Sands	2[E]				<0.61			<0.53	
Seawater	North Gare	2[E]		<3.1		<0.28			<0.23	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Plaice	Pipeline	1				<0.05				
Crabs	Pipeline	1				<0.15				
Winkles	South Gare	2	18	0.0061	0.041	0.022	*	*		
Seaweed	Pilot Station	2[E]				<0.66				
Sediment	Old Town Basin	2[E]				<0.52				
Sediment	Seaton Carew	2[E]				<0.32				
Sediment	Paddy's Hole	2[E]				<0.63				
Sediment	North Gare	2[E]				<0.34				
Sediment	Greatham Creek	2[E]				<0.82				
Sea coal	Old Town Basin	2[E]				<0.54				
Sea coal	Carr House Sands	2[E]				<0.61				
Seawater	North Gare	2[E]				<0.28			<4.0	17

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<2.0	16	<0.26	<0.06	<0.06		
Milk	max			17	<0.30		<0.07		
Potatoes		1	<2.0	23	0.30	<0.09	<0.08		
Wheat		1	<2.0	80	1.1	<0.05	<0.06		
Freshwater	Public supply	2[E]	<3.0		<0.75	<0.23	<0.19	<0.094	0.16
Freshwater	Borehole, Dalton Piercy	2[E]	<3.1		<1.0	<0.23	<0.19	<0.15	<0.16

* *Not detected by the method used*

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

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

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

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

Table 4.5(b). Monitoring of radiation dose rates near Hartlepool nuclear power station, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.068
Fish Sands	Sand and stones	1	0.072
Old Town Basin	Sand	1	0.077
Old Town Basin	Sand and coal	1	0.070
Carr House	Sand	1	0.068
Carr House	Sand and coal	1	0.065
Seaton Carew	Sand	1	0.064
Seaton Carew	Pebbles and sand	1	0.061
Seaton Sands	Sand	2	0.061
North Gare	Sand	2	0.064
Paddy's Hole	Pebbles and slag	1	0.17
Paddy's Hole	Pebbles and stones	1	0.16
Greatham Creek Bird Hide	Mud and rock	1	0.091

Table 4.6(a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2014

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{137}Cs	^{155}Eu
Marine samples											
Flounder	Morecambe	2	<29	39	53	<0.09	0.028	<0.38	<0.23	5.4	<0.22
Shrimps	Morecambe	2	<43	<39	55	<0.08	0.034	<0.75	<0.23	<4.6	<0.22
Winkles[b]	Middleton Sands	2	130	130	47	<0.09	0.17	8.1	<0.24	3.2	<0.24
Mussels[c]	Morecambe	2	34	59	50	<0.09	0.28	31	<0.20	2.5	<0.18
Wildfowl	Morecambe	1				<0.07			<0.16	0.75	<0.16
Seaweed	Half Moon Bay	2[E]				<0.76		120	<2.9	3.0	
Sediment	Half Moon Bay	2[E]				<0.53				72	
Sediment	Pott's Corner	2[E]				<0.34				15	
Sediment	Morecambe Central Pier	2[E]				<0.28				13	
Sediment	Red Nab Point	2[E]				<0.33				20	
Sediment	Sunderland Point	4[E]				<0.45			<1.7	70	<0.90
Sediment	Conder Green	4[E]				<0.47			<1.7	62	<2.0
Sediment	Sand Gate Marsh	4[E]				<0.43			<1.5	71	<0.73
Seawater	Heysham Harbour	2[E]		46		<0.34				<0.26	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples										
Flounder	Morecambe	2	0.00081	0.0039		0.0074	*	0.000026		
Shrimps	Morecambe	2	0.0057	0.036		0.050	*	0.000057		
Winkles[b]	Middleton Sands	2	0.28	1.6	8.9	3.2	*	*		110
Mussels[c]	Morecambe	2	0.33	1.9	11	3.7	*	0.011		120
Wildfowl	Morecambe	1				<0.19				
Seaweed	Half Moon Bay	2[E]				<0.68				
Sediment	Half Moon Bay	2[E]	6.7	42		86				
Sediment	Pott's Corner	2[E]				13				
Sediment	Morecambe Central Pier	2[E]				12				
Sediment	Red Nab Point	2[E]				23				
Sediment	Sunderland Point	4[E]				64			310	780
Sediment	Conder Green	4[E]				72			260	650
Sediment	Sand Gate Marsh	4[E]				52			<160	590
Seawater	Heysham Harbour	2[E]				<0.36			<3.4	13

Material	Location or selection[d]	No. of sampling observations[e]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<2.5	15	<0.29	<0.05	<0.09		
Milk	max		<2.7	16	<0.33		<0.11		
Potatoes		1	<4.1	22	0.70	<0.08	<0.13		
Wheat		1	18	80	0.70	<0.04	<0.11		
Freshwater	Lancaster	2[E]	<3.3		<0.77	<0.25	<0.21	<0.043	0.080

* *Not detected by the method used*

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

[b] *The concentration of ^{210}Po was 12 Bq kg^{-1}*

[c] *The concentration of ^{210}Po was 36 Bq kg^{-1}*

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

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

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

Table 4.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass and mud	1	0.078
Greenodd Salt Marsh	Grass	1	0.078
Sand Gate Marsh	Grass	4	0.085
High Foulshaw	Mud	1	0.076
High Foulshaw	Sand and mud	1	0.080
High Foulshaw	Grass and mud	1	0.077
High Foulshaw	Grass	1	0.078
Arnside 1	Mud	2	0.083
Arnside 1	Sand and mud	2	0.082
Arnside 2	Grass	4	0.090
Morecambe Central Pier	Sand	2	0.075
Half Moon Bay	Sand and stones	1	0.082
Half Moon Bay	Stones	1	0.081
Red Nab Point	Sand	2	0.083
Middleton Sands	Sand	2	0.078
Sunderland	Salt marsh	4	0.093
Sunderland Point	Mud	1	0.098
Sunderland Point	Mud and sand	3	0.10
Colloway Marsh	Grass	1	0.12
Colloway Marsh	Salt marsh	2	0.12
Lancaster	Grass	4	0.082
Aldcliffe Marsh	Grass	1	0.095
Aldcliffe Marsh	Salt marsh	3	0.097
Conder Green	Mud	3	0.090
Conder Green	Mud and sand	1	0.090

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Stolford	2	<29	<27	30	<0.05			0.23
Shrimps	Stolford	1	<25	36	28	<0.07			0.12
Limpets	Stolford	1	<25	<25	23	<0.17			0.32
Seaweed	Pipeline	2[E]				<0.64		2.5	<0.47
Sediment	Watchet Harbour	2[E]				<0.52	<2.0		4.0
Sediment	Pipeline	2[E]				<0.96	<2.0		16
Sediment	Stolford	2[E]				<1.1	<2.3		17
Sediment	Steart Flats	2[E]				<0.39	<2.0		6.2
Sediment	River Parrett	2[E]				<1.1	<2.0		20
Sediment	Weston-Super-Mare	2[E]				<0.35	<2.0		1.3
Sediment	Burnham-On-Sea	2[E]				<0.30	<2.0		3.7
Sediment	Kilve	2[E]				<0.34	<2.0		1.5
Sediment	Blue Anchor Bay	2[E]				<0.35	<2.0		<0.56
Seawater	Pipeline	2[E]				<0.27	<0.025		<0.21

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Cod	Stolford	2			<0.05				
Shrimps	Stolford	1	0.000077	0.00050	0.00051	*	*		
Limpets	Stolford	1			<0.12				
Seaweed	Pipeline	2[E]			<0.63				
Sediment	Watchet Harbour	2[E]			<0.67				
Sediment	Pipeline	2[E]			<1.2				
Sediment	Stolford	2[E]			<1.2				
Sediment	Steart Flats	2[E]			<0.73				
Sediment	River Parrett	2[E]			<1.1				
Sediment	Weston-Super-Mare	2[E]			<0.48				
Sediment	Burnham-On-Sea	2[E]			<0.48				
Sediment	Kilve	2[E]			<0.56				
Sediment	Blue Anchor Bay	2[E]			<0.40				
Seawater	Pipeline	2[E]			<0.27			<3.0	11

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<2.6	25	<0.33	<0.04	<0.06		
Milk	max		<3.2	32	<0.38	<0.05	<0.07		
Honey		1	<2.0	79	<0.10	<0.01	<0.01		
Potatoes		1	<2.0	23	0.50	<0.06	<0.04		
Wheat		1	<2.0	78	1.0	<0.04	<0.10		
Freshwater	Durleigh Reservoir	2[E]	<3.1		<0.65	<0.23	<0.21	<0.044	0.17
Freshwater	Ashford Reservoir	2[E]	<3.9		<0.19	<0.24	<0.22	<0.033	0.087

* *Not detected by the method used*

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

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

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

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

Table 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Mud	1	0.066
Weston-Super-Mare	Sand and mud	3	0.063
Burnham	Sand and mud	3	0.059
Burnham	Sand	1	0.062
River Parrett	Mud	1	0.065
River Parrett	Mud and salt marsh	2	0.071
River Parrett	Mud and rock	1	0.076
Steart Flats	Mud	3	0.072
Steart Flats	Mud and pebbles	1	0.081
Stolford	Mud and rock	4	0.097
Hinkley Point	Mud and rock	4	0.085
Kilve	Mud and stones	1	0.082
Kilve	Mud and rock	3	0.081
Watchet Harbour	Rock and mud	3	0.098
Blue Anchor Bay	Sand and mud	3	0.081
Blue Anchor Bay	Sand and stones	1	0.064

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu
Marine samples								
Cod	Sizewell	1	<25	<25		0.28		
Skates/rays	Sizewell	1	<25	<25		<0.10		
Crabs	Sizewell	1	<25	<25		<0.08		
Mussels	River Alde	1	<25	<25	23	0.06	0.0010	0.0060
Sediment	Rifle range	2[E]				0.33		
Sediment	Aldeburgh	2[E]				<0.23		
Sediment	Southwold	2[E]				5.7		
Seawater	Sizewell	2[E]		<3.5		<0.25		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Cod	Sizewell	1	<0.03				
Skates/rays	Sizewell	1	<0.07				
Crabs	Sizewell	1	<0.22				
Mussels	River Alde	1	0.0069	0.00013	0.00014		
Sediment	Rifle range	2[E]	<0.28				
Sediment	Aldeburgh	2[E]	<0.28				
Sediment	Southwold	2[E]	<0.68				800
Seawater	Sizewell	2[E]	<0.29			<3.7	14

Material	Location or selection[c]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		2	<2.7	18	<0.25	<0.06		
Milk	max		<2.9	20	<0.30			
Potatoes		1	<2.1	20	0.20	<0.09		
Wheat		1	<4.3	87	<0.20	<0.07		
Freshwater	Nature Reserve	2[E]	<3.1		<0.79	<0.31	<0.037	0.22
Freshwater	The Meare	2[E]	<3.3		<0.46	<0.20	<0.039	0.29
Freshwater	Leisure Park	2[E]	33		<1.1	<0.25	<0.055	0.36

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

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

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

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

Table 4.8(b). Monitoring of radiation dose rates near Sizewell, 2014

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Sand and shingle	2	0.048
Dunwich	Sand and shingle	1	0.047
Dunwich	Shingle	1	0.050
Rifle Range	Sand and shingle	2	0.047
Aldeburgh	Sand and shingle	2	0.048
Southwold Harbour	Mud	2	0.065

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs
Marine samples												
Flounder	Inner Solway	2		50	<0.12	<0.10	<0.46	<1.3	<0.15	<0.97	<0.26	<0.12
Salmon	Inner Solway	1	<5.0		<0.10			<0.47		<0.48	<0.12	<0.10
Sea trout	Inner Solway	1	<5.0		<0.10		<3.1	<0.89		<0.75	<0.18	<0.10
Shrimps	Inner Solway	2	<5.0		<0.10	0.10	<0.54	<0.80	0.47	<0.92	<0.25	<0.10
Cockles	North Solway	1	<5.0		<0.10		<0.16	<0.14		<0.37	<0.11	<0.10
Mussels	North Solway	2	<5.0	49	<0.12	0.24	<0.40	<0.30	7.1	<0.59	<0.20	<0.10
Fucus vesiculosus	Pipeline	4			<0.10		<0.67	<0.40	39	<0.71	<0.20	<0.10
Fucus vesiculosus	Browhouses	2			<0.10		<0.25	<0.16	13	<0.37	<0.12	<0.10
Fucus vesiculosus	Dornoch Brow	2			<0.10		<0.46	<0.40	17	<0.45	<0.13	<0.10
Sediment	Priestside Bank	1			<0.10		<0.46	<0.25		<0.75	<0.25	<0.11
Sediment	Pipeline	4	<5.0		0.48		<2.1	<0.49		<1.5	<0.57	<0.17
Sediment	Dornoch Brow	1			0.33		<1.1	<0.55		0.88	<0.39	<0.14
Sediment	Powfoot	1			0.14		<0.52	<0.28		<0.89	<0.28	<0.13
Sediment	Redkirk	1			<0.10		<0.89	<0.48		<0.84	<0.29	<0.10
Sediment	Stormont	1			0.24		<0.21	<0.14		<0.78	<0.31	<0.10
Seawater	Pipeline	2	<1.4		<0.10		<0.39	<0.29		<0.64	<0.18	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples											
Flounder	Inner Solway	2	9.4	<0.13	<0.21	<0.0065	<0.013		<0.61		
Salmon	Inner Solway	1	0.30	<0.10	<0.11				<0.10		
Sea trout	Inner Solway	1	1.6	<0.10	<0.18				<0.10		
Shrimps	Inner Solway	2	3.6	<0.12	<0.21	0.0037	0.013		0.020		
Cockles	North Solway	1	0.46	<0.10	<0.10	0.080	0.29		2.7		
Mussels	North Solway	2	1.8	<0.11	<0.18	0.28	2.0	<3.9	4.3		
Fucus vesiculosus	Pipeline	4	2.8	<0.12	<0.21	0.21	1.5		2.0	3.8	330
Fucus vesiculosus	Browhouses	2	5.9	<0.10	<0.26	0.55	3.4		7.4	6.7	210
Fucus vesiculosus	Dornoch Brow	2	5.4	<0.10	<0.17	0.27	1.8		2.6	5.7	290
Sediment	Priestside Bank	1	22	<0.18	0.69	1.9	12		24		
Sediment	Pipeline	4	130	<0.35	1.1	9.9	75		140		
Sediment	Dornoch Brow	1	84	<0.19	1.0	7.0	48		89		
Sediment	Powfoot	1	26	<0.22	1.8	2.7	18		33		
Sediment	Redkirk	1	48	<0.18	0.72	4.4	22		43		
Sediment	Stormont	1	71	<0.25	<0.44	11	54		100		
Seawater	Pipeline	2	<0.10	<0.11	<0.19				<0.10		

Table 4.9(a). continued

Material	Location or selection[b]		No. of sampling ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
				^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru
Terrestrial samples										
Milk			12	<6.3	<15	<0.84	<0.05	<0.10	<0.23	<0.32
Milk		max		<11		<1.7			<0.35	<0.43
Apples			2	<5.0	<16	<0.50	<0.05	<0.10	<0.12	<0.33
Apples		max			17				<0.18	<0.46
Beef			1	<5.0	35	<0.62	<0.05	<0.10	<0.42	<0.45
Cabbage			1	<5.0	<15		<0.05	<0.10	<0.05	<0.17
Carrots			1	<5.0	<15	<0.50	<0.05	<0.10	<0.07	<0.33
Cauliflower			1	<5.0	<15	<0.50	<0.05	<0.10	<0.08	<0.25
Duck			1	<5.0	<15	<0.50	<0.05	<0.10	<0.15	<0.34
Goose			2	<5.0	30	<0.50	<0.05	<0.20	<0.10	<0.33
Goose		max			31			0.30	<0.13	<0.41
Honey			1	10	91	<0.87	<0.05	<0.10	<0.12	<0.49
Leeks			1	<5.0	<15	<0.50	<0.05	<0.10	<0.08	<0.28
Potatoes			1	<5.0	16		<0.05	<0.10	<0.07	<0.40
Rosehips			1	<5.0	60	<0.50	<0.05	0.92	<0.10	<0.30
Wheat			1	<5.0	47	<1.2	<0.05	0.18	<0.15	<0.33
Grass			4	<7.9	<21	<0.72	<0.05	<0.25	<1.4	<0.41
Grass		max		14	27	<1.2		0.55		<0.48
Soil			4	<5.0	<15	<1.9	<0.05	1.0	<0.43	<0.47
Soil		max				<2.4		1.8	<0.63	<0.51
Freshwater	Purdomstone		1	1.2			<0.01		<0.01	<0.06
Freshwater	Winterhope		1	1.7			<0.01		<0.02	<0.09
Freshwater	Black Esk		1	<1.0			<0.01		<0.01	<0.04
Freshwater	Gullielands Burn		1	19			<0.01		<0.01	<0.02

Material	Location or selection[b]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
				^{134}Cs	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples									
Milk			12	<0.05	<0.05		<0.05		
Milk		max					<0.07		
Apples			2	<0.05	<0.05		<0.06		
Beef			1	<0.05	<0.05		<0.15		
Cabbage			1	<0.05	0.25		<0.07		
Carrots			1	<0.05	<0.05		<0.05		
Cauliflower			1	<0.05	<0.05		<0.05		
Duck			1	<0.05	0.48		<0.11		
Goose			2	<0.05	0.31		<0.14		
Goose		max			0.32		<0.16		
Honey			1	<0.05	0.20		<0.07		
Leeks			1	<0.05	<0.05		<0.05		
Potatoes			1	<0.05	<0.05		<0.07		
Rosehips			1	<0.05	<0.05		<0.12		
Wheat			1	<0.05	<0.05		<0.09		
Grass			4	<0.05	<0.05		<0.11	<0.64	450
Grass		max					<0.16	0.79	530
Soil			4	<0.06	8.8	1.6	<0.22	150	1600
Soil		max		<0.07	12	1.9	<0.25	180	1700
Freshwater	Purdomstone		1	<0.01	<0.01		<0.01	<0.010	0.044
Freshwater	Winterhope		1	<0.01	<0.01		<0.01	<0.010	0.075
Freshwater	Black Esk		1	<0.01	<0.01		<0.01	<0.010	0.027
Freshwater	Gullielands Burn		1	<0.01	<0.01		<0.01	<0.010	0.26

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

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

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

Table 4.9(b). Monitoring of radiation dose rates near Chapelcross, 2014

Location	Material or Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Glencaple Harbour	Sand	2	0.085
Priestside Bank	Salt marsh	1	0.065
Priestside Bank	Sand	1	0.061
Powfoot Merse	Sand	2	0.078
Gullielands	Grass/soil	1	0.062
Seafield	Sand	2	0.079
Woodhead	Grass/soil	1	0.067
East Bretton	Grass/soil	1	0.068
Pipeline	Salt marsh	2	0.092
Pipeline	Sand	2	0.083
Dumbretton	Grass/soil	1	0.071
Battlehill	Sand and stones	1	0.077
Battlehill	Sediment and rocks	1	0.077
Dornoch Brow	Salt marsh	2	0.089
Dornoch Brow	Sand	2	0.084
Browhouses	Sand	2	0.087
Redkirk	Sand	2	0.086
Stormont	Sand	2	0.078
Mean beta dose rates			µSv h^{-1}
Pipeline 500m east	Sand	1	<1.0
Pipeline 500m west	Sand	1	<1.0
Pipeline	Stake nets	3	<1.0

Table 4.9(c). Radioactivity in air near Chapelcross, 2014

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.010	<0.012	<0.20
Kirtlebridge	10	<0.010	<0.011	<0.20
Brydekirk	10	<0.010	<0.012	<0.20

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{35}S	^{54}Mn	^{60}Co	^{65}Zn	^{95}Nb	^{99}Tc	^{110m}Ag
Marine samples										
Cod	Millport	2			<0.10	<0.10	<0.23	<0.17		<0.12
Hake	Millport	2			<0.10	<0.10	<0.22	<0.29		<0.12
Crabs	Millport	2			<0.13	<0.12	<0.31	<0.41	0.74	<0.13
Nephrops	Millport	2			<0.11	<0.10	<0.25	<0.29		<0.12
Lobsters	Largs	1			<0.10	<0.10	<0.25	<0.23	11	<0.11
Squat lobsters	Largs	2			<0.10	<0.10	<0.22	<0.26	0.50	<0.10
Mussels	Hunterston	1			<0.10	<0.10	<0.25	<0.41		<0.11
Winkles	Pipeline	2			<0.14	<0.10	<0.35	<0.44		1.3
Scallops	Largs	2			<0.10	<0.10	<0.19	<0.24		<0.10
Oysters	Hunterston	1			<0.10	<0.10	<0.20	<0.15		0.27
Fucus vesiculosus	N of pipeline	2			<0.10	<0.19	<0.20	<0.39		<0.13
Fucus vesiculosus	S of pipeline	2			0.19	<0.21	<0.22	<0.58		<0.11
Sediment	Largs	1			<0.10	<0.10	<0.24	<0.39		<0.11
Sediment	Millport	1			<0.10	<0.10	<0.18	<0.53		<0.10
Sediment	Gull's Walk	1			<0.10	<0.10	<0.21	<0.55		<0.11
Sediment	Ardneil Bay	1			<0.10	<0.10	<0.11	<0.21		<0.10
Sediment	Fairlie	1			<0.10	<0.10	<0.14	<0.18		<0.10
Sediment	Pipeline	1			<0.10	<0.10	<0.18	<0.24		<0.10
Sediment	Ardrossan North Bay	1			<0.10	<0.10	<0.17	<0.46		<0.10
Sediment	Ardrossan South Bay	1			<0.10	<0.10	<0.25	<0.64		<0.11
Seawater	Pipeline	2	6.9	0.50	<0.10	<0.10	<0.21	<0.22		<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Marine samples									
Cod	Millport	2	<0.25	1.6	<0.11	<0.19			<0.12
Hake	Millport	2	<0.22	0.89	<0.12	<0.20			<0.12
Crabs	Millport	2	<0.29	0.19	<0.15	<0.27	<0.0019	0.011	<0.036
Nephrops	Millport	2	<0.24	0.63	<0.12	<0.22			<0.13
Lobsters	Largs	1	<0.26	0.30	<0.13	<0.26			<0.24
Squat lobsters	Largs	2	<0.21	<0.12	<0.12	<0.21	<0.016	0.032	0.072
Mussels	Hunterston	1	<0.25	0.15	<0.13	<0.24			<0.13
Winkles	Pipeline	2	<0.32	0.27	<0.17	<0.25	0.031	0.17	0.14
Scallops	Largs	2	<0.18	0.17	<0.11	<0.17	<0.020	0.047	0.052
Oysters	Hunterston	1	<0.23	<0.10	<0.11	<0.21			<0.12
Fucus vesiculosus	N of pipeline	2	<0.19	5.60	<0.11	<0.19			<0.14
Fucus vesiculosus	S of pipeline	2	<0.15	0.26	<0.11	<0.15			<0.11
Sediment	Largs	1	<0.20	6.3	<0.17	<0.34			<0.03
Sediment	Millport	1	<0.14	3.4	<0.10	<0.20			<0.17
Sediment	Gull's Walk	1	<0.17	7.0	<0.16	0.36			1.3
Sediment	Ardneil Bay	1	<0.11	1.9	<0.11	<0.20			<0.19
Sediment	Fairlie	1	<0.13	7.4	<0.11	<0.23			<0.15
Sediment	Pipeline	1	<0.15	3.9	<0.13	<0.26			<0.26
Sediment	Ardrossan North Bay	1	<0.13	2.9	<0.10	<0.22			<0.22
Sediment	Ardrossan South Bay	1	<0.17	2.6	<0.12	0.38			0.91
Seawater	Pipeline	2	<0.21	<0.10	<0.12	<0.20			<0.12

Table 4.10(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples								
Milk		3	<5.0	<16	<0.57	<0.05	<0.10	<0.23
Milk	max			<17	<0.65			<0.25
Apples		1	<5.0	25	<0.50	<0.05	0.12	<0.05
Beef		1	<5.0	45	<0.60	<0.06	<0.10	<1.7
Broccoli		1	<5.0	<15	<0.50	<0.05	0.20	<0.08
Cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.10
Carrots		1	6.1	16		<0.05	<0.10	<0.11
Cauliflower		1	<5.0	<15	<0.50	<0.05	<0.10	<0.09
Eggs		1	<5.0	39	<1.0	<0.05	<0.10	<0.27
Leeks		1	<5.0	<15	<0.50	<0.05	0.12	<0.11
Pheasant		1	<5.0	28	<0.50	<0.05	<0.10	<0.08
Pork		1	<5.0	33	<0.50	<0.07	<0.10	<1.3
Potatoes		1	<5.0	<15	<0.50	<0.05	<0.10	<0.22
Rosehips		1	<5.0	28	<1.7	<0.05	0.90	<0.14
Turnip		1	<5.0	18	<0.50	<0.05	<0.05	<0.12
Wild blackberries		1	<5.0	21	<0.50	<0.05	0.36	<0.14
Grass		3	<5.0	<17	<0.50	<0.05	<0.18	<0.70
Grass	max			21	<0.51	<0.06	0.22	<1.1
Soil		3	<5.0	<15	<1.1	<0.05	1.0	<0.23
Soil	max				<1.2		1.2	0.36
Freshwater	Knockenden	1	1.1			<0.01		<0.01
Freshwater	Loch Ascog	1	<1.0			<0.01		<0.01
Freshwater	Munnoch Reservoir	1	<1.0			<0.01		<0.02
Freshwater	Camphill	1	<1.0			<0.01		<0.02
Freshwater	Outerwards	1	1.1			<0.01		<0.02

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		3	<0.05	<0.06		<0.06		
Apples		1	<0.05	<0.05		<0.05		
Beef		1	<0.11	0.18		<0.10		
Broccoli		1	<0.05	0.18		<0.06		
Cabbage		1	<0.05	<0.05		<0.05		
Carrots		1	<0.05	<0.05		<0.05		
Cauliflower		1	<0.05	<0.05		<0.06		
Eggs		1	<0.05	<0.05		<0.06		
Leeks		1	<0.05	<0.05		<0.05		
Pheasant		1	<0.06	0.76		<0.16		
Pork		1	<0.10	0.32		<0.09		
Potatoes		1	<0.05	0.11		<0.06		
Rosehips		1	<0.05	0.09		<0.10		
Turnip		1	<0.05	<0.05		<0.05		
Wild blackberries		1	<0.05	0.09		<0.06		
Grass		3	<0.06	<0.10		<0.08	<0.36	240
Grass	max		<0.07	0.14		<0.09	<0.40	310
Soil		3	<0.07	9.5	1.1	<0.19	<180	1200
Soil	max		<0.08	15		<0.21	210	1400
Freshwater	Knockenden	1	<0.01	<0.01		<0.01	<0.010	0.020
Freshwater	Loch Ascog	1	<0.01	<0.01		<0.01	<0.010	0.10
Freshwater	Munnoch Reservoir	1	<0.01	<0.01		<0.01	<0.010	0.060
Freshwater	Camphill	1	<0.01	<0.01		<0.01	<0.010	0.061
Freshwater	Outerwards	1	<0.01	<0.01		<0.01	<0.010	0.030

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

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

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

Table 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Meigle Bay	Sediment	2	0.061
Largs Bay	Sediment	2	0.062
Kilchatten Bay	Sediment	2	<0.047
Millport	Sand	2	0.047
Gull's Walk	Sediment	2	0.058
Hunterston	Sediment	2	0.058
0.5 km north of pipeline	Sediment	2	0.063
0.5 km south of pipeline	Sediment	2	0.068
Portencross	Grass/soil	1	0.054
Ardneil Bay	Sediment	2	<0.046
Ardrossan North Bay	Sediment	2	<0.047
Ardrossan South Bay	Sediment	2	0.052
Milstonford	Grass/soil	1	0.065
Biglies	Grass/soil	2	0.067
Beta dose rates			μSv h^{-1}
Millport	Sand	1	<1.0
0.5 km north of pipeline	Sand	1	<1.0
0.5 km south of pipeline	Sand	1	<1.0

Table 4.10(c). Radioactivity in air near Hunterston, 2014

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	12	<0.010	<0.010	<0.20
West Kilbride	12	<0.010	<0.0093	<0.23
Low Ballees	12	<0.010	0.013	<0.18

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{54}Mn	^{60}Co	^{65}Zn	^{99}Tc	^{110m}Ag	^{137}Cs
Marine samples								
Cod	White Sands	2	<0.11	<0.10	<0.21		<0.13	0.24
Crabs[d]	Torness	1	<0.10	<0.10	<0.14	0.40	<0.10	<0.10
Lobsters	Torness	1	<0.10	<0.10	<0.23	3.3	<0.10	<0.10
Nephrops	Dunbar	2	<0.10	<0.10	<0.21		<0.10	0.13
Winkles	Pipeline	2	<0.16	<0.17	<0.28		<0.79	<0.10
Fucus vesiculosus	Pipeline	2	0.44	0.48	<0.16		<0.06	<0.10
Fucus vesiculosus	Thornton Loch	2	<0.17	<0.18	<0.18	7.6	<0.10	<0.10
Fucus vesiculosus	White Sands	2	<0.10	<0.10	<0.18		<0.10	<0.10
Fucus vesiculosus	Pease Bay	2	<0.10	<0.10	<0.15		<0.10	<0.10
Fucus vesiculosus	Coldingham Bay	2	<0.10	<0.10	<0.22		<0.10	<0.10
Sediment	Dunbar	1	<0.10	<0.10	<0.22		<0.11	1.4
Sediment	Barns Ness	1	<0.10	<0.10	<0.14		<0.10	0.84
Sediment	Thornton Loch	1	<0.10	<0.10	<0.15		<0.10	0.80
Sediment	Heckies Hole	1	<0.10	<0.10	<0.22		<0.10	1.2
Sediment	Belhaven Bay	1	<0.10	<0.10	<0.27		<0.11	2.0
Sediment	Coldingham Bay	1	<0.10	<0.10	<0.16		<0.10	0.89
Sediment	Pease Bay	1	<0.10	<0.10	<0.25		<0.10	0.95
Seawater[e]	Pipeline	2	<0.10	<0.10	<0.17		<0.10	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples								
Cod	White Sands	2	<0.25			<0.13		
Crabs[d]	Torness	1	<0.12			<0.10		
Lobsters	Torness	1	<0.20			<0.12		
Nephrops	Dunbar	2	<0.21	<0.012	0.015	0.53		
Winkles	Pipeline	2	<0.18			<0.10	1.9	67
Fucus vesiculosus	Pipeline	2	<0.14			<0.11		
Fucus vesiculosus	Thornton Loch	2	<0.16			<0.11		
Fucus vesiculosus	White Sands	2	<0.15			<0.10		
Fucus vesiculosus	Pease Bay	2	<0.13			<0.10		
Fucus vesiculosus	Coldingham Bay	2	<0.13			<0.11		
Sediment	Dunbar	1	0.44			<0.25		
Sediment	Barns Ness	1	<0.23			<0.22		
Sediment	Thornton Loch	1	0.34			<0.21		
Sediment	Heckies Hole	1	<0.31			<0.28		
Sediment	Belhaven Bay	1	1.0			<0.29		
Sediment	Coldingham Bay	1	0.59			<0.27		
Sediment	Pease Bay	1	<0.31			<0.29		
Seawater[e]	Pipeline	2	<0.18			<0.11		

Table 4.11(a). continued

Material	Location or Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{95}Nb	^{110m}Ag
Terrestrial Samples								
Milk		2	<5.0	<15	<0.52	<0.10	<0.20	<0.05
Milk	max			<16	<0.53			
Broccoli		1	<5.0	<15	<0.50	<0.10	<0.20	<0.05
Cabbage		1	<5.0	<15	<0.50	<0.10	<0.11	<0.05
Carrots		1	<5.0	<15	<0.50	0.16	<0.11	<0.05
Cauliflower		1	<5.0	<15	<0.50	<0.10	<0.22	<0.05
Duck		1	13	32	<0.94	<0.10	<0.07	<0.05
Eggs		1	<5.0	25		<0.10	<0.05	<0.05
Kohlrabi		1	<5.0	<15	<0.50	<0.10	<0.21	<0.05
Leeks		1	<5.0	<15		<0.10	<0.37	<0.05
Pheasant		1	<5.0	22	<0.87	<0.10	<0.05	<0.05
Potatoes		1	<5.0	27	<0.50	<0.10	<0.19	<0.05
Rosehips		1	<5.0	29	<0.50	0.42	<0.05	<0.05
Turnips		1	<5.0	<15	<0.50	0.30	<0.11	<0.05
Venison		1	<5.0	27	<0.76	<0.10	<1.3	<0.08
Wood Pigeon		1	<5.0	32	<1.4	0.16	<1.8	<0.11
Grass		3	<5.0	<22	<0.50	0.18	<0.20	<0.05
Grass	max			32		0.27	<0.22	
Soil		3	<5.0	<15	<1.1	0.67	<0.77	<0.09
Freshwater	Hopes Reservoir	1	<1.0				<0.01	<0.01
Freshwater	Thorter's Reservoir	1	<1.0				<0.02	<0.01
Freshwater	Whiteadder	1	<1.0				<0.01	<0.01
Freshwater	Thornton Loch Burn	1	<1.0				<0.01	<0.01

Material	Location or Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples							
Milk		2	<0.05		<0.05		
Broccoli		1	<0.05		<0.07		
Cabbage		1	<0.05		<0.05		
Carrots		1	<0.05		<0.07		
Cauliflower		1	<0.05		<0.07		
Duck		1	<0.05		<0.12		
Eggs		1	<0.05		<0.05		
Kohlrabi		1	<0.05		<0.06		
Leeks		1	<0.05		<0.05		
Pheasant		1	<0.05		<0.09		
Potatoes		1	<0.05		<0.07		
Rosehips		1	<0.05		<0.15		
Turnips		1	<0.05		<0.09		
Venison		1	0.07		<0.08		
Wood Pigeon		1	<0.07		<0.16		
Grass		3	<0.05		<0.11	0.63	250
Grass	max				<0.13	0.73	300
Soil		3	<8.5	1.1	<0.24	150	1300
Soil	max				<0.25	180	1500
Freshwater	Hopes Reservoir	1	<0.01		<0.01	<0.0080	0.040
Freshwater	Thorter's Reservoir	1	<0.01		<0.01	<0.0097	0.056
Freshwater	Whiteadder	1	<0.01		<0.01	<0.011	0.095
Freshwater	Thornton Loch Burn	1	<0.01		<0.01	<0.0079	0.033

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

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

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

[d] *The concentration of ^{14}C was 21 Bq kg^{-1}*

[e] *The concentrations of ^{3}H and ^{35}S were <4.0 and <0.50 Bq l^{-1} respectively*

Table 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Mud	2	0.070
Dunbar Inner Harbour	Rocks	2	0.080
Belhaven Bay	Salt marsh	2	0.057
Barns Ness	Sand	2	0.048
Skateraw	Sand	2	0.054
Thornton Loch	Grass and soil	1	0.063
Thornton Loch beach	Sand	2	<0.046
Ferneylea	Grass and soil	1	0.070
Pease Bay	Sand	2	0.061
St Abbs Head	Rocks	2	0.070
Coldingham Bay	Sand	2	<0.046
West Meikle Pinkerton	Grass and soil	2	0.073
Mean beta dose rates on fishing gear			μSv h^{-1}
Torness	Crab and lobster Pots	1	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2014

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	12	<0.010	<0.018	<0.21
Cockburnspath	12	<0.010	<0.012	<0.20
West Barns	5	<0.010	0.022	<0.17

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	1			<0.16	1.4	<0.16	49	<0.47
Rainbow trout	Trawsfynydd Lake	1			<0.06		<0.08	1.6	<0.22
Sediment	Lake shore	2[E]			<0.57	<2.0	<0.52	400	
Sediment	Bailey Bridge	2[E]			<0.88	<2.0	<0.79	150	
Sediment	Fish farm	2[E]			<2.5	5.6	<0.89	840	3.2
Sediment	Footbridge	2[E]			<0.71	<2.0	<0.69	160	
Sediment	Cae Adda	2[E]			<0.50	<2.0	<0.44	110	
Freshwater	Public supply	2[E]	<3.3	<0.66	<0.22		<0.23	<0.19	
Freshwater	Gwylan Stream	2[E]	<3.3	<0.59	<0.24		<0.25	<0.20	
Freshwater	Hot Lagoon	2[E]	<3.1	<1.7	<0.23		<0.25	<0.20	
Freshwater	Afon Prysor	2[E]	<3.1	<0.39	<0.24		<0.25	<0.41	
Freshwater	Trawsfynydd Lake	2[E]	<3.1	<0.84	<0.17		<0.17	<0.21	
Freshwater	Afon Tafarn-helyg	2[E]	<3.1	<0.96	<0.24		<0.25	<0.20	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	1	0.000060	0.00018	0.00027	*	*		
Rainbow trout	Trawsfynydd Lake	1			<0.17				
Sediment	Lake shore	2[E]	<0.55	1.2	2.2				
Sediment	Bailey Bridge	2[E]	<0.56	<0.45	<1.1				
Sediment	Fish farm	2[E]	5.7	15	31				
Sediment	Footbridge	2[E]	<0.53	<0.53	<1.0				
Sediment	Cae Adda	2[E]	<0.30	<0.47	<0.88				
Freshwater	Public supply	2[E]						<0.026	<0.029
Freshwater	Gwylan Stream	2[E]						<0.030	0.075
Freshwater	Hot Lagoon	2[E]						<0.029	0.052
Freshwater	Afon Prysor	2[E]						<0.030	0.28
Freshwater	Trawsfynydd Lake	2[E]						<0.027	<0.090
Freshwater	Afon Tafarn-helyg	2[E]						<0.027	0.051

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Total ^{3}H	^{14}C	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am
Terrestrial Samples									
Milk		2	<2.0	16	<0.025	<0.07			<0.16
Milk	max				<0.026	<0.08			<0.20
Grass		1	<2.7	15		0.34	0.00066	0.0047	0.0066
Potatoes		1	<2.7	25		<0.08	<0.000039	0.00047	0.00020

* *Not detected by the method used*

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

[b] *The concentration of ^{14}C was 43 Bq kg^{-1}*

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

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

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

Table 4.12(b). Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2014

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Pebbles and stones	1	0.10
Footbridge	Stones	1	0.11
Lake shore	Pebbles and stones	2	0.096
Bailey Bridge	Stones	2	0.095
Fish Farm	Pebbles and stones	1	0.098
Fish Farm	Stones	1	0.098
Cae Adda	Pebbles and stones	1	0.088
Cae Adda	Rock and stones	1	0.093

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu + ^{240}Pu
Marine samples									
Plaice	Pipeline	1	<25	<25	41		0.68		
Crabs	Pipeline	1	<25	<25	50		0.28		
Lobsters	Pipeline	1	<25	<25	63	24	0.41	0.0037	0.020
Winkles	Cemaes Bay	1	<25	<25	25	9.8	0.19	0.017	0.11
Seaweed	Cemaes Bay	2[E]				17	<0.97		
Sediment	Cemaes Bay	2[E]					4.1		
Sediment	Cemlyn Bay West	2[E]					2.6		
Seawater	Cemaes Bay	2[E]		<3.1			<0.20		
Seawater	Cemlyn Bay West	2[E]					<0.20		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Pipeline	1		<0.17				
Crabs	Pipeline	1		0.07				
Lobsters	Pipeline	1	0.11	0.33	0.00018	0.00028		110
Winkles	Cemaes Bay	1	0.63	0.14	*	*		56
Seaweed	Cemaes Bay	2[E]		<0.63				
Sediment	Cemaes Bay	2[E]		<0.94				
Sediment	Cemlyn Bay West	2[E]		<0.36				
Seawater	Cemaes Bay	2[E]		<0.30			<1.4	7.9
Seawater	Cemlyn Bay West	2[E]		<0.30			<3.1	14

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		2	<2.1	18	<0.35	<0.07		
Milk	max		<2.2	19	<0.38			
Potatoes		1	<2.0	16	<0.10	<0.05		
Wheat		1	<8.3	73	1.6	<0.12		
Freshwater	Public supply	1[E]	<3.1		<0.19	<0.20	<0.034	0.17

* *Not detected by the method used*

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

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

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

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

Table 4.13(b). Monitoring of radiation dose rates near Wylfa nuclear power station, 2014

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand and stones	1	0.067
Cemaes Bay	Sand and shingle	1	0.076
Cemlyn Bay West	Sand and shingle	1	0.072
Cemlyn Bay West	Shingle	1	0.074

5. Defence establishments

This section considers the results of monitoring by the Environment Agency, FSA and SEPA undertaken routinely near nine defence-related establishments in the UK. In addition, the MoD makes arrangements for monitoring at other defence sites where contamination may occur. The operator at the Atomic Weapons Establishment (AWE) in Berkshire carries out environmental monitoring to determine the effects from low level gaseous discharges at its sites. Monitoring at nuclear submarine berths is also conducted by the MoD (DSTL Radiological Protection Services, 2013).

The medium-term trends in doses, discharges and environmental concentrations at Aldermaston, Devonport, Faslane and Coulport, and Rosyth have been considered in a summary report (Environment Agency, FSA, NIEA and SEPA, 2010b).

Key points

- *Total doses* for the representative person were similar to or less than 1 per cent of the dose limit at all those sites assessed except at Barrow where the effects of historical discharges from Sellafield were apparent
- Discharges, environmental concentrations and dose rates in 2014 were broadly similar to those in 2013 at all establishments

Barrow, Cumbria

- *Total dose* for the representative person was 6 per cent of the dose limit but dominated by effects from Sellafield

5.1 Aldermaston, Berkshire

AWE at Aldermaston provides and maintains the fundamental components of the UK's nuclear deterrent (Trident). The site and facilities at Aldermaston remain in Government ownership under a Government Owned Contractor Operator (GOCO) arrangement. The day-to-day operations and the maintenance of Britain's nuclear stockpile are managed, on behalf of the MoD, by AWE plc. The site is regulated by the Environment Agency to discharge low concentrations of radioactive waste to the environment. The most recent discharge permit was issued in 2012.

A habits survey has been conducted to determine the consumption and occupancy rates by members of the public in the vicinity of the site (Ly *et al.*, 2012). Data for consumption, handling and occupancy rates are provided in Appendix 1 (Table X2.2).

Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), or less than 0.5 per cent of the dose limit. The representative person was an infant consuming local cows' milk at high-rates.

Source specific assessments for high-rate consumers of locally grown foods, for sewage workers and for anglers, give exposures that were also less than 0.005 mSv in 2014 (Table 5.1). Estimates of activity concentrations in fish have been based on shellfish samples from the aquatic monitoring programme for dose determination, and for anglers the assessment has conservatively included consumption of fish at a low rate of 1 kg per year.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks on the site. Discharges in 2014 were generally similar to those reported in 2013. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the site (Figure 3.4). Activity concentrations in milk and foodstuffs (Table 5.2(a)) were generally below the limits of detection, as in 2013. The tritium concentrations in milk, foodstuffs, grass and soil are reported as less than values in 2014. Tritium is considered in the dose assessment and is of very low significance. In soil samples, where comparisons can be drawn at the same location, concentrations of caesium-137 were similar to values in 2013. Levels of uranium isotopes also remained similar to 2013. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Liquid waste discharges and aquatic monitoring

Discharges of radioactive liquid effluent are made under permit to the sewage works at Silchester (Figure 3.4), and to the Aldermaston stream. Discharges of alpha and other beta radionuclides to Silchester in 2014 were similar to those reported in 2013; discharges of tritium to Aldermaston Stream were very low and similar to those in previous years. There are two factors behind the longer-term decline in discharges of tritium from Aldermaston (Figure 5.1): the closure and decommissioning of the original tritium facility (the replacement facility uses sophisticated abatement technology that results in the discharge of significantly less tritium into the environment), and the historical contamination of groundwater. The historical contamination has been reduced in recent years by radioactive decay and dilution by natural processes. Environmental monitoring of the River Thames (Pangbourne and Mapledurham) has continued to assess the effect of historical discharges.

Activity concentrations for freshwater, fish, crayfish and sediment samples, and measurements of dose rates, are given in Tables 5.2(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2013. Concentrations of tritium in samples are reported as less than values. Activity concentrations of artificial radionuclides in River Kennet shellfish were at very low levels and similar to those reported in 2013. Analyses of radiocaesium and uranium activity levels in River Kennet sediments were broadly consistent with previous years. Gross alpha and beta activities in freshwater samples were below the WHO screening levels for drinking water, and this pathway of exposure has been shown to be insignificant (Environment Agency, 2002a).

5.2 Barrow, Cumbria

At Barrow, BAE Systems Marine Limited (BAESM) builds, tests and commissions new nuclear powered submarines. Discharges may be made under permit but there were none in 2014. The FSA's terrestrial monitoring is limited to vegetable and grass sampling and the Environment Agency monitors dose rates and analyses sediment samples from local intertidal areas. The latter is directed primarily at the far-field effects of Sellafield discharges. A habits survey was undertaken in 2012 (Garrod *et al.*, 2013b). The *total dose* from all pathways and sources of radiation was 0.055 mSv (Table 5.1), which was less than 6 per cent of the dose limit. The representative person was an adult living on a local houseboat. Virtually all of this dose was due to the effects of Sellafield discharges. A similar dose was found in 2013 (0.076 mSv). The decrease observed was due to a decrease in dose rates underlying the houseboat. Source specific assessments for a vegetable consumer and a person living on a local houseboat were also carried out. The doses in 2014 were both less than 6 per cent of the dose limit. As for *total dose*, the Sellafield source dominated the effects at the houseboat. No assessment of seafood consumption was undertaken in 2014 because of the absence of relevant monitoring data. However the dose from seafood consumption is less important than that from external exposure on a houseboat (EA, FSA, NIEA, NRW and SEPA, 2014).

Dose rates in intertidal areas near Barrow were slightly enhanced above those expected due to natural background (Table 5.3(b)). This enhancement was due to the far-field effects of historical discharges from Sellafield as evidenced by the results of sediment analysis from the local area (Table 5.3(a)). No effects of discharges from Barrow were apparent in the concentrations of radioactivity in vegetables and grass. All such results are reported as less than values (Table 5.3(a)).

5.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Limited (RRMPOL), a subsidiary of Rolls-Royce plc, carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Megaloughton Lane Sewage Treatment Works to the River Derwent and very low concentrations of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including the LLWR near Drigg. A revised permit became effective on 1st November 2013, reducing the gaseous discharge limit for uranium. The variation has removed a limit for aerial emissions associated with "legacy" waste from the Nuclear Fuel Production Plant (NFPP) permit. The limits for "normal fuel production" are retained and in the varied permit no distinction will be drawn between "normal" and "legacy" emissions. There have been no aerial emissions reported from NFPP under the legacy limit for a number of years.

A habits survey was undertaken at Derby in 2009 (Elliott *et al.*, 2010).

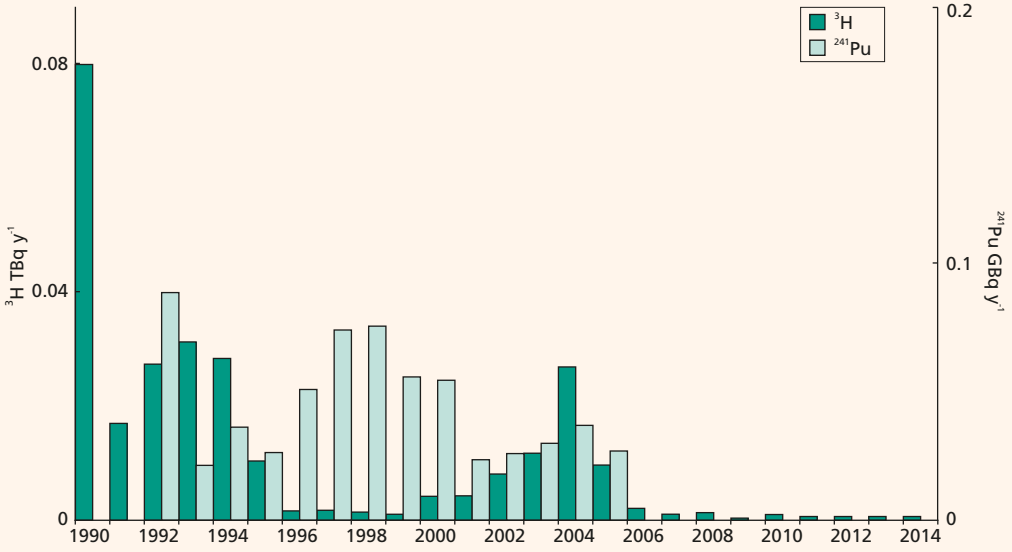


Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2014 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

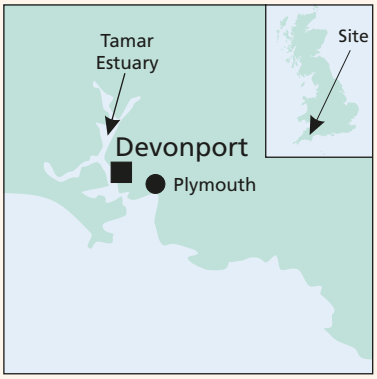
Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. Source specific assessments for consumption of vegetables, fish and drinking river water at high-rates, and for a local resident exposed to external and inhalation pathways from gaseous discharges, give exposures that were also less than 0.005 mSv in 2014 (Table 5.1).

Results of the routine monitoring programme at Derby are given in Table 5.3(a). Analysis of uranium activity in samples taken around the site in 2014 found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. Gross alpha and beta activities in water from the River Derwent were less than the WHO screening levels for drinking water, and the dose from using the river as a source of drinking water was much less than 0.005 mSv per year (Table 5.1). Caesium-137 detected in sediments from local water courses is most likely to have been from fallout from overseas sources.

Table 5.3(a) also includes analysis results from a water sample taken from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for the controlled burial of solid low level radioactive waste. Uranium isotopes detected in the sample were similar to those levels observed elsewhere in Derbyshire (Table 8.8).

5.4 Devonport, Devon



Devonport consists of two parts: the Naval Base and Devonport Royal Dockyard, which are owned and operated by the MoD and by Babcock International Group plc, respectively. Devonport Royal Dockyard refits, refuels, repairs and maintains the Royal Navy's nuclear powered submarines and has a permit granted by the Environment Agency to discharge liquid radioactive waste to the Hamoaze, which is part of the Tamar Estuary, and to the local sewer, and gaseous waste to the atmosphere. During June 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al.*, 2012). The routine monitoring programme in 2014 consisted of measurements of gamma dose rate and analysis of grass, vegetables, fish, shellfish and other marine indicator materials (Tables 5.3(a) and (b)).

Doses to the public

In 2014, the *total dose* from all pathways and sources of radiation was less than 0.005 mSv (Table 5.1), which was less than 0.5 per cent of the dose limit. The representative person was an adult living on a houseboat. Trends in *total dose*s in the area of the south coast (and the Severn Estuary) are shown in Figure 6.1.

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

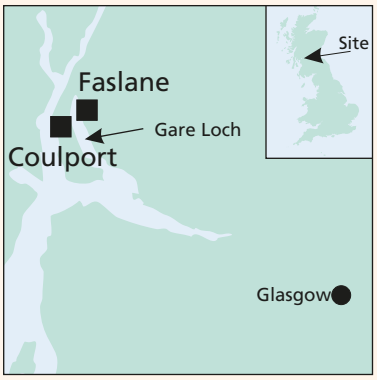
Gaseous discharges and terrestrial monitoring

Gaseous discharges were generally similar to those in 2013. Samples of grass and vegetables were analysed for a number of radionuclides, and concentrations were below the limits of detection in both.

Liquid waste discharges and marine monitoring

Discharges to the Hamoaze were lower than those reported in 2013. Figure 5.2 shows the discharge history of tritium and cobalt-60 since 1990. The main contributor to the variations in tritium discharges over time has been the re-fitting of Vanguard class submarines. These submarines have a high tritium inventory as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. The underlying reason for the overall decrease in cobalt-60 discharges over this period was the improvement in submarine reactor design so that less cobalt-60 was produced during operation, and therefore less was released during submarine maintenance operations. In marine samples, concentrations of tritium and cobalt-60 were close to or below limits of detection. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapon test fallout, were measured in sediment samples. The seaweed samples contained very low concentrations of iodine-131 in 2014. These were most likely to have originated from the therapeutic use of this radionuclide in a local hospital. Gamma dose rates in the vicinity of Devonport were similar to 2013, although some small changes (at the same locations) were noted because rates were measured on different types of ground type from one year to the next. They reflect the local effects of enhanced background radiation from natural sources.

5.5 Faslane and Coulport, Argyll and Bute



The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Marine, a subsidiary of Babcock International Group plc, operates HMNB Clyde, Faslane in partnership with the MoD. However, the MoD remains in control of the undertaking, through the Naval Base Commander, Clyde (NBC Clyde) in relation to radioactive waste disposal. MoD through NBC Clyde also remains in control of the undertaking at Coulport although many of the activities undertaken at Coulport have been outsourced to an industrial alliance comprising of AWE plc, Babcock and Lockheed Martin UK (known as ABL). Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD. SEPA reviewed these letters in 2012 and the process of updating the letters continued in 2014. The discharges released during 2014 are shown in Appendix 2. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the MoD. There were no disposals of solid waste from the sites during 2014.

During August 2011, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Rumney *et al.*, 2013b). Data for consumption, handling and occupancy rates are summarised in Appendix 1 (Table X2.2).

The *total dose* from all pathways and sources of radiation was less than 0.005 mSv in 2014 (Table 5.1). The representative person was an adult exposed to radioactivity in marine sediments, but as in 2013 the dose was less than 0.5 per cent of the dose limit for members of the public. Source specific assessments for a high-rate consumer of fish and shellfish and a consumer of locally grown food (based on limited data), give exposures that were also less than 0.005 mSv.

The routine marine monitoring programme consisted of the analysis of shellfish, seawater, seaweed and sediment samples, and gamma dose rate measurements. Terrestrial monitoring included beef, honey, water, grass and soil sampling. The results are given in Tables 5.3(a) and (b) and were similar to those in 2013. Radionuclide concentrations were generally below the limits of detection, with caesium-137 concentrations in sediment consistent with

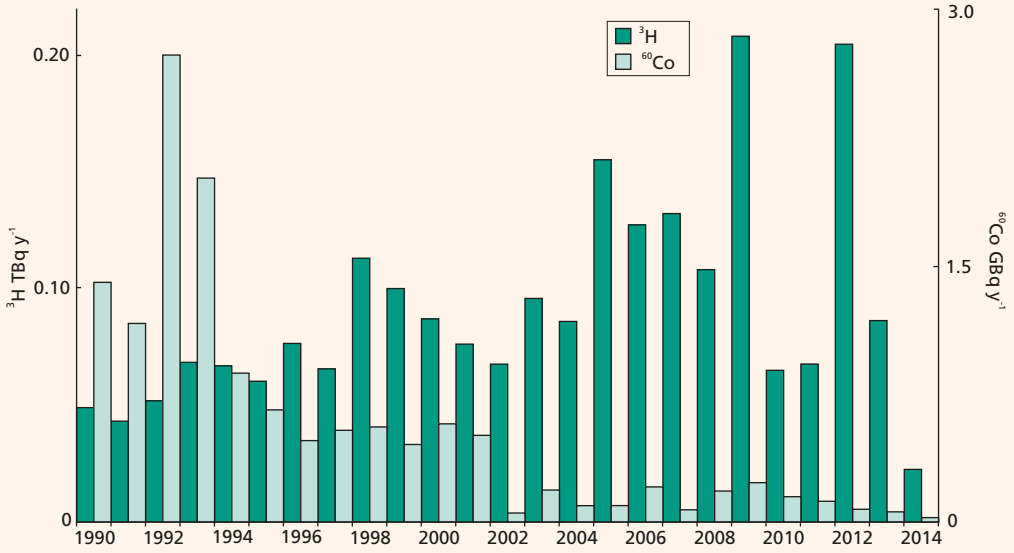


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2014

the distant effects of discharges from Sellafield, and with weapon testing and Chernobyl fallout. Carbon-14 concentrations in shellfish were similar to natural background levels. Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background.

5.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued during 2014 in order to determine the effects of past discharges from the US submarine support facilities which closed in 1992. Radionuclide concentrations were low (Table 5.3(a)). Gamma dose rate measurements from intertidal areas (Table 5.3(b)) were similar to those observed in 2013. A small increase in the dose rate at Kilmun Pier was observed and this is likely to be due to natural variations in the environment. The external radiation dose to a person spending time on the loch shore was 0.011 mSv in 2014, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 5.1).

5.7 Rosyth, Fife

The site is operated by Babcock Marine, a division of Babcock International Group plc, who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006 and has mainly been completed, with the exception of some small areas of the site where facilities continue to be required to manage radioactive wastes. To date, more than 99 per cent of the waste arising as a result of site decommissioning is being recycled.

Radioactive waste produced during decommissioning has been disposed of under an authorisation granted to Rosyth Royal Dockyard Limited (RRDL) in October 2008. Radioactive aqueous and gaseous wastes continue to be discharged in accordance with conditions in the same authorisation.

SEPA has received an application under RSA 93 from RRDL to dispose of solid, liquid and gaseous low level radioactive wastes arising from work to dismantle the seven redundant submarines currently berthed at Rosyth. SEPA has also received an application from the MoD to transfer solid and liquid radioactive waste from the submarines to allow RRDL to carry out the dismantling work. This application will be handled administratively in the form of letters of agreement between SEPA and the MoD rather than

under RSA 1993. Currently, SEPA is determining both applications.

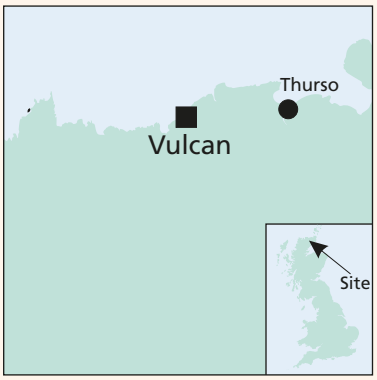
SEPA, and other stakeholders, are currently engaging with the MoD Nuclear Legacy Works Team based at Rosyth to identify the Best Practicable Environmental Option (BPEO) for managing radiologically contaminated ion-exchange resins stored securely in the Active Waste Accumulation Facility on the Rosyth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

The *total dose* from all pathways and sources was less than 0.005 mSv in 2014 (Table 5.1), which was less than 0.5 per cent of the dose limit. The representative person was an adult with exposure over marine sediments. The source specific assessments for a local fisherman and beach user also give an exposure that was less than 0.005 mSv in 2014.

In 2014, authorised gaseous discharges from Rosyth were reported as nil. Liquid wastes are discharged via pipeline to the Firth of Forth. In all cases the activities in the liquid discharged were below authorised limits. Discharges of tritium from Rosyth decreased in 2014, due to a reduction in the numbers of samples of nuclear submarine primary coolant that were disposed of following analysis in the Rosyth Radiochemistry Laboratory.

SEPA's routine monitoring programme included analysis of shellfish, environmental indicator materials and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 5.3(a) and (b). The radioactivity levels detected were at similar low levels to 2013 and in most part due to the combined effects of Sellafield, weapon testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2010 (Rumney *et al.*, 2013c).

5.8 Vulcan NRTE, Highland



The Vulcan Naval Reactor Test Establishment is operated by Defence Equipment and Support (Submarines), part of the Ministry of Defence, and acts as the test bed for prototype submarine nuclear reactors. It is located adjacent to the Dounreay site and the impact of its discharges is considered along with those from Dounreay (in Section 3). The site continued operations in 2014. In Written Parliamentary Statements made on 2nd of November 2011, it was stated that "the Vulcan NRTE site will not be required to support reactor core prototyping activity when the current series of PWR2 reactor core prototype tests are completed in 2015. In 2014, the Secretary of State for Defence announced a decision to refuel HMS Vanguard following the discovery of a fuel cladding failure in the reactor at Vulcan. He also asked the MOD's Chief Scientific Advisor to review the evidence on which the 2011 decision was based. Options for the future of the site are currently being assessed; these range from placing the prototype facilities into care and maintenance while retaining the site's strategic capabilities, to decommissioning the site and returning it to Nuclear Decommissioning Authority ownership. Following the discovery of the fuel cladding failure, Vulcan introduced engineering measures to restrict discharges as an application of Best Practicable Means.

Table 5.1. Individual doses – defence sites, 2014

Site	Representative person[a,b]	Exposure mSv, per year					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways
Aldermaston and Burghfield							
***Total dose* – all sources**	**Infant milk consumer**	**<0.005[c]**	**–**	**<0.005**	**–**	**–**	**–**
Source specific doses	Anglers	<0.005[c]	<0.005	–	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	<0.005[c]	–	<0.005	–	–	<0.005
	Workers at Silchester STW	<0.005	–	–	<0.005[d]	<0.005[e]	–
Barrow							
***Total dose* – all sources**	**Adult occupants on houseboats[g]**	**0.055**	**–**	**–**	**0.055**	**–**	**–**
Source specific doses	Houseboat occupants	0.053	–	–	0.053	–	–
	Prenatal children of consumers of locally grown food	<0.005	–	<0.005	–	–	–
Derby							
***Total dose* – all sources**	**Adult consumer of domestic fruit**	**<0.005[c]**	**–**	**<0.005**	**–**	**–**	**–**
Source specific doses	Anglers consuming fish and drinking water[f]	<0.005	<0.005	–	<0.005	<0.005	–
	Inhabitants and consumers of locally grown food	<0.005[c]	–	<0.005	–	–	<0.005
Devonport							
***Total dose* – all sources**	**Adult occupants on houseboats**	**<0.005**	**<0.005**	**–**	**<0.005**	**–**	**–**
Source specific doses	Prenatal children of consumers of seafood	<0.005	<0.005	–	<0.005	–	–
	Houseboat occupants	<0.005	–	–	<0.005	–	–
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	–	<0.005	–	–	<0.005
Faslane							
***Total dose* – all sources**	**Adult occupants over sediment**	**<0.005**	**<0.005**	**–**	**<0.005**	**–**	**–**
Source specific doses	Seafood consumer	<0.005	<0.005	–	<0.005	–	–
	Consumers of locally grown food	<0.005	–	<0.005	–	–	–
Holy Loch							
Source specific doses	Anglers	0.011	–	–	0.011	–	–
Rosyth							
***Total dose* – all sources**	**Adult occupants over sediment**	**<0.005**	**–**	**–**	**<0.005**	**–**	**–**
Source specific doses	Fishermen and beach users	<0.005	<0.005	–	<0.005	–	–

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

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

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

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

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

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

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

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Flounder	Woolwich Reach	1		<25	<1.0	<0.06			
Signal crayfish	Ufton Bridge – Theale	1	<25	<25	*	<0.06	0.041	0.0012	0.032
Sediment	Pangbourne	4[E]				<1.8	15	<1.2	17
Sediment	Mapledurham	4[E]				16	7.9	<0.69	8.2
Sediment	Aldermaston	4[E]				5.2	23	<1.3	23
Sediment	Spring Lane	4[E]				<1.2	10	<0.94	10
Sediment	Stream draining south	4[E]				<0.73	28	<2.2	30
Sediment	Reading (Kennet)	4[E]				3.3	14	<0.97	14
Gullypot sediment	Falcon Gate	1[E]		<9.2		<1.3	18	<1.3	19
Gullypot sediment	Main Gate	1[E]		<6.9		<0.35	13	<1.1	13
Gullypot sediment	Tadley Entrance	1[E]		<7.3		23	19	<1.2	18
Gullypot sediment	Burghfield Gate	1[E]		<6.2		<1.4	13	0.46	13
Freshwater	Pangbourne	4[E]		<3.3		<0.22	0.010	<0.0017	0.0071
Freshwater	Mapledurham	4[E]		<3.5		<0.26	0.0097	<0.0013	0.0079
Freshwater	Aldermaston	4[E]		<4.1		<0.21	0.0081	<0.0015	0.0059
Freshwater	Spring Lane	4[E]		<3.4		<0.24	<0.0030	<0.0016	<0.0028
Freshwater	Reading (Kennet)	4[E]		<3.6		<0.19	<0.0059	<0.0013	0.0046
Crude liquid effluent	Silchester treatment works	4[E]		<8.0		<0.22	<0.0057	<0.0038	<0.0050
Final Liquid effluent	Silchester treatment works	4[E]		<8.4		<0.20	<0.0037	<0.0022	<0.0028
Sewage sludge	Silchester treatment works	4[E]		<7.9		<0.16	0.80	<0.048	0.79

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Flounder	Woolwich Reach	1			<0.06				
Signal crayfish	Ufton Bridge – Theale	1	<0.000028	0.00021	0.00017	*	*		
Sediment	Pangbourne	4[E]	<0.75	<0.36	<0.73			310	350
Sediment	Mapledurham	4[E]	<0.47	<0.60	<0.45			<120	<140
Sediment	Aldermaston	4[E]	<0.42	1.1	<0.67			310	620
Sediment	Spring Lane	4[E]	<0.40	<0.22	<0.61			<150	<240
Sediment	Stream draining south	4[E]	<0.40	<0.19	<0.70			370	960
Sediment	Reading (Kennet)	4[E]	<0.37	<0.31	<0.55			<150	300
Gullypot sediment	Falcon Gate	1[E]	<0.43	<0.18	<1.7			250	650
Gullypot sediment	Main Gate	1[E]	<0.58	<0.40	<0.50			180	250
Gullypot sediment	Tadley Entrance	1[E]	<0.45	1.2	<0.66			250	530
Gullypot sediment	Burghfield Gate	1[E]	<0.43	<0.18	<1.3			140	340
Freshwater	Pangbourne	4[E]	<0.0035	<0.0018	<0.0077			<0.059	0.29
Freshwater	Mapledurham	4[E]	<0.0028	<0.0019	<0.0056			<0.047	0.24
Freshwater	Aldermaston	4[E]	<0.0029	<0.0017	<0.0060			<0.032	0.20
Freshwater	Spring Lane	4[E]	<0.0031	<0.0017	<0.0059			<0.030	0.16
Freshwater	Reading (Kennet)	4[E]	<0.0034	<0.0020	<0.0060			<0.039	0.099
Crude liquid effluent	Silchester treatment works	4[E]	<0.0078	<0.0039	<0.27			<0.077	0.61
Final Liquid effluent	Silchester treatment works	4[E]	<0.0038	<0.0022	<0.28			<0.073	0.54
Sewage sludge	Silchester treatment works	4[E]	<0.016	0.014	<0.23			<5.6	9.3

Table 5.2(a). continued

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples							
Milk		2	<2.0	<0.07	<0.00052	<0.00045	<0.00038
Milk	max			<0.08	<0.00067	<0.00054	
Potatoes		1	<2.0	<0.05	0.015	0.00051	0.016
Wheat		1	<2.0	<0.11	0.0015	<0.0016	0.0021
Grass	Location 7	1[E]	<14	<1.1	<0.31	<0.25	<0.25
Grass	Opposite Gate 26A	1[E]	<20	<1.3	<0.21	<0.19	<0.21
Grass	Kestrel Meads	1[E]	<9.5	<0.61	0.55	<0.13	0.51
Grass	Young's Industrial Estate	1[E]	<8.2	<1.6	<0.37	<0.17	<0.34
Soil	Location 7	1[E]	<7.2	13	19	<1.7	23
Soil	Opposite Gate 26A	1[E]	<11	22	13	<1.3	11
Soil	Kestrel Meads	1[E]	<6.4	4.1	17	<1.2	18
Soil	Young's Industrial Estate	1[E]	<7.7	1.8	15	<1.3	15

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples							
Milk		2	<0.000029	<0.000024	<0.000031		
Milk	max		<0.000035	<0.000025	<0.000034		
Potatoes		1	<0.000045	0.00025	0.00017		
Wheat		1	<0.000049	0.000022	0.000077		
Grass	Location 7	1[E]	<0.16	<0.071		<3.5	180
Grass	Opposite Gate 26A	1[E]	<0.15	<0.11		<2.0	160
Grass	Kestrel Meads	1[E]	<0.14	<0.20		<6.7	300
Grass	Young's Industrial Estate	1[E]	<0.14	<0.057		<4.8	270
Soil	Location 7	1[E]	<0.51	0.47		210	540
Soil	Opposite Gate 26A	1[E]	<0.41	0.82		<130	290
Soil	Kestrel Meads	1[E]	<0.48	<0.42		160	420
Soil	Young's Industrial Estate	1[E]	<0.62	<0.35		<130	340

* *Not detected by the method used*

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

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

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

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

Table 5.2(b). Monitoring of radiation dose rates near Aldermaston, 2014

Location	Ground type type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	3	0.064
Pangbourne, riverbank	Grass and mud	1	0.059
Mapledurham, riverbank	Grass	3	0.062
Mapledurham, riverbank	Grass and mud	1	0.053

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2014

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{125}Sb	^{131}I	^{134}Cs	^{137}Cs
Barrow										
Grass	Barrow	1[F]		<2.0		<0.13	<0.31		<0.16	<0.16
Potato	Barrow	1[F]		<2.0		<0.06	<0.14		<0.07	<0.08
Sediment	Walney Channel – N of discharge point	2				<0.53	<1.8		<0.46	76
Sediment	Walney Channel – S of discharge point	2				<0.51	<1.6		<0.53	49
Derby										
Carrot	Derby	1[F]				<0.10	<0.14		<0.09	<0.07
Wheat	Derby	1[F]				<0.09	<0.14		<0.09	<0.07
Sediment	River Derwent, upstream	1				<0.62				3.8
Sediment	Fritchley Brook	1				<0.47				1.1
Sediment	River Derwent, downstream	4				<0.71				3.8
Water	River Derwent, upstream	1				<0.39				
Water[c]	Fritchley Brook	1		<3.2		<0.22				<0.19
Water	River Derwent, downstream	4				<0.21				
Devonport										
Grey mullet	Plymouth Sound	1[F]	<25	<25	23	<0.04	<0.11	*	<0.05	<0.04
Crabs	Plymouth Sound	1[F]			30	<0.17	<0.34	*	<0.17	<0.14
Shrimp	River Lynher	1[F]			27	<0.03	<0.09	*	<0.04	<0.03
Mussels	River Lynher	1[F]	<25	<25	21	<0.15	<0.29	*	<0.14	<0.13
Seaweed[d]	Kinterbury	2				<0.96		2.9		
Sediment[e]	Kinterbury	2		<5.1		<1.0				2.7
Sediment	Torpoint South	2		<3.8		<0.68				0.86
Sediment	Lopwell	2		<7.4		<0.89				5.7
Seawater	Torpoint South	2		<2.9	<2.9	<0.32				
Seawater	Millbrook Lake	2		<2.8	<3.2	<0.22				
Beetroot		1[F]		<2.0		<0.07	<0.14		<0.07	<0.06
Grass		1[F]		<2.0		<0.07	<0.23		<0.11	<0.08
Faslane										
Mussels	Rhu	1			29	<0.10	<0.25		<0.10	0.53
Winkles	Rhu	1			32	<0.10	<0.19		<0.10	0.44
Fucus vesiculosus	Rhu	1				<0.10	<0.10		<0.10	0.20
Fucus vesiculosus	Garelochhead	1				<0.10	<0.10		<0.10	0.16
Fucus vesiculosus	Carnban boatyard	1				<0.10	<0.12		<0.10	0.21
Sediment	Rhu	1				<0.10	<0.15		<0.10	9.2
Sediment	Garelochhead	1				<0.10	<0.22		<0.10	3.6
Sediment	Carnban boatyard	1				<0.10	<0.20		<0.10	2.7
Seawater	Carnban boatyard	2		<1.1		<0.10	<0.18		<0.10	<0.10
Beef muscle	Faslane	1		<5.0		<0.05			<0.05	0.14
Honey	Faslane	1		<5.0		<0.05			<0.05	0.22
Grass	Auchengaich	1		<5.0		<0.05			<0.05	0.21
Grass	Lochan Ghlas Laoigh	1		<5.0		<0.05			<0.09	2.2
Soil	Auchengaich	1		<5.0		<0.12			<0.16	39
Soil	Lochan Ghlas Laoigh	1		<5.0		<0.15			<0.18	18
Freshwater	Helensburgh Reservoir	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Loch Finlas	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Auchengaich	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Lochan Ghlas Laoigh	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Loch Eck	1		<1.0		<0.05			<0.05	<0.05
Freshwater	Loch Lomond	1		<1.0		<0.01			<0.01	<0.01
Holy Loch										
Sediment	Mid-Loch	1				<0.10	<0.18		<0.10	5.9
Rosyth										
Mackerel	Firth of Forth	1				<0.10	<0.24		<0.10	0.15
Winkles	St David's Bay	1				<0.10	<0.27		<0.11	0.19
Fucus vesiculosus	East of dockyard	1				<0.10	<0.13		<0.10	<0.10
Sediment	East of dockyard	1				<0.10	<0.20		<0.10	2.2
Sediment	Port Edgar	1				<0.10	<0.29		<0.15	8.2
Sediment	West of dockyard	1				<0.10	<0.14		<0.10	1.1
Sediment	East Ness Pier	1				<0.10	<0.18		<0.10	5.8
Sediment	Blackness Castle	1				<0.10	<0.27		<0.12	5.7
Sediment	Charlestown Pier	1				<0.10	<0.14		<0.10	0.60
Seawater	East of dockyard	2		<1.0		<0.10	<0.18		<0.10	<0.10
Freshwater	Castlehill	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Holl Reservoir	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Gartmorn	1		<1.0		<0.01			<0.01	<0.01
Freshwater	Morton No. 2	1		1.2		<0.05			<0.05	<0.05

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Barrow									
Grass	Barrow	1[F]	<0.26				<0.16		
Potato	Barrow	1[F]	<0.09				<0.10		
Sediment	Walney Channel – N of discharge point	2	<0.77				180	460	580
Sediment	Walney Channel – S of discharge point	2	<0.77				99	310	550
Derby									
Carrot	Derby	1[F]	<0.20	0.0054	<0.00051	0.0049	<0.15		
Wheat	Derby	1[F]	<0.12	<0.0013	<0.00089	0.0012	<0.07		
Sediment	River Derwent, upstream	1		36	<1.7	36		310	430
Sediment	Fritchley Brook	1		24	<1.0	23		<110	450
Sediment	River Derwent, downstream	4		32	<1.9	32		380	570
Water	River Derwent, upstream	1						<0.066	0.19
Water[c]	Fritchley Brook	1		0.022	<0.0026	0.017		<0.072	0.31
Water	River Derwent, downstream	4						<0.083	0.21
Devonport									
Grey mullet	Plymouth Sound	1[F]	<0.13				<0.12		
Crabs	Plymouth Sound	1[F]	<0.22				<0.12		
Shrimp	River Lynher	1[F]	<0.09				<0.08		
Mussels	River Lynher	1[F]	<0.19				<0.10		
Sediment[e]	Kinterbury	2					<0.23		
Beetroot		1[F]	<0.09				<0.11		
Grass		1[F]	<0.21				<0.06		
Faslane									
Mussels	Rhu	1	<0.21				0.18		
Winkles	Rhu	1	<0.15				<0.10		
Fucus vesiculosus	Rhu	1	<0.10				<0.10		
Fucus vesiculosus	Garelochhead	1	<0.10				<0.10		
Fucus vesiculosus	Carnban boatyard	1	<0.13				<0.10		
Sediment	Rhu	1	1.0				0.72		
Sediment	Garelochhead	1	0.38				<0.29		
Sediment	Carnban boatyard	1	0.51				0.35		
Seawater	Carnban boatyard	2	<0.17				<0.10		
Beef muscle	Faslane	1					<0.07		
Honey	Faslane	1					<0.07		
Grass	Auchengaich	1					<0.06		
Grass	Lochan Ghlas Laoigh	1					<0.09		
Soil	Auchengaich	1	1.5				0.22		
Soil	Lochan Ghlas Laoigh	1					0.78		
Freshwater	Helensburgh Reservoir	1					<0.01	<0.0091	0.059
Freshwater	Loch Finlas	1					<0.01	<0.010	0.037
Freshwater	Auchengaich	1					<0.01	<0.010	0.015
Freshwater	Lochan Ghlas Laoigh	1					<0.01	<0.010	0.020
Freshwater	Loch Eck	1					<0.05	<0.0075	0.039
Freshwater	Loch Lomond	1					<0.01	<0.077	0.032
Holy Loch									
Sediment	Mid-Loch	1	0.56				<0.31		
Rosyth									
Mackerel	Firth of Forth	1	<0.22				<0.14		
Winkles	St David's Bay	1	<0.23				<0.13		
Fucus vesiculosus	East of dockyard	1	<0.12				<0.10		
Sediment	East of dockyard	1	0.32				<0.26		
Sediment	Port Edgar	1	1.5				1.3		
Sediment	West of dockyard	1	<0.24				<0.25		
Sediment	East Ness Pier	1	<0.31				<0.30		
Sediment	Blackness Castle	1	1.2				<0.47		
Sediment	Charlestown Pier	1	<0.26				<0.28		
Seawater	East of dockyard	2	<0.17				<0.11		
Freshwater	Castlehill	1					<0.02	<0.012	0.050
Freshwater	Holl Reservoir	1					<0.01	<0.013	0.063
Freshwater	Gartmorn	1					<0.01	<0.011	0.10
Freshwater	Morton No. 2	1					<0.05	<0.011	0.11

* *Not detected by the method used*

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

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

[c] *The concentrations of ^{228}Th, ^{230}Th and ^{232}Th were <0.014, <0.0097 and <0.0031 Bq l^{-1} respectively*

[d] *The concentration of ^{99}Tc was <1.4 Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.20 and <0.45 Bq kg^{-1}*

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

Table 5.3(b). Monitoring of radiation dose rates near defence establishments, 2014

Establishment	Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Barrow	Walney Channel, N of discharge point	Mud	1	0.10
Barrow	Walney Channel, N of discharge point	Mud and sand	1	0.086
Barrow	Walney Channel, S of discharge point	Mud	1	0.085
Barrow	Walney Channel, S of discharge point	Mud and sand	1	0.090
Devonport	Torpoint South	Mud and slate	1	0.12
Devonport	Torpoint South	Rock and mud	1	0.093
Devonport	Kinterbury Access Gate	Mud and stones	2	0.091
Devonport	Lopwell	Mud	2	0.087
Faslane	Garelochhead	Sand and shingle	2	0.058
Faslane	Gulley Bridge Pier	Stones and pebbles	2	0.061
Faslane	Rhu	Shingle	2	0.056
Faslane	Helensburgh	Sand	2	0.064
Faslane	Carnban boatyard	Shingle	2	0.061
Faslane	Rahane	Shingle	2	0.065
Faslane	Rosneath Bay	Shingle	2	0.052
Faslane	Auchengaich	Grass	1	0.069
Faslane	Lochan Ghlas	Grass	1	0.079
Holy Loch	Kilmun Pier	Rock/sediment	1	0.079
Holy Loch	Mid-Loch	Sediment	1	0.057
Rosyth	Blackness Castle	Sand	2	0.062
Rosyth	Charlestown Pier	Sand	2	0.052
Rosyth	East Ness Pier	Sand	2	0.056
Rosyth	East of Dockyard	Sand and shingle	2	0.053
Rosyth	Port Edgar	Sand	2	0.063
Rosyth	West of Dockyard	Sand	2	0.053

6. Radiochemical production

This section considers the results of monitoring by the Environment Agency and FSA at two sites associated with the radiopharmaceutical industry. The sites, at Amersham and Cardiff, are operated by GE Healthcare Limited. This is a health science company functioning in world-wide commercial healthcare and life science markets.

Permits have been issued by the Environment Agency to the sites respectively allowing the discharge of gaseous and liquid radioactive wastes (Appendix 2). Independent monitoring of the environment around the Amersham and Cardiff sites is conducted by the Environment Agency and FSA. The Environment Agency has an agreement with NRW to carry out monitoring on its behalf in Wales. The medium-term trends in discharges, environmental concentrations and dose at Amersham and Cardiff have been considered in a summary report (Environment Agency, FSA, NIEA and SEPA, 2010b).

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- *Total dose* for the representative person decreased in 2014, down to 14 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Concentrations of radioactivity in terrestrial and aquatic samples, and gamma dose rates, were low and generally similar to those in 2013

GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- *Total dose* for the representative person decreased and was the lowest reported value in 2014. The highest dose was due to the consumption of seafood
- Gaseous and liquid discharges of tritium and carbon-14 remained low in 2014; carbon-14 gaseous discharges were the lowest reported in 2014
- Tritium concentrations in fish species continued their long-term decline; levels in fish were the lowest reported in 2014

6.1 Grove Centre, Amersham, Buckinghamshire

GE Healthcare Limited's principal establishment is located in Amersham, Buckinghamshire. It consists of a range of plants for manufacturing diagnostic imaging products for use in medicine and research. The monitoring programme consists of analysis of fish, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 3.4. The most recent habits survey was undertaken in 2009 (Clyne *et al.*, 2010b).

Doses to the public

The *total dose* from all pathways and sources of radiation was 0.14 mSv in 2014 (Table 6.1) or 14 per cent of the dose limit, and down from 0.22 mSv in 2013. The lower value in 2014 was due to changes in working practices (for distribution activities, products spend less time in the dispatch yard) and the construction of a shield wall on the western side of a building that contains legacy radioactive wastes. The representative person was a prenatal child of local inhabitants in 2014 (as opposed to a local adult in 2013). As in previous years, the *total dose* received was almost entirely due to direct radiation in 2014. Exposure from direct radiation varies around the boundary of the Grove Centre and therefore the *total dose* is determined as a cautious upper value. The trend in *total dose* over the period 2004 – 2014 is given in Figure 1.2. *Total doses* remained broadly similar with time (up until 2013) and were dominated by direct radiation.

Source specific assessments for a high-rate consumer of locally grown foods, for an angler and for a worker at Maple Lodge STW, which serves the sewers to which permitted discharges are made, give exposures that were less than the *total dose* in 2014 (Table 6.1). The dose for a high-rate consumer of locally grown foods (which included a contribution from the gaseous plume related pathways) was 0.009 mSv, or less than 1 per cent of the dose limit to members of the public of 1 mSv. The small increase in dose, from 0.008 mSv in 2013, was primarily due to higher atmospheric discharges of radon-222 in 2014; this radionuclide remains the dominant contributor. It should be noted that the current assessment methodology uses a conservative dose factor based on this nuclide being in

equilibrium with its daughter products. The dose to a local angler in 2014 was less than 0.005 mSv, as in 2013.

The 2009 habits survey at Amersham did not directly identify any consumers of fish, shellfish or freshwater plants. As in previous surveys, however, there was anecdotal evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg per year for fish has been included in the dose assessment for an angler.

The Grove Centre discharges liquid waste to Maple Lodge STW, and the proximity to raw sewage and sludge experienced by sewage treatment workers is a likely exposure pathway (National Dose Assessment Working Group, 2004). The dose received by one of these workers in 2014 was modelled using the methods described in Appendix 1. The dose from a combination of external exposure to contaminated raw sewage and sludge and the inadvertent ingestion and inhalation of re-suspended radionuclides was 0.005 mSv.

Gaseous discharges and terrestrial monitoring

The Amersham facility is permitted to discharge gaseous radioactive wastes via stacks on the site. In 2014, gaseous discharges were generally similar to those in 2013. The results for the terrestrial food monitoring, including those for local milk, crops and grass samples, are given in Table 6.2. Sulphur-35 was positively detected at low concentrations (just above the LoD) in some crop samples in 2014. As in previous years, caesium-137 activities were detected in soil near the site, and this is likely to be due to global fallout from testing of weapons or from the Chernobyl accident.

Liquid waste discharges and aquatic monitoring

Radioactive liquid wastes are discharged to sewers serving the Maple Lodge STW; treated effluent subsequently enters the Grand Union Canal and the River Colne. In 2014, liquid discharges were generally similar to those in recent years. The results of the aquatic monitoring programme are given in Table 6.2. Activity concentrations in freshwater, and effluent and sludge from Maple Lodge STW, are reported as less than values. The sludge samples contained very low concentrations of iodine-131 (just above the LoD) in 2014, which were most likely to have originated from the therapeutic use of this radionuclide in a local hospital. The caesium-137 detected in sediments upstream of the STW outfall is likely to be derived from weapons test fallout or the Chernobyl accident. Gross alpha and beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates (given in footnote, Table 6.2) above the banks of the Grand Union Canal remained low in 2014.

6.2 Maynard Centre, Cardiff

GE Healthcare Limited operates a second establishment, on the Forest Farm industrial estate near Whitchurch, Cardiff. GE Healthcare Limited ceased manufacturing a range of radio-labelled products containing tritium in 2009 and products containing carbon-14 in 2010. The site is being decommissioned and the bulk of the site will be de-licensed (subject to ONR approval), leaving a smaller licensed area for storage of historical radioactive wastes. In 2014, the operator informed ONR their intention is to apply for a licence to operate the storage site, to be called the Cardiff Nuclear Licensed Site (CNLS), the boundary of which is entirely within the confines of the current Maynard Centre nuclear licensed site and its security boundary. Gaseous discharges from the Maynard Centre are now the result of out-gassing of tritium and carbon-14 from stored wastes with only small amounts originating from decommissioning.

GE Healthcare Limited's custom radio-labelling division was acquired by Quotient Bioresearch, (a division of Quotient Bioscience) which operates from different premises in Cardiff (a purpose-built laboratory at Trident Park). This non-nuclear facility also discharges carbon-14 and tritium to atmosphere and in liquid wastes. These are at much reduced levels in comparison to when the Maynard Centre was manufacturing radio-labelled products. The effluents discharged from the site are also treated to ensure that organic matter present is destroyed prior to discharge. The facility has an environmental permit issued and regulated by NRW.

The Environment Agency and FSA conduct a routine monitoring programme on behalf of NRW and the Welsh Government. This includes sampling of locally produced food, fish and shellfish, and external dose rate measurements over muddy, intertidal areas. Environmental materials including seawater, intertidal sediment, freshwater, seaweed, and grass provide additional information. The most recent habits survey was undertaken in 2003 (McTaggart *et al.*, 2004a).

Previous monitoring data from Cardiff has been reviewed in order to compare the apparent enhancement of tritium concentrations on uptake by marine biota with bioaccumulation at other UK sites (Hunt *et al.*, 2010). The observed enhancement factor at Cardiff remains at least an order of magnitude greater than at the other sites studied, although the organically bound fractions were uniformly high. Various earlier monitoring and research

efforts have targeted OBT in foodstuffs (FSA, 2001b; Swift, 2001; Williams *et al.*, 2001; Leonard *et al.*, 2001 and McCubbin *et al.*, 2001).

Doses to the public

The *total dose* from all pathways and sources was less than 0.005 mSv (Table 6.1), or less than 0.5 per cent of the dose limit, and down from 0.010 mSv in 2013, and the lowest reported value in 2014. This dose estimates take into account the increased dose coefficients for OBT derived for discharges from the Maynard Centre and includes consideration of prenatal children. The decreased value was mostly due to lower carbon-14 concentrations in milk and, to a lesser extent, phosphorous-32 concentrations in milk (due to a lower assessed less than value used) in 2014. As in 2013, an infant consuming milk at high-rates was the representative person. Trends in *total doses* over time (2004 – 2014) in the Severn Estuary (and areas of the south coast) are shown in Figure 6.1. At Cardiff, the most significant reductions in the total dose, prior to 2007, were largely due to lower concentrations of tritium and carbon-14 in seafood. Since 2007, the total doses have generally continued to decrease over time and were low.

Source specific assessments for a recreational user of the River Taff, and for a worker at Cardiff East Waste Water Treatment Works (WWTW), give doses that were less than the total dose in 2014 (Table 6.1). The dose to a high-rate consumer of locally grown foods was 0.005 mSv, and the reason for the decrease in dose (from 0.016 mSv in 2013) was the same as that for total dose. The dose to a high-rate consumer of seafood was 0.006 mSv, and down from 0.009 mSv in 2013. The lower value in 2014 was due to a decrease from external exposure over intertidal areas, near the Cardiff pipeline (east of pipeline). An assessment of exposure was estimated (modelled using the methods described in Appendix 1) for a worker at WWTW; the dose was much less than 0.005 mSv.

The dose coefficients for OBT differ from those for tritiated water (see Appendix 1, A3.4) and the estimates of dose to members of the public account for this. For ingestion of seafood caught near Cardiff, an area taken to be equivalent to the Bristol Channel, a dose coefficient based on a site-specific study of the consumption of fish caught in Cardiff Bay is used. An experimental study by Hunt *et al.*, (2009) suggests that this raised dose coefficient is conservative, but it is retained for 2014 dose assessments on the advice of PHE. For ingestion of other food, the ICRP dose coefficient for OBT is applied.

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

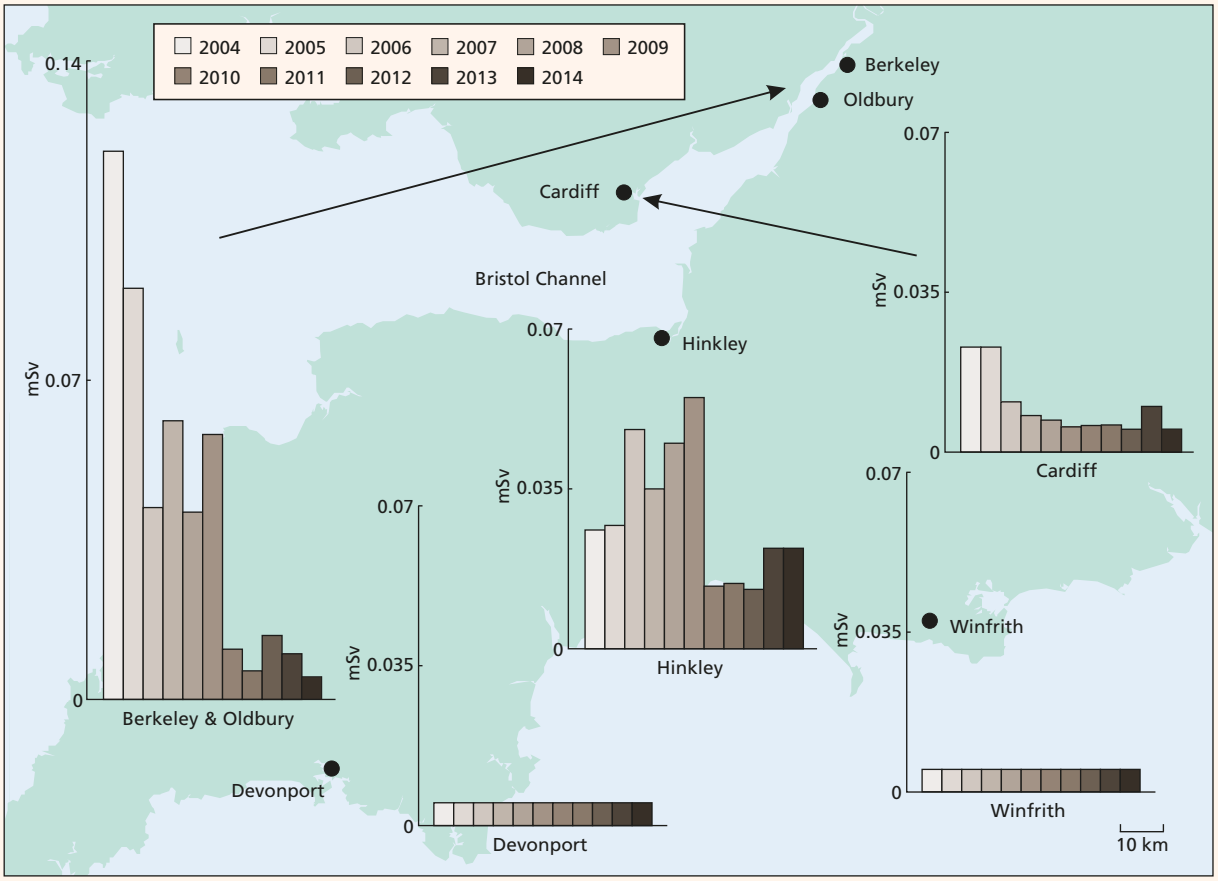


Figure 6.1. *Total dose* for major sites in the Severn Estuary and south coast, 2004-2014
(Note different scales used for Berkeley and Oldbury; small doses, less than or equal to 0.005 mSv, are recorded as being 0.005 mSv)

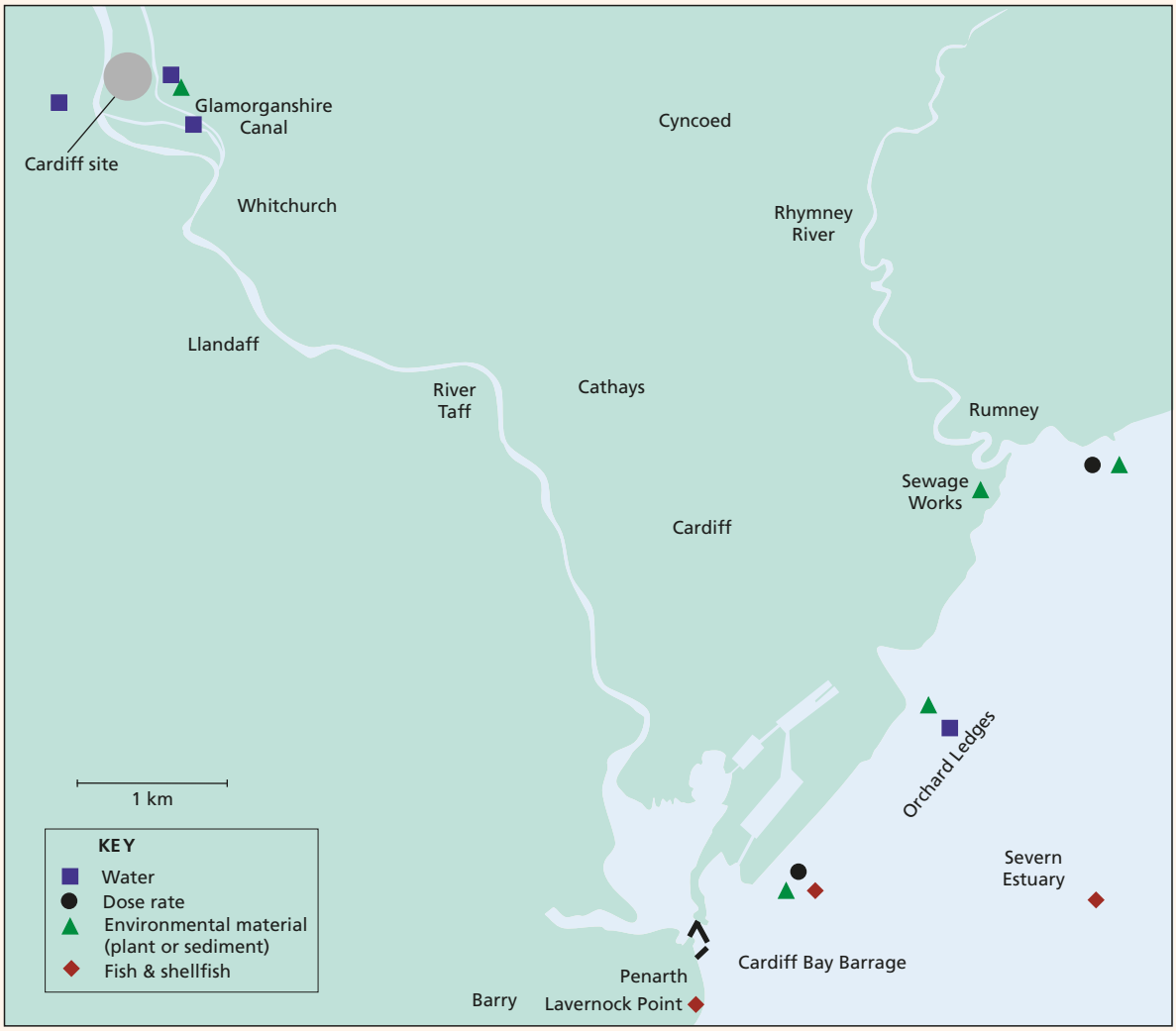


Figure 6.2. Monitoring locations at Cardiff, 2014 (not including farms)

Gaseous discharges and terrestrial monitoring

The Maynard Centre discharges radioactivity to the atmosphere via stacks on the site. As a result of reduced commercial operations, in relation to the site's planned shutdown, discharges of tritium continued to be low in 2014. Carbon-14 discharges were slightly reduced in 2014 and these were the lowest releases in recent years. There were no discharges of radionuclides other than those of tritium and carbon-14

The focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops, freshwater and grass. In recent years, the Environment Agency have also analysed additional samples of sewage products from the Cardiff East WWTW. This additional monitoring ceased in 2013 and monitoring returned to normal frequencies in 2014. The constraints of the Sludge (Use in Agriculture) Regulations (United Kingdom – Parliament, 1989) (commonly referred to as the Safe Sludge Matrix) require that crops cannot be harvested within 10 months of the application of sludge pellets. An FSA research project investigated the transfer of tritium from treated soil to crops, under the Safe Sludge Matrix conditions, and concluded that the transfer of tritium to each of the crops considered was small (Ham *et al.*, 2007).

Tritium concentrations in terrestrial food samples are reported as less than values in 2014 (Table 6.3(a)). These values were similar in comparison to those in 2013 and are consistent with progressive discharge reductions in recent years. Carbon-14 was detected in locally produced foods at concentrations above background values; carbon-14 concentrations in milk decreased in comparison to those in 2013. Low concentrations of sulphur-35, which is not discharged by the site, were detected in food and grass samples and were generally similar to those in 2013. Phosphorus-32 and iodine-125 concentrations are reported as less than values in all terrestrial samples. Samples of raw effluent, treated effluent and sludge pellets (analysed in previous years) from Cardiff East WWTW were not sampled in 2014. The results in 2013 show that all activity concentrations in effluent are reported as less than values (Environment Agency, FSA, NIEA, NRW and SEPA, 2014).

Unlike in previous years, there was no evidence of tritium being detected in sediment and freshwater from the

Glamorganshire Canal in 2014; however, this is not used as a source of water for the public water supply. Tritium concentrations in freshwater, downstream (and upstream) from the outfall into the River Taff (potentially containing site run-off water) are reported as less than values in 2014. Freshwater samples from the outfall were not collected in 2014 (as run-off water originating from the site is not continuous); no flow of water occurred during the planned bi-annual sampling visits. The trend of discharges, with tritium concentrations in sediment from the marine and freshwater environments, over time (2004 – 2014) are shown in Figure 6.3. The overall decline in activity concentrations generally replicates that of the tritium discharges, although the decrease in marine levels (east/west of the pipeline) is less pronounced than that in the canal sediments over the whole time period.

Liquid waste discharges and aquatic monitoring

The Maynard Centre discharges liquid wastes into the Ystradyfodwg and Pontypridd (YP) public sewer. This joins the Cardiff East sewer, which after passing through a WWTW discharges into the Severn Estuary near Orchard Ledges. During periods of high rainfall, effluent from the YP sewer has been known to overflow into the River Taff. In addition, there is run-off from the site into the river via surface water drains.

The bulk of the radioactivity discharged to the YP sewer is tritium and carbon-14. The amounts of these radionuclides released to the sewer were both very low in 2014 (as in recent years). Over the longer term both discharge rates have decreased substantially (Figures 6.4 and 6.5). It is anticipated that radioactive liquid waste discharges from the site will cease in 2015, as part of the operator's proposals to de-licence a portion of the Maynard Centre site.

Marine sampling included locally caught seafood, and indicator materials (e.g. seaweed). These were supported by external dose rate measurements over intertidal areas. The results of routine monitoring in 2014 are given in Tables 6.3(a) and (b). The effects of liquid discharges remained evident in enhanced tritium and carbon-14 concentrations in fish samples. Further analysis of these samples showed that a high proportion of the tritium was still associated with organic matter, a situation that has been observed since the late 1990's (McCubbin *et al*., 2001; Leonard *et al*., 2001; Williams *et al*., 2001). The tritium is strongly bound to organic matter and has the potential to transfer through the marine food chain from small organisms to accumulate in fish. In 2014, tritium concentrations in both sampled fish species (flounder and dogfish) decreased as compared with concentrations of their respective species in recent years. Moreover, the tritium concentrations reported in both fish species were the lowest values in recent years. The continued overall decline in tritium concentrations in fish from the Cardiff area is likely to be a direct response to the decreasing inputs from the Maynard Centre, as well as a shift in the composition of this discharge away from organically bound compounds. However, the annual uncertainty and variation in certain species in recent years suggests that complex indirect uptake mechanisms continue to affect tritium concentrations in the region.

Figure 6.4 indicates that the overall tritium concentrations in mollusc samples have decreased significantly over a period of time. The mean concentration for tritium in fish was the lowest reported values in 2014. Tritium in marine sediment samples was measured at similar levels to those in recent years. The mean concentrations of carbon-14 in fish and molluscs in 2014 were generally similar to those in 2013. The longer term trend in concentrations and the relationship to discharges is shown in Figure 6.5 (overall, concentrations in both species declining). Concentrations of caesium-137 in marine samples remain low and can largely be explained by other sources such as Chernobyl, weapon test fallout and discharges from other establishments such as the Hinkley Point, Berkeley and Oldbury nuclear licensed sites. Overall, gamma dose rates over sediment in 2014 (Table 6.3(b)) were generally similar to those in 2013 (albeit with a small decrease at east of pipeline) but are not (in the main) attributable to discharges from the Maynard Centre or Quotient Biosciences at Trident Park.

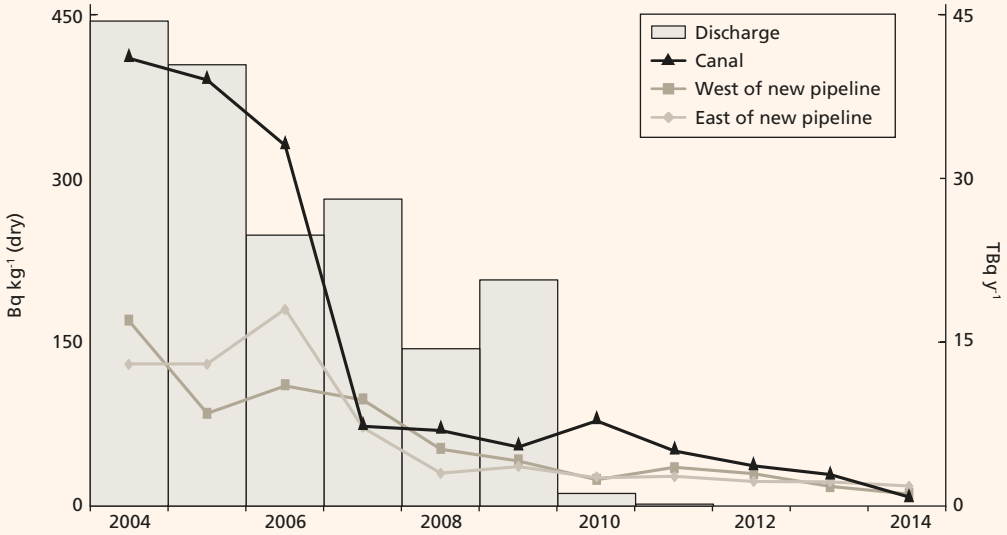


Figure 6.3. Tritium liquid discharge from Cardiff and mean concentrations in sediment near Cardiff, 2004-2014

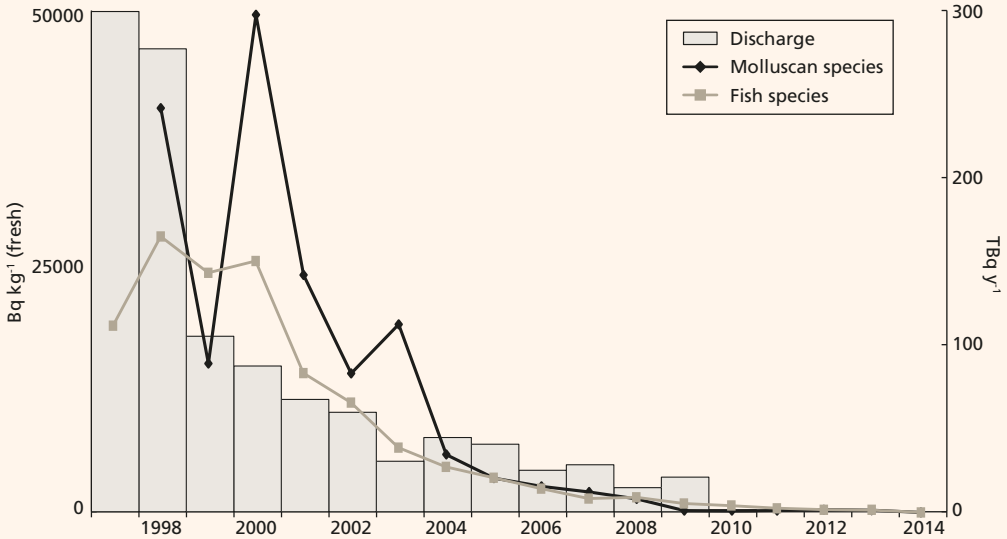


Figure 6.4. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1997-2014 (species include all those reported in RIFE for the given year)

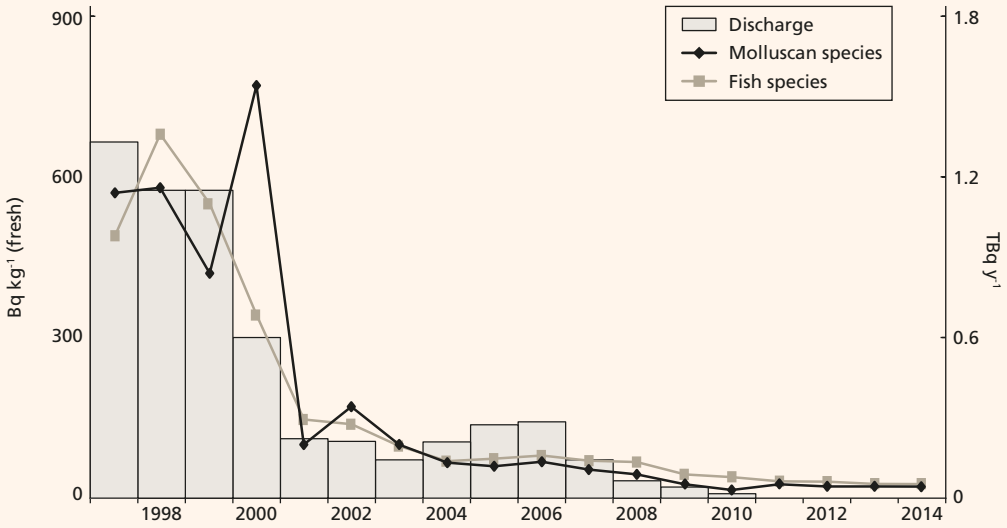


Figure 6.5. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1997-2014 (species include all those reported in RIFE for the given year)

Table 6.1. Individual doses – radiochemical sites, 2014

Site	Representative person[a]	Exposure, mSv per year						
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways	Direct radiation from site
Amersham								
***Total dose* – all sources**	**Prenatal children of local inhabitants (0–0.25km)**	**0.14[d]**	**–**	**<0.005**	**<0.005**	**–**	**<0.005**	**0.14**
Source specific doses	Anglers	<0.005	<0.005	–	<0.005	–	–	–
	Infant inhabitants and consumers of locally grown food	0.009[d]	–	<0.005	–	–	0.008	–
	Workers at Maple Lodge STW	<0.005	–	–	<0.005[b]	<0.005[c]	–	–
Cardiff								
***Total dose* – all sources**	**Infant milk consumer**	**<0.005**	**–**	**<0.005**	**–**	**–**	**–**	**–**
Source specific doses	Prenatal children of seafood consumers	0.006	<0.005	–	0.006	–	–	–
	Recreational users of River Taff	<0.005	–	–	<0.005	<0.005	–	–
	Infant inhabitants and consumers of locally grown food	0.005	–	0.005	–	–	<0.005	–
	Workers at Cardiff East WWTW	<0.005	–	–	<0.005[b]	<0.005[c]	–	–

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

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

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

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

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2014[g]

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{32}P	^{35}S	^{125}I	^{131}I	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Freshwater samples											
Flounder	Woolwich Reach	1	<25				<1.0	<0.06	<0.06		
Sediment	River Colne (Grand Union Canal)	2[E]				<1.1	<1.6	<2.0		<110	220
Sediment	Upstream of outfall (Grand Union Canal)	2[E]				<1.7	<3.5	5.1		<250	240
Freshwater	Maple Cross	2[E]	<3.3			<0.15	<0.23	<0.22		<0.082	0.43
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<3.3			<0.17	<0.26	<0.26		<0.063	0.17
Freshwater	River Chess	1[E]	<3.3			<0.20	<0.31	<0.23		<0.041	0.067
Freshwater	River Misbourne – upstream	1[E]	<3.2			<0.19	<0.28	<0.24		<0.031	0.063
Freshwater	River Misbourne – downstream	1[E]	<3.3			<0.19	<0.23	<0.18		<0.058	0.062
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<8.0	<0.55	<0.43	<0.18		<0.22	<0.27	<0.10	0.82
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<10	<0.93	<0.87	<0.18	0.74	<0.23	<0.29	<0.80	3.7
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<9.1	<0.32	<0.55	<0.16		<0.21	<0.28	<0.10	0.61

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		1	<2.0	<0.23	<0.0080	<0.0020	<0.05		
Potatoes		1	<2.0	0.60	<0.0020		<0.07		
Wheat		1	<2.0	0.50	<0.039		<0.06		
Grass	Next to site	1[E]		<6.5	<0.80	<1.6	<1.2	3.6	200
Grass	Orchard next to site	1[E]		<5.7	<0.82	<1.4	<1.2	<2.7	200
Grass	Water Meadows (River Chess)	1[E]		<3.8	<0.67	<1.3	<0.97	<2.7	130
Soil	Next to site	1[E]			<0.40	<0.57	11	360	480
Soil	Orchard next to site	1[E]			<1.4	<2.4	3.3	240	510
Soil	Water Meadows (River Chess)	1[E]			<0.30	<0.51	12	140	290

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

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

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

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

[e] *The concentration of ^{3}H as tritiated water was <5.6 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <4.5 Bq l^{-1}*

[g] *The gamma dose rates in air at 1m over grass and mud, and grass on the bank of the Grand Union Canal were 0.065 and 0.062 mGy h^{-1} respectively*

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

Table 6.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{125}I	^{137}Cs
Marine samples								
Flounder	East of new pipeline	2	43	<54		31		0.32
Lesser spotted dogfish	Off Orchard Ledges	1	<25	<25		23		0.33
Limpets	Lavernock Point	1	<25	<25		23		0.25
Seaweed[d]	Orchard Ledges	2[E]		<12	<3.9	20	<0.36	<0.50
Sediment	East of new pipeline	2[E]		<18		<6.4	<2.1	16
Sediment	West of new pipeline	2[E]		<11	<6.4	<25	<2.3	14
Seawater	Orchard Ledges	2[E]		<9.0	<3.1	<2.4	<0.27	<0.26

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{35}S	^{125}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples											
Milk[g]		2	<2.5	<2.5		21	<0.46	<0.012	<0.06		
Milk[g]	max						<0.48	<0.014	<0.07		
Jerusalem Artichoke		1	<2.0	<2.0		22	0.40	<0.015	<0.07		
Grass		1	<4.7	<4.7		21	1.7	<0.051	0.18		
Sediment	Canal	2[E]		<31		18		<1.9	7.2		
Freshwater	River Taff upstream	2[E]		<8.5	<2.7	<4.2		<0.20	<0.22	<0.055	0.29
Freshwater	River Taff downstream	2[E]		<9.2	<3.3	<3.4		<0.19	<0.17	<0.057	0.22
Freshwater	Canal	2[E]		<11	<3.6	<3.4		<0.19	<0.21	<0.050	<0.061

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

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

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

[d] *The concentration of ^{99}Tc was <1.7 Bq kg^{-1}*

[e] *The organic fraction may be higher than the total tritium value for some analyses due to uncertainties in the analytical methods for tritium. For dose assessments in this report, the higher of the two values has been used*

[f] *As tritiated water*

[g] *The concentration of ^{32}P was <0.14 (max <0.16) Bq l^{-1}*

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

Table 6.3(b). Monitoring of radiation dose rates near Cardiff, 2014

Location	Ground type type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	2	0.073
West of Pipeline	Mud and sand	1	0.10
West of Pipeline	Sand and stones	1	0.087
Peterstone Wentlooge	Mud	1	0.098
Peterstone Wentlooge	Salt marsh	1	0.076

7. Industrial and landfill sites

This section considers the effects of (i) the main disposal site on land for solid radioactive wastes in the UK, at the LLWR near Drigg in Cumbria, as well as other landfill sites which have received small quantities of solid wastes and (ii) other sites where industries or incidents may have introduced radioactivity into the environment.

Key points

LLWR, near Drigg

- Site operators have applied for a permit variation to allow for continued waste disposal at the site
- Concentrations and dose rates at the LLWR were similar to those in 2013
- Doses were dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven

Other sites

- Tritium found in leachate from other landfill sites. Probably due to disposal of Gaseous Tritium Light Devices. Doses were less than 0.5 per cent of dose limit
- Monitoring relating to the disposal of LLW at Kings Cliffe showed similar results to other landfill sites
- Very small discharges from the Studsvik Metals Recycling Facility (MRF) were made in 2014
- Enhancement in natural radionuclides at Whitehaven from phosphate processing is now very difficult to detect. However the radiation dose from the enhancement, taken with effects of disposal of other local wastes, was estimated to be 22 per cent of the dose limit
- The investigation into the radium-226 contamination at Dalgety Bay, Fife continued in 2014
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in regulations. Limited monitoring of such sites was undertaken and no significant effects were found

7.1 Low Level Waste Repository near Drigg, Cumbria

The LLWR is the UK's national LLW disposal facility and is located on the west Cumbrian coast, approximately 7 km south east of Sellafield. The main function of the LLWR is to receive low-level solid radioactive wastes from all UK nuclear licensed sites (except Dounreay) and many non-nuclear sites. Where possible the waste is compacted, and then most waste is grouted within containers before disposal. Wastes may be disposed of in engineered concrete vaults on land, whereas prior to the early 1990's waste was disposed of in open clay lined trenches. The site is operated by LLWR Limited on behalf of NDA. From April 2008, a consortium, UK Nuclear Waste Management Limited (UKNWM), took over as the PBO for LLWR Limited. A plan setting out the long term future of the site through to its final closure, currently planned for 2079, has been published (LLW Repository Ltd, 2015). The LLWR currently has no permitted disposal capacity beyond Vault 8 and all new waste received is being stored pending further permission for disposal. The operator has applied for a permit variation to allow future waste disposals and closure engineering. The permit variation application was supported by the submission of an Environmental Safety Case (ESC) to the Environment Agency in May 2011. The purpose of the ESC submission is to demonstrate to the Environment Agency that the continued use of the site is safe for people and the environment both now and in the long term. The permit variation application and the 2011 ESC have been reviewed by the Environment Agency, who will consult and come to a final decision in 2015.

The current disposal permit allows for the discharge of leachate from the site through a marine pipeline. These discharges are small compared with those discharged from the nearby Sellafield site (Appendix 2). Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme, described in Section 2. The contribution to exposures due to LLWR discharges is negligible compared with that attributable to Sellafield and any effects of LLWR discharges in the marine environment could not, in 2014, be distinguished from those due to Sellafield. A new habits survey was published in 2013 and the results have been included in the dose assessments for the site (Clyne *et al*., 2013c).

No disposals of solid radioactive waste were made at the LLWR in 2014 since the current capacity for permitted disposals has been reached. Future waste disposals will depend on the permitting of any future disposal capacity.

Although the permit for disposal to the Drigg Stream has been revoked, reassurance monitoring of samples of water and sediment has continued. The results are given in Table 7.2. The gross alpha and beta concentrations were below the WHO screening levels for drinking water from the Drigg stream. Although the stream is not known

to be used as a source of drinking water, it is possible that occasional use could occur, for example by campers. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2013. They reflect the legacy of direct discharges of leachate from the disposal site into the stream (BNFL, 2002). This practice stopped in 1991.

In the past, groundwater from some of the trenches on the LLWR site moved eastwards towards a railway drain along the perimeter of the site. Radioactivity from the LLWR was detected in the drain water. The previous operators of the site (BNFL) took steps in the early 1990's to reduce ingress of water from the trenches by building a "cut-off wall" to reduce lateral migration of leachate. The results of monitoring in the drain in 2014 have shown that the activity concentrations are now very low and have reduced significantly since the "cut-off wall" was constructed. Both gross alpha and gross beta concentrations were below or just above the relevant WHO screening limit. Concentrations of tritium are reported as less than values.

The monitoring programme of terrestrial foodstuffs at the site was primarily directed at the potential migration of radionuclides from the waste burial site via groundwater. Results for 2014 are given in Table 7.2. Evidence in support of the proposition that radioactivity in leachate from the LLWR might be transferring to foods was very limited in 2014, as it was in 2013. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 2). There were no elevated concentrations of plutonium-239+240, plutonium-238 and americium-241 in sheep samples (muscle and offal) as was the case in 2013. The *total dose* from all pathways and sources, including a component due to Chernobyl and weapon test fallout, was 0.22 mSv, or 22 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). This was dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven, which are near to the LLWR site. If these effects were to be excluded, and the sources of exposure from the LLWR are considered, the representative person was a child aged 1 year spending time near the site. Their *total dose* in 2014 was 0.034 mSv (Table 1.2), mostly due to direct radiation. Source specific assessments of exposures for consumers of water from Drigg stream and of locally grown terrestrial food were less than 0.010 mSv.

7.2 Other landfill sites

Some organisations are granted authorisations or permits by SEPA (in Scotland) or the Environment Agency (in England and Wales) respectively to dispose of solid wastes containing low levels of radioactivity to approved landfill sites. In Northern Ireland, this type of waste is transferred to Great Britain for incineration. Waste with very low levels of radioactivity can also be disposed of in general refuse. Radioactivity in wastes can migrate into leachate and in some cases can enter the groundwater. SEPA and the Environment Agency carry out monitoring of leachates. The distribution of landfill sites considered in 2014 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4.

The results, in common with previous years, showed evidence for migration of tritium from some of the disposal sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al*., 1998). Inadvertent ingestion of leachate (2.5 l per year) from the site with the highest observed concentration of tritium would result in a dose of less than 0.005 mSv or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). Similarly the dose from ingestion of uranium isotopes in leachate from Clifton Marsh was also less than 0.005 mSv.

In March 2007, the UK Government introduced a more flexible framework for the disposal of certain categories of LLW to landfill. Further details and information are provided on DECC's website: https://www.gov.uk/government/policies/managing-the-use-and-disposal-of-radioactive-and-nuclear-substances-and-waste/supporting-pages/providing-policy-for-the-safe-and-secure-disposal-of-radioactive-waste.

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

- Waste Recycling Group (WRG) Limited at the Lillyhall Landfill Site in Cumbria. Their permit, issued in 2011, allows them to dispose of VLLW
- Augean at the East Northants Resource Management Facility, near Kings Cliffe, Northamptonshire. Their permit, issued in 2011, allows them to dispose of low activity LLW and VLLW.
- Sita (Lancashire) Limited at Clifton Marsh in Lancashire. They received a permit to dispose of LLW in September 2012. This permit replaced previous arrangements authorising disposals at Clifton Marsh by operators at the Springfields and Capenhurst nuclear licensed sites, whose permits used to allow disposal of solid LLW at Clifton Marsh in their own right. The varied permits now allow those operators to transfer LLW to landfill operators who hold an appropriate EPR 10 permit.

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

Disposals of LLW at the Kings Cliffe site began in December 2011 and were from non-nuclear site remediation works.

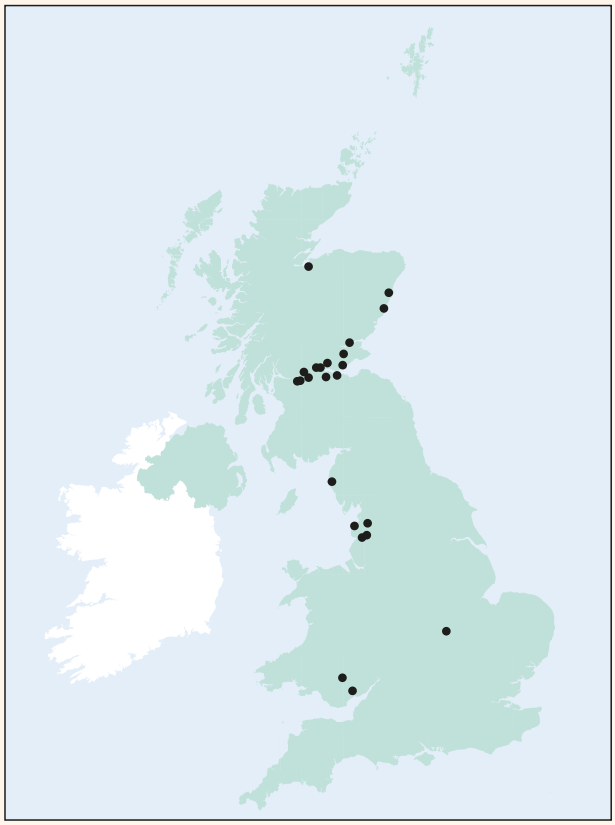


Figure 7.1. Landfill sites monitored in 2014

The first consignment from a nuclear licensed site was from Harwell in March 2012 this comprised soil, concrete, rubble and clay pipes from the drains on the Harwell site. In parallel, the Environment Agency began a programme of monitoring within and around the Kings Cliffe landfill site in order to provide a baseline and allow any future changes to be detected. In 2014, samples were taken and analysed for radiological composition from both upstream and downstream groundwater boreholes, off-site watercourses, on-site surface water, on-site leachate and on-site soil. Samples of leachate, borehole water and surface water were taken and filtered. Both the filtrate and the particulate were analysed for their radioactivity content, along with some bulk water samples. The results are given in Table 7.5. The results for man-made radionuclides were generally at limits of detection or at low levels expected due to UK-wide fallout from weapon testing and overseas accidents. Naturally occurring radionuclides were present at levels expected due to natural sources. Tritium was enhanced in a few samples as is found at other landfill sites. Elevated gross beta concentrations in water were observed in some samples. This is likely to be due to the presence of potassium-40 from natural sources. The results were similar to those in previous years.

In 2012, 2013 and 2014 the Environment Agency supported by the National Nuclear Laboratory undertook audit and assurance checks of the waste characterisation carried out by Harwell prior to disposal as low level Waste at the Kings Cliffe site. The Harwell site is excavating the Old Main Active Drain (OMAD). The OMAD drain wastes are heterogeneous in form and radioactive content. The radioactivity from historic activity on the site is mostly present as a thin layer of dried sludge in the bottom of the drain. This has been sandwiched between the drain pipe and grout which had been injected into the drain to stabilise the structure. The OMAD itself was originally laid on a concrete raft and surrounded on both sides and on top with concrete. The waste from excavation is a mixture of concrete, glazed pipe, grout infill and small amounts of sediment containing radioactivity. Most of the material by mass is concrete - largely or completely uncontaminated but containing natural radionuclides; followed by grout - some of which contains contamination from the sediment layer; followed by glazed pipe, of which the surface has a layer of contamination, and small amount of sediment carrying most of the radionuclides.

Materials from OMAD excavation were sampled by Harwell at regular intervals and waste from the OMAD was placed in one ton dumpy bags. These bags are subject to further checks by High Resolution Gamma-ray Spectroscopy which will detect gamma emitting radionuclides.

The Environment Agency sampled the wastes at 4 locations on the OMAD excavation, and made *in situ* measurements with a sodium iodide detector (gamma spectrometry).

The audit showed that Harwell are working to minimise the amount of waste disposed of to the Kings Cliffe site and are reusing spoil from the OMAD trench as backfill. Harwell have learned from experience and the later stages generated much less waste per metre of pipe excavated. The assurance checks indicate that the majority of the wastes generated contain little or no radionuclides from the site's historic activities. Most of the radionuclides are found in a layer of the sediment on the bottom of the pipe and as amount of sediment is small, most of the waste disposed of contains no radioactivity from the site.

None of the samples taken during witnessing and independently analysed by the Environment Agency have identified any additional radionuclides to those presented in Harwell's characterisation reports. Levels found by the Environment Agency are consistent with or lower than those reported by Harwell.

SEPA continued its programme of monitoring at the Stoneyhill Landfill Site in Aberdeenshire which is authorised to dispose of conditioned NORM waste. This programme is complementary to, but independent of, the operator's monitoring programme.

NORM is found within oil and gas reserves and is consequently extracted along with the oil and gas. The NORM can precipitate onto oil and gas industry equipment creating an insoluble scale (NORM scale). The presence of this scale reduces the efficiency of the equipment and must be removed. Sita UK Limited, who operates Stoneyhill Landfill site, has constructed a descaling facility adjacent to the landfill in partnership with Nuvia Limited. This

facility descales oil and gas industry equipment (such as pipes) using pressurised water. The solid scale removed from the equipment is then grouted into drums and can be consigned to Stoneyhill Landfill site in accordance with their authorisation granted in May 2012.

The SEPA monitoring programme involves the collection and analysis of landfill leachate, groundwater and surface water on a quarterly basis and analysing for radium-226 and radium-228, with results reported as less than values in 2014 (Table 7.6). The programme also includes the sampling and analysis of final effluent from Nigg Sewage Treatment Works (STW) and seawater from the surrounding area as Stoneyhill landfill sends their leachate by tanker to Nigg STW for treatment and subsequent release into the environment as part of the STW final treated effluent.

7.3 Metals Recycling Facility, Lillyhall, Cumbria

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

A permit for disposal of radioactive waste from the site was issued by the Environment Agency in March 2008, although no radioactive waste disposals were made until September 2009. The permit allows discharges of gaseous waste to the environment via a main stack and aqueous waste to the sewer. Low discharge limits are set for both aqueous and gaseous discharges. Very small discharges were made during 2014 (Appendix 2). The permit includes conditions requiring Studsvik UK Limited to monitor discharges and undertake environmental monitoring.

7.4 Phosphate processing, Whitehaven, Cumbria

An important historic man-made source of naturally occurring radionuclides in the marine environment has been the chemical plant at Whitehaven in Cumbria, which used to manufacture phosphoric acid from imported phosphate ore (Rollo *et al.*, 1992). Phosphogypsum, containing thorium, uranium and their daughter products, was discharged as a liquid slurry by pipeline to Saltom Bay. Processing of phosphate ore ceased in 1992 and processing of phosphoric acid at the plant ceased at the end of 2001. However, there is an environmental legacy from past operations. Such sources are said to give rise to Technologically enhanced Naturally Occurring Radioactive Material (TNORM). Decommissioning of the plant was undertaken in 2002 and released small quantities of uranium to sea, but discharges were very much lower than in previous years. The plant was subsequently demolished in 2004 and the permit to discharge radioactive wastes revoked by the Environment Agency.

The results of routine monitoring for naturally occurring radioactivity near the site in 2014 are shown in Table 7.7. Analytical effort has focused on lead-210 and polonium-210, which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally occurring radionuclides were slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figures 7.2 and 7.3 show how concentrations of polonium-210 in winkles and crabs have generally decreased since 1998. Concentrations in the early 1990's were in excess of 100 Bq kg^{-1} (fresh weight). There were some variations in concentrations of polonium-210 in local samples in 2014 compared with 2013. However, taking into account the ranges of values observed, it is now difficult to distinguish between the measured radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. The latter are shown in Figures 7.2 and 7.3 and in Appendix 1 (Annex 4). There were small enhancements for some samples at other locations above the expected natural background median levels for marine species, but the majority were within the ranges observed in the undisturbed marine environment. It is considered prudent to continue to estimate doses at Whitehaven based on the positive difference, if any, between observed concentrations and median levels indicative of natural background. A recent analysis has confirmed

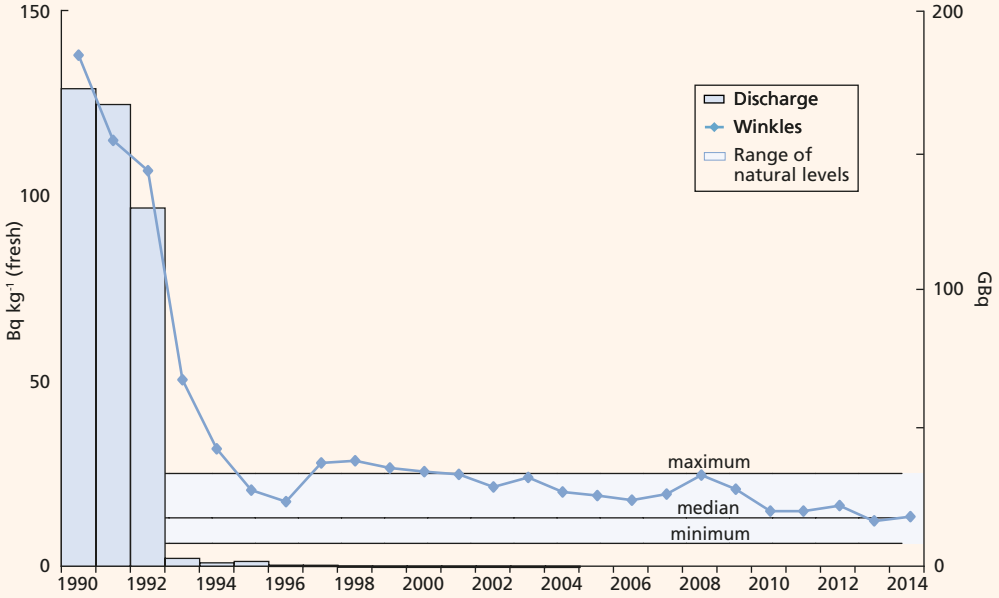


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2014

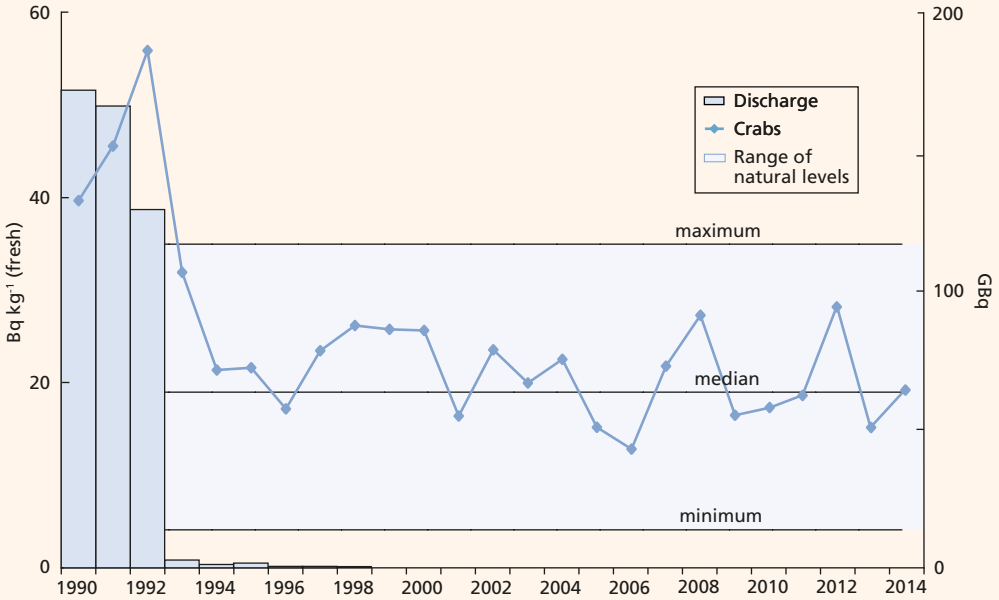


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2014

that this approach is unlikely to underestimate doses (Dewar *et al.*, 2014).

The critical radiation exposure pathway considered for the assessment at Whitehaven was internal irradiation, due to the ingestion of naturally occurring radioactivity in local fish and shellfish. The representative person was a consumer who, centred on the Sellafield site to the south of Whitehaven, obtained their sources of seafood from locations such as Whitehaven, Saltom Bay and Parton. This consumer is also considered in the assessment of the marine impacts of the Sellafield and LLWR (near Drigg) sites (Sections 2 and 7). An additional, smaller area limited to Saltom Bay is no longer assessed separately because the larger area provides adequate protection and a more robust assessment. The estimated contribution due to background median concentrations of naturally occurring radionuclides is subtracted. Consumption rates for people who eat at high-rates were reviewed and revised in 2013. The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

The *total dose* to a local high rate consumer of seafood was 0.22 mSv in 2014 (Table 7.1), below the dose limit for members of the public of 1 mSv. The value for 2013 was 0.061 mSv. The dose includes the effects of all sources near the site, enhanced naturally occurring radionuclides from the non-nuclear industrial activity (i.e. TNORM), and Sellafield operations. The source specific assessment of dose, targeted directly at a high-rate seafood consumer

confirms the *total dose* assessment and gives the same result in 2014, 0.22 mSv.

The contribution to the *total dose* from enhanced natural radionuclides was 0.15 mSv in 2014, compared with 0.021 mSv in 2013. This large increase in dose was due to (i) a significant increase in the proportion of lobsters in the diet of high rate seafood consumers and (ii) a return to a wide range of seafood species being consumed by individuals. Lobsters tend to have a more pronounced enhancement in polonium-210 concentrations above background levels. With these changes, the largest contribution to dose to a seafood consumer near Whitehaven is now from historic discharges from Whitehaven as was the case preceding 2013. The longer term trend in *total dose*, shown in Figure 7.4, is one of a reduction in exposures with variability from year to year.

7.5 Aberdeen

Scotoil operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. They are authorised to discharge liquid effluent to sea with the primary discharge being radium-226 and radium-228, with lead-210 and polonium-210 in smaller quantities. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring. Prior to their operations, a fertiliser manufacturing process was operated on the site, which made discharges to sea.

Seaweed (*Fucus vesiculosus*) from Aberdeen Harbour was monitored in 2014. Technetium-99 was detected in seaweed (17 Bq kg^{-1}, fresh), in line with the expected effect from Sellafield discharges (as the releases become diluted or mixed in moving further afield). Gamma-emitting radionuclides were all below or close to the LoD. In 2014, the dose rate on sediment was 0.092 µGy h^{-1} and similar to background. The dose rate was lower than the results in earlier years when discharges were higher.

7.6 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected at Dalgety Bay in Fife since at least 1990. The contamination is associated with historical disposals of waste from past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959 and upon which large areas of the town of Dalgety Bay have been built. The air station played a role as an aircraft repair, refitting and salvage yard. It is believed that waste was incinerated and the resultant ash and clinker was disposed of by reclaiming land from the sea. Following years of erosion at the site the contamination is being exposed on and adjacent to the foreshore. Some of the incinerated material contained items such as dials and levers which had been painted with luminous paint containing radium-226.

In June 1990, environmental monitoring showed elevated radiation levels in the Dalgety Bay area. The monitoring was undertaken as part of the routine environmental monitoring programme for Rosyth Royal Dockyard conducted in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material was removed for analysis, which indicated the presence of radium-226. Further investigation confirmed that the contamination could not have originated from the dockyard and was most likely to be associated with past practices related to the nearby former RNAS Donibristle/HMS Merlin military airfield. Since this initial discovery, there have been several monitoring exercises to determine the extent of this contamination.

Following the increased number of particle finds and the discovery of the high activity particles in 2011, additional public protection measures were established and these were maintained during 2014 and into 2015. A monthly beach monitoring and particle recovery programme was adopted in 2012 by a contractor working on behalf of the MoD and this remains in place. The fence demarcating the area where the highest activity particles were discovered remains in place, as well as the information signs advising the public of the contamination and precautions to be taken. In addition, the FEPA Order issued by the Food Standards Agency in Scotland prohibiting the collection of seafood from the Dalgety Bay area remains in force. SEPA undertook a programme of shellfish monitoring between February 2012 and February 2013 during which no particles were detected in the shellfish. All shellfish samples collected were analysed for the presence of radium-226 and all were found to be less than the LoD. The continuation of these protection measures is reducing the risks to members of the public whilst further work continues to address the contamination.

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

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

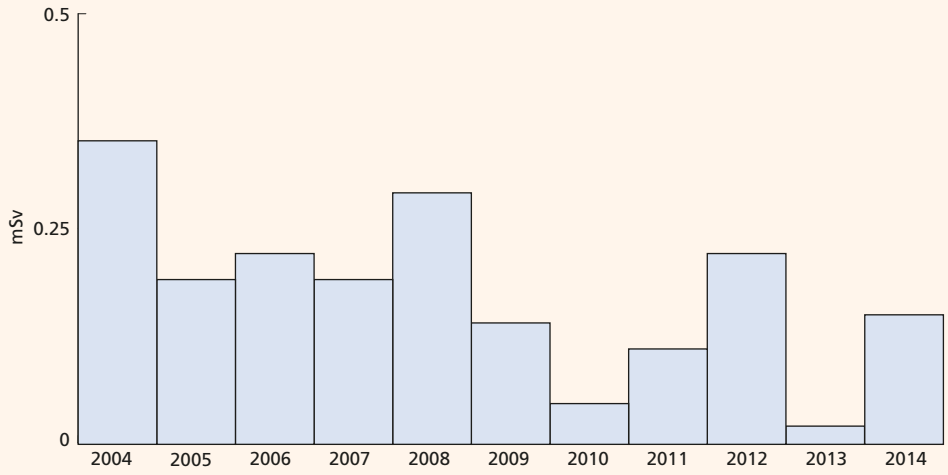


Figure 7.4. Trend in *total dose* to seafood consumers from naturally-occurring radionuclides near Whitehaven, 2004-2014

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

7.7 Other non-nuclear sites

Routine discharges of small quantities of radioactive wastes to air and water are made from a wide range of other non-nuclear sites in the UK on land, and from offshore oil and gas installations.

A summary of the most recent data for the quantities discharged under regulation is given in Tables 7.8 and 7.9. The data are grouped according to the main industries giving rise to such wastes in the UK and exclude information for other industries considered in other sections of this report, principally the nuclear sector. The main industries are:

- Oil and gas (on and off-shore)
- Education (Universities and Colleges)
- Hospitals
- Other (research, manufacturing and public sector)

Discharges may also occur without an authorisation or permit when the quantities are considered to be below the need for specific regulatory control. For example discharges of natural radionuclides are made from coal-fired power stations because of the presence of trace quantities of uranium and thorium and their decay products in coal.

As indicated in Section 1, general monitoring of the British Isles as reported elsewhere in this report has not detected any gross effects from non-nuclear sources. Occasionally, routine programmes directed at nuclear licensed site operations detect the effects of discharges from the non-nuclear sector and, when this occurs, a comment is made in the relevant nuclear licensed site text. The radiological impact of the radioactivity from the non-nuclear sector detected inadvertently in this way is very low.

Monitoring of the effects of the non-nuclear sector is limited because of the relatively low impact of the discharges. However, programmes are carried out to confirm that impacts are low and, when these occur, they are described in this report.

In 2014, SEPA undertook a small-scale survey (as part of the annual programme) of the effects of discharges from non-nuclear operators by taking and analysing samples of mussels and other materials from the River Clyde, the Firth of Forth and sludge pellets from a STW. The results are given in Table 7.10. They show the expected effects of Sellafield discharges at this distance and the presence of iodine-131, probably from a hospital source. The results were generally similar to those in 2013. An assessment of the dose to a representative high-rate mollusc consumer was undertaken. The dose was less than 0.005 mSv or less than 0.5 per cent of the dose limit.

Table 7.1. Individual doses – industrial and landfill sites, 2014

Site	Representative person[a,b]	Exposure, mSv per year					
		Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas	Intakes of sediment and water
***Total dose* – all sources**							
Whitehaven and LLWR near Drigg	**Adult mollusc consumer**	**0.22**[d]	**0.051**	**0.15**	**–**	**0.017**	**–**
Source specific doses							
LLWR near Drigg	Infant consumers of locally grown food	0.007	–	–	0.007	–	–
	Consumers of water from Drigg stream	<0.005[c]	–	–	–	–	<0.005
Landfill sites for low–level radioactive wastes	Inadvertent leachate consumers (infants)	<0.005	–	–	–	–	<0.005
Whitehaven (habits averaged 2010–14)	Seafood consumer	0.22[d]	0.057	0.13	–	0.032	–

[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. The representative person is an adult unless otherwise stated*

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

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

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

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2014

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<3.1	18	<0.05	<0.047	<0.12	<0.13	<0.034	<0.44	<0.14
Deer muscle		1	<2.0	31	<0.09	<0.048	<0.25	<0.23	<0.19	<0.51	<0.08
Eggs		1	<2.0	27	<0.08	<0.047	<0.54	<0.37		<0.77	<0.21
Potatoes		1	<2.0	21	<0.12	0.037	<0.27	<0.25	<0.20	<0.72	<0.20
Sheep muscle		1	<2.0	35	<0.09	<0.049	<0.22	<0.20	<0.21	<0.71	<0.19
Sheep offal		1	<2.0	32	<0.05	0.032	<0.11	<0.12	<0.21	<0.43	<0.12
Grass		1	<2.6	22	<0.11	1.6	<0.73	<0.29	<0.22	<0.84	<0.13
Sediment	Drigg Stream	4[E]			<0.37	<2.8	<0.26	<0.90		<2.7	<1.4
Freshwater	Drigg Stream	4[E]	<3.9		<0.29	<0.040					
Freshwater	Railway drain	1[E]	<3.1		<0.23	0.17					

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{129}I	^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th
Milk		1	<0.0053	<0.07	<0.15		<0.32				
Deer muscle		1	0.031	<0.08	0.54		<0.35				
Eggs		1	<0.020	<0.08	<0.08		<0.46				
Potatoes		1	<0.026	<0.10	<0.09	0.067	<0.43				
Sheep muscle		1	<0.018	<0.07	1.1		<0.49				
Sheep offal		1	<0.018	<0.05	0.37		<0.34				
Grass		1	<0.022	<0.12	0.41		<0.34				
Sediment	Drigg Stream	4[E]		<0.38	110		<1.7	7.4	15	14	14
Freshwater	Drigg Stream	4[E]		<0.30	<0.25			<0.0026	<0.0095	<0.0058	<0.0028
Freshwater	Railway drain	1[E]		<0.23	<0.19			<0.0016	<0.0048	<0.0020	<0.0015

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{235}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1				<0.000029	<0.000033	<0.13	<0.000042		
Deer muscle		1				<0.00011	0.000085	<0.40	0.00022		
Eggs		1				<0.000091	0.000074	<0.27	0.00032		
Potatoes		1				0.00044	0.0043	<0.23	0.0035		
Sheep muscle		1				0.00085	0.0067	<0.34	<0.011		
Sheep offal		1				0.0069	0.039	<0.29	0.066		
Grass		1				0.0040	0.022	0.20	0.045		
Sediment	Drigg Stream	4[E]	31	<1.6	29	6.8	53	200	43	250	450
Freshwater	Drigg Stream	4[E]	0.0085	<0.0020	<0.0074	<0.0049	<0.0028	<0.15	<0.0065	<0.056	0.41
Freshwater	Railway drain	1[E]	0.0040	<0.0016	0.0047	<0.0038	<0.0019	<0.18	0.0042	<0.074	1.0

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

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

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

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

Table 7.3. Concentrations of radionuclides in surface water leachate from landfill sites in Scotland, 2014

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	8.4	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	26	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	290	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	24	<15	<0.05	<0.05
Dunbartonshire	Birdston	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	8.0	<15	<0.05	<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	39	<15	<0.05	<0.05
Fife	Melville Wood	1	180	<15	<0.05	<0.05
Highland	Longman Tip	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	190	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	540	<15	0.13	<0.05

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2014

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			Total ^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{137}Cs	^{228}Th
Glamorgan									
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	760	710	<2.6				
Trecatti Landfill, Merthyr Tydfil	Treated leachate	2	740	700	<3.0				
Lancashire									
Clifton Marsh	Borehole 6	2		<4.6		<4.5	<0.24	<0.20	<0.0077
Clifton Marsh	Borehole 19	2		<3.6		<4.8	<0.27	<0.24	<0.0088
Clifton Marsh	Borehole 40	2		<3.2		<5.3	<0.28	<0.23	<0.0067
Clifton Marsh	Borehole 59	2		11		<5.4	<0.27	<0.22	<0.0041
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2		5.4	<5.8	<4.9	<0.29	<0.24	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
			^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Lancashire									
Clifton Marsh	Borehole 6	2	<0.0038	<0.0024	0.059	<0.0036	0.058	<0.46	2.5
Clifton Marsh	Borehole 19	2	<0.0052	<0.0034	0.062	<0.0041	0.055	<1.6	6.3
Clifton Marsh	Borehole 40	2	<0.0029	<0.0014	0.0080	<0.0014	0.0077	<0.17	2.0
Clifton Marsh	Borehole 59	2	<0.0031	<0.0013	<0.0034	<0.0030	<0.0036	<0.21	2.1
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2						<0.088	0.46

[a] *As tritiated water*

[b] *The concentrations of ^{125}I and ^{131}I were <0.20 and <1.2 Bq l^{-1} respectively*

Table 7.5. Concentrations of radionuclides in leachate and water near the East Northants Resource Management Facility landfill site, 2014

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{3}H	^{40}K	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th
A1 Leachate	38	100	<0.1	<0.02	0.014	<0.01	<0.01
A2 Leachate	42	18	<0.1	<0.02	<0.01	<0.01	<0.01
B1 Leachate	130	140	0.15	0.65	0.12	<0.01	<0.01
5A Leachate	230	450	<0.1	0.35	0.074	<0.01	<0.01
05 Groundwater borehole	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
06A Groundwater borehole	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
07 Groundwater borehole	<4	<5	<0.1	<0.02	<0.01	<0.01	<0.01
08 Groundwater borehole	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
11 Groundwater borehole	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
12 Groundwater borehole	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
13A Groundwater borehole	<4	<1	<0.1	<0.02	0.012	<0.01	0.009
15A Groundwater borehole	<4	<1	<0.1	<0.02	0.033	0.011	0.023
17 Groundwater borehole	5.6	<1	<0.1	0.031	0.014	0.01	<0.01
01 Upstream groundwater borehole	<4	<1	<0.1	0.036	0.021	0.01	0.015
SWLAG Surface Water	<4	7.4	<0.1	<0.02	<0.03	<0.02	<0.02
SWNWPOND Surface Water	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
Horse Water spring	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
Willow brook	<4	<1	<0.1	<0.02	<0.01	<0.01	<0.01
South of site Soil	<4	540	2.7	35	22	24	19
West of site soil	<4	500	3.5	45	9.3	9.2	9.8

Site reference	Mean radioactivity concentration[a], Bq kg^{-1}						
	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239/240}$Pu	Gross alpha	Gross beta
A1 Leachate	0.015	<0.01	0.011	<0.01	<0.01	2.6	94
A2 Leachate	0.028	<0.01	0.033	<0.01	<0.01	<0.39	16
B1 Leachate	<0.01	<0.01	<0.01	<0.01	<0.01	<1.6	120
5A Leachate	<0.01	<0.01	<0.01	<0.01	<0.01	<3.2	270
05 Groundwater borehole	0.023	<0.01	0.022	<0.01	<0.01	0.073	0.088
06A Groundwater borehole	0.029	<0.01	0.017	<0.01	<0.01	0.11	0.11
07 Groundwater borehole	0.018	<0.01	0.017	<0.01	<0.01	0.07	0.22
08 Groundwater borehole	0.008	<0.01	0.012	<0.01	<0.01	0.089	0.11
11 Groundwater borehole	0.013	<0.01	0.014	<0.01	<0.01	0.052	0.23
12 Groundwater borehole	0.036	<0.01	0.029	<0.01	<0.01	0.08	0.28
13A Groundwater borehole	0.021	<0.01	0.018	<0.01	<0.01	0.092	0.23
15A Groundwater borehole	0.023	<0.01	0.021	<0.01	<0.01	0.13	0.10
17 Groundwater borehole	0.061	<0.01	0.047	<0.01	<0.01	0.18	0.82
01 Upstream groundwater borehole	0.029	<0.01	0.03	<0.01	<0.01	0.18	0.26
SWLAG Surface Water	0.023	<0.01	0.015	<0.01	<0.01	<0.21	5.4
SWNWPOND Surface Water	0.058	<0.01	0.054	<0.01	<0.01	<0.091	1.7
Horse Water spring	0.009	<0.01	0.009	<0.01	<0.01	0.022	0.34
Willow brook	0.022	<0.01	0.017	<0.01	<0.01	0.047	0.31
South of site Soil	18	<1	12	<2	<2	500	680
West of site soil	10	<1	31	<2	<2	570	640

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

Table 7.6. Concentrations of radionuclides in water and effluents near the Stoneyhill Landfill site and the associated Nigg Sewage Treatment Works, Aberdeenshire, 2014

Sample location and type	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}	
		^{226}Ra[a]	^{228}Ra[b]
Stoneyhill Landfill			
Borehole 50 (Groundwater)	4	<0.08	<0.18
Borehole 78 (Groundwater)	4	<0.07	<0.18
Laeca Burn, adjacent to site (Surface water)	4	<0.09	<0.22
Laeca Burn, downstream of site (Surface water)	4	<0.10	<0.22
Laeca Burn, upstream of site (Surface water)	4	<0.06	<0.15
Leachate collection tank (Leachate)	4	<0.09	<0.19
Nigg Bay Sewage Treatment Works			
Aberdeen beach (Seawater)	4	<0.10	<0.25
Cove Bay (Seawater)	4	<0.11	<0.21
Gregg Ness (Seawater)	4	<0.08	<0.18
Greyhope Bay (Seawater)	4	<0.09	<0.20
Nigg Bay (Seawater)	4	<0.08	<0.18
Nigg Bay Sewage Treatment Works (Final Effluent)	4	<0.08	<0.18

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

Table 7.7. Concentrations of naturally occurring radionuclides in the environment, 2014

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Phosphate processing, Whitehaven										
Winkles	Parton	2	14	1.7						
Winkles	Nethertown	4	14	1.3	0.58	0.52	0.34	0.72	0.02	0.65
Mussels	Whitehaven	2	50	1.5						
Mussels	Ravenglass	2	39	1.6						
Prawns	Seascale	2	6.7	<0.019						
Crabs	Parton	2	19	0.29						
Crabs	Sellafield coastal area	2	20	0.30	0.12	0.011	0.0053	0.084	0.0029	0.074
Lobsters	Parton	2	10	0.10						
Lobsters	Sellafield coastal area	2	15	0.19						
Nephrops	Whitehaven	2	1.5	<0.09	0.043	0.023	0.017	0.020	0.00089	0.021
Cod	Parton	2	0.52	0.043						
Cod	Whitehaven	2	1.3	<0.0046						
Plaice	Whitehaven	2	1.5	0.17	0.056	0.0011	0.00075	0.021	0.00045	0.019
Plaice	Drigg	1	1.7	0.14	0.0077	0.0051	0.0014	0.015	0.00054	0.012
Flounder	Drigg	1	2.4	0.12						
Other samples										
Winkles	South Gare (Hartlepool)	2	18	1.8						
Winkles	Middletons Sands	1	12							
Winkles	Kirkcudbright	1	2.2							
Mussels	Morecambe	1	36							
Mussels	Ribble Estuary	1			1.9	2.5	1.2			
Limpets	Kirkcudbright	1	5.2							
Crabs	Kirkcudbright	1	3.8							
Lobsters	Kirkcudbright	1	0.83							
Shrimps	Ribble Estuary	1			0.78	<0.0013	<0.0013			
Wildfowl	Ribble Estuary	1				0.0042	0.0022			
Seaweed	Isle of Man	3						2.2	<0.16	2.0
Sediment	Kirkcudbright	1						12	<1.7	11
Sediment	Balcary Bay	1						5.7	<0.44	5.6

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

Table 7.8. Discharges of gaseous radioactive wastes from non-nuclear establishments in the United Kingdom, 2014[a]

	Discharges during 2014, Bq								
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)		
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland
^{3}H	2.2E+09						5.0E+12		3.7E+08
^{14}C	5.8E+07					6.9E+07	1.7E+13	1.3E+05	1.6E+10
^{18}F	6.6E+11						3.6E+11		
^{35}S							5.7E+08		
^{85}Kr							9.6E+07		
^{99m}Tc				7.3E+08			1.7E+06		
^{106}Ru							1.2E+07		
^{125}I	5.5E+05			4.3E+07			2.7E+08		2.2E+06
^{129}I							5.0E+06		
^{131}I				5.4E+08			5.1E+08		
^{131m}Xe				1.3E+08					
^{133}Xe							7.0E+06		
^{137}Cs							3.6E+08		
^{222}Rn							2.0E+09		
Uranium Alpha							2.0E+00		
Plutonium Alpha							3.4E+02		
^{241}Am							6.4E+02		
Other Alpha particulate							7.3E+10		8.9E+02
Other Beta/Gamma					6.2E+08				
Other Beta/Gamma Particulate	2.6E+11		3.9E+10	2.5E+08			7.4E+12		3.2E+10

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. England and Wales discharge data refers to 2013*

Table 7.9. Discharges of liquid radioactive waste from non-nuclear establishments in the United Kingdom, 2014[a]

	Discharges during 2014, Bq										
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)			Oil and gas (on-shore)	Oil and gas (off-shore)
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	Scotland	United Kingdom
^{3}H	1.8E+10	1.1E+04	8.7E+09	2.6E+08	3.3E+05		1.4E+14	8.5E+04	9.2E+09		
^{14}C	2.4E+09	1.6E+03	5.9E+07	1.8E+07		7.5E+07	1.6E+11	2.4E+05	3.0E+10		
^{18}F	6.8E+11			3.1E+12	2.7E+08	4.1E+11	2.3E+12		1.0E+06		
^{22}Na			6.2E+05				9.8E+02				
^{32}P	1.0E+10	7.5E+03	2.0E+09	9.0E+09		1.0E+09	6.1E+09		4.8E+08		
^{33}P	2.8E+08		9.6E+09				6.1E+09		1.3E+10		
^{35}S	1.0E+10	2.7E+02	5.7E+09	2.7E+09			6.8E+09		2.2E+08		
^{51}Cr	1.5E+09		2.3E+07	4.2E+10	6.1E+05	1.9E+09	1.7E+09				
^{57}Co	3.8E+01			9.8E+03	1.5E+01		7.2E+03		2.0E+06		
^{58}Co					1.3E+01		5.2E+00				
^{60}Co	3.9E+02						2.1E+04				
^{67}Ga	1.0E+08			1.4E+10		1.4E+08	1.6E+08				
^{75}Se	6.2E+06			3.4E+09	3.4E+04	5.6E+07	3.2E+07				
^{89}Sr				3.8E+09		3.6E+08	7.2E+01				
^{90}Sr	2.2E+04						1.6E+05				
^{90}Y				5.1E+11	1.2E+04	2.3E+09	7.7E+04		1.5E+07		
^{99}Tc	5.8E+05			2.5E+02			2.0E+05				
^{99m}Tc	4.7E+10			5.2E+13	1.7E+09	4.9E+12	7.4E+11				
^{111}In	1.5E+09			4.1E+11	1.2E+07	4.8E+10	5.3E+09				
^{125}Sb							2.3E+01				
^{123}I	5.3E+07		1.1E+08	1.1E+12	5.9E+07	8.5E+10	4.9E+10				
^{125}I	6.9E+09	8.9E+04	1.8E+08	1.4E+09	1.5E+04	1.0E+08	1.9E+10	1.9E+02	6.9E+07		
^{129}I							2.0E+05				
^{131}I	6.2E+06		3.8E+09	8.6E+12	4.4E+07	6.0E+11	2.9E+11				
^{134}Cs							2.5E+07				
^{137}Cs	1.4E+06		3.0E+07				8.0E+08				
^{153}Sm				1.0E+11							
^{201}Tl	1.4E+08			4.5E+10		2.2E+10					
^{210}Pb										1.8E+06	
^{210}Po										1.8E+06	
^{226}Ra										1.1E+09	
^{228}Ra										1.4E+09	
^{230}Th							4.0E+00				
^{232}Th							1.3E+10		1.7E+06		
Uranium Alpha	2.3E+01		3.3E+07				2.4E+10				
^{237}Np							6.2E+01				
^{241}Pu							1.7E+05				
Plutonium Alpha	6.0E+00		3.0E+06				1.3E+05				
^{241}Am	4.2E+02		3.3E+07				7.4E+04				
^{242}Cm							7.0E+00				
Total Alpha	4.5E+02			2.2E+08			3.4E+11				1.9E+15
Total Beta/Gamma (Excl Tritium)	7.7E+11			6.3E+13			3.5E+12				1.4E+15
Other Alpha									5.9E+03		
Other Alpha particulate				1.6E+08			1.6E+09				
Other Beta/ Gamma[b]	5.0E+10		1.3E+11	2.5E+12	5.4E+02	4.7E+10	1.3E+11		3.7E+07		
Other Beta/Gamma particulate							6.9E+09				

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. England and Wales discharge data refers to 2013*

[b] *Excluding specific radionuclides*

Table 7.10. Monitoring in the Firth of Forth, River Clyde and Glasgow, 2014[a]

Location	Material and selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[c], Bq kg^{-1}					
			^{3}H	^{14}C	^{32}P	^{54}Mn	^{90}Sr	^{99}Tc
Between Finlaystone and Woodhall	Mussels	1		30		<0.10		3.6
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1			18	<0.10		7.5
Dalmuir Clydebank	Sediment	1		22	<13	0.58		
Downstream of Dalmuir	Freshwater	4			<0.34	<0.10		
River Clyde	Freshwater	4	<1.0				<0.0050	
Firth of Forth	Freshwater	4	<1.0				<0.0050	
Daldowie	Sludge pellets	4			<50	<0.09		

Location	Material and selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[c], Bq kg^{-1}					
			^{125}Sb	^{131}I	^{137}Cs	^{155}Eu	^{241}Am	Gross beta
Between Finlaystone and Woodhall	Mussels	1	<0.25	<0.84	0.50	<0.23	<0.14	
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1	<0.12	<0.50	0.20	<0.12	<0.10	
Dalmuir Clydebank	Sediment	1	<0.34	<0.64	29	1.2	1.3	
Downstream of Dalmuir	Freshwater	4	<0.12	<0.25	<0.10	<0.12	<0.10	
River Clyde	Freshwater	4			<0.06			1.7
Firth of Forth	Freshwater	4			<0.03			<0.28
Daldowie	Sludge pellets	4	<0.26	170	2.9	1.2	<0.37	

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

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

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

8. Regional monitoring

Key points

- Monitoring in areas remote from nuclear licensed sites continued (i) to establish the effect of long distance transport of radioactivity from UK and other nuclear licensed sites, (ii) to detect any general contamination of the food supply and the environment and (iii) to provide data under UK obligations under Article 36 of the Euratom Treaty and the OSPAR Convention
- Sampling of marine life from the Channel Islands continued to monitor possible effects from French nuclear facilities discharging radioactivity into the English Channel. Doses were less than one per cent of the limit
- Monitoring in Northern Ireland and the Isle of Man showed low concentrations of man-made radionuclides from Sellafield and other UK nuclear facilities. Doses were less than 1 per cent of the dose limit
- Contamination of fish in upland lakes with caesium-137 from the accident at Chernobyl in 1986 is now low and monitoring ceased in 2013 due to the low risks involved. Similarly restrictions of sheep movement on farms, due to Chernobyl caesium in sheep meat, has been withdrawn due to the low consumer risks involved
- The UK Governments reacted quickly to the Fukushima Dai-ichi accident in 2011 to ensure the safety of UK citizens, especially those overseas, and to monitor the effects in the UK. These effects were found to be of no radiological significance in the UK in 2011 and no Fukushima Dai-ichi derived radioactivity was identified in the UK environment in 2014. Monitoring of imported food from Japan continued in 2014. No shipments were withdrawn because of high levels
- Monitoring at ports of entry to the UK for non-specific contamination continued. A single consignment of blueberries through Harwich port triggered the equipment but the concentration of caesium-137 was low and no further regulatory action was required
- Samples from the UK food supply, air, rain and drinking water were analysed. Natural radionuclides from consumption of general diet and drinking water dominated the doses
- Surveys of seas around the UK supported international assessments for the OSPAR Treaty and showed the extent of tritium and caesium-137 contamination

Regional monitoring in areas remote from nuclear licensed sites has continued in 2014 (i) to establish long distance transport of radioactivity from UK and other nuclear licensed sites, (ii) to indicate general contamination of the food supply and the environment and (iii) to provide data under UK obligations under Article 36 of the Euratom Treaty and the OSPAR Convention.

The routine component parts of this programme are:

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

8.1 Channel Islands

Samples of marine environmental materials provided by the Channel Island states have been analysed for levels of radioactivity. The programme monitors the effects of radioactive discharges from the French reprocessing plant at La Hague and the power station at Flamanville. It also monitors any effects of historical disposals of radioactive waste in the Hurd Deep, a natural trough in the western English Channel. Fish and shellfish are monitored to determine exposure from the internal radiation pathway; sediment is analysed for external exposures. Seawater and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers. A review of marine radioactivity in the Channel Islands from 1990 to 2009 has been published (Hughes *et al.*, 2011).

Table 8.1 shows analysis results for 2014. There was evidence of routine releases from the nuclear industry in some samples (cobalt-60, technetium-99 and iodine-129). However, activity concentrations in fish and shellfish were low and similar to those in previous years. It is generally difficult to attribute the results to different sources, including fallout from weapon testing, due to the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the dose to a representative person who consumes large amounts of fish and shellfish was carried out. In 2014, the representative person was estimated to receive less than 0.010 mSv, which is less than 1 per cent of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources, therefore, continued to be of negligible radiological significance.

Milk and crop samples from the Channel ceased in 2014 following the completion of the risk-based review of the FSA's monitoring programme. Results up to 2013 are included in earlier RIFE reports and they show no significant effects of UK or other nuclear installations.

8.2 Isle of Man

The Environment Agency carries out a limited programme of radioactivity monitoring in collaboration with the Department of Environment, Food and Agriculture (DEFA) on the Isle of Man for marine materials and gamma dose rates on beaches (Table 8.3). The results complement the Isle of Man Government's own independent radiation monitoring programme and provide an indication of the far-field effects of current and historic discharges from Sellafield and other UK nuclear sites. Monitoring of food on the Isle of Man ceased in 2014 following completion of the risk-based review of FSA's programme.

The analyses carried out showed that levels of most radionuclides are reported as less than values of the method used. Positive values for technetium-99, caesium-137 and americium-241 were detected in seaweed and/or sediments but at the low levels consistent with those observed in recent years. The gamma dose rate at Ramsey was also low and similar to earlier measurements. The results demonstrate that there was no significant impact on the Isle of Man in 2014 from discharges to sea from mainland nuclear installations.

8.3 Northern Ireland

NIEA monitors the far-field effects of liquid discharges from Sellafield into the Irish Sea. The programme involves sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 8.1). The external exposure pathway is studied by monitoring gamma dose rates over intertidal areas. The results are presented in Tables 8.4(a) and (b).

In 2014, the main effect of discharges from Sellafield was observed in concentrations of technetium-99 in shellfish and seaweed samples. These were generally similar to those in 2013, reflecting the considerably decreased inputs to the Irish Sea in recent years (see also Section 2.3.3). Caesium-137 concentrations were low and similar to 2013 levels, and trace amounts of transuranic nuclides were detected. Observed concentrations were less than those found nearer to Sellafield and continued at the low levels seen in recent years (Figure 8.2). Further information on the trends in radioactivity in the marine environment of Northern Ireland is described in Ly *et al.,* (2015). The radiation dose rates over intertidal areas were similar to those in previous years.

A survey of consumption and occupancy in coastal regions of Northern Ireland (Smith *et al*., 2002) established habits representative of people consuming large quantities of fish and shellfish. Based on the monitoring results from the marine environment in 2014, the dose to the most exposed person was 0.009 mSv, which is less than 1 per cent of the dose limit for members of the public.

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

8.4 Overseas sources

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

For Chernobyl, the main sustained impact on the UK environment has been in upland areas where heavy rain fell in the days following the accident. In particular, restrictions were put in place on moving, selling and slaughtering sheep from the affected areas to prevent meat from animals above the action level of 1,000 Bq kg^{-1} of radiocaesium, a level based on the recommendations of an EU expert committee in 1986, from entering the food chain. Following a review, including an assessment of the potential dose to people eating sheep meat, a public consultation and further consideration from the consultation (FSA, 2012b), all remaining post-Chernobyl restrictions on farm holdings in the UK were lifted on 31st May 2012.

Sampling locations for freshwater fish affected by Chernobyl ceased in 2014 following a risk-based review by FSA. In the last year of sampling in 2013, the highest concentration of caesium-137 detected was 120 Bq kg^{-1} in perch from Devoke Water. The long term time-trend is shown in Figure 8.3. A cautious assessment has been made of the dose received from consuming fish contaminated with radiocaesium following the Chernobyl accident. A consumption rate of 37 kg a year, sustained for one year, was taken to be an upper estimate for an adult subject to the highest exposure. In 2013, estimated doses were less than 0.1 mSv. Actual exposure is likely to be much lower, not only because this consumption rate is higher than expected (Leonard *et al*., 1990), but also because, in practice, people are likely to eat mostly

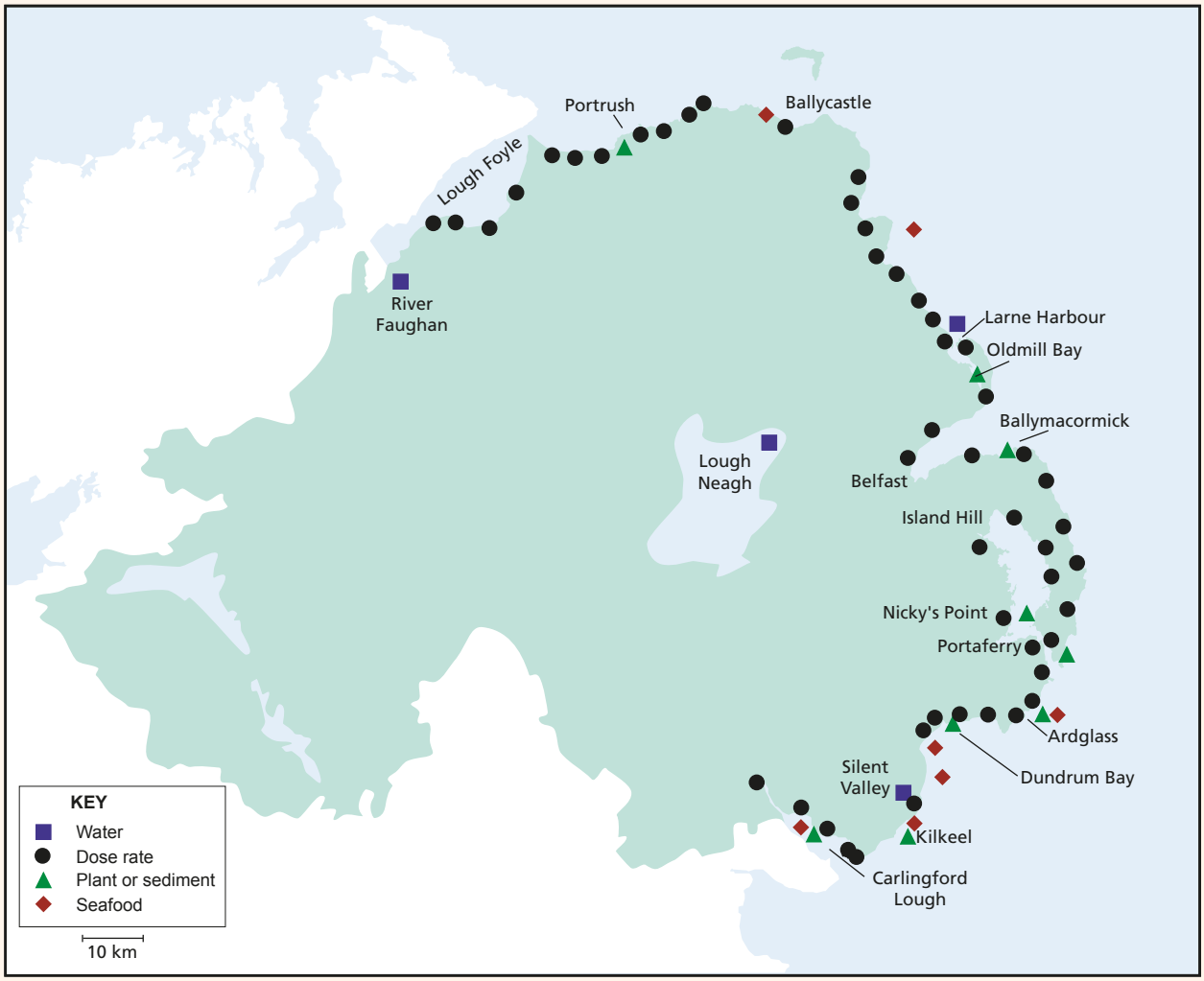


Figure 8.1. Monitoring locations in Northern Ireland, 2014

hatchery-reared or farmed fish that have a much lower radiocaesium concentration.

On 25 March 2011, the EC implemented controls (Regulation EU/297/2011) on the import of food and feed originating in or consigned from Japan following the Fukushima Dai-ichi accident (EC, 2011).

Various amendments have been made to legislative controls since that time. The legislation at the start of 2013 was Regulation EU/996/2012, issued in October 2012 (EC, 2012b) and amended by Regulation EU/495/2013 in May 2013 (EC, 2013a). This was replaced in March 2014 by Regulation EU/322/2014 (EC, 2014b) which was subsequently amended by Regulation EU/215/328 in March 2015 (EC, 2015). All food and feed imported from Japan (with the exception of certain alcoholic beverages and, since March 2014, tea) has to be certified by the Japanese authorities. As part of this certification, certain food and feed types from specified prefectures (regions) of Japan known to have been affected by radioactive contamination have to be tested to confirm contamination is below the maximum permissible levels for caesium-134 and caesium-137. Further information is available on the FSA's website: http://food.gov.uk/business-industry/imports/banned_restricted/japan.

A percentage of Japanese imports into the EU are monitored at ports of entry and this work continued in 2014. None of the imports to the UK have contained radioactivity exceeding the maximum permissible levels; most results have been below the limits of detection, with the highest recorded result being less than 100 Bq kg^{-1}. The doses received due to the imports were of negligible radiological significance.

Screening instruments are used at importation points of entry to the UK as a general check on possible contamination from unknown sources. In 2014, the instruments were triggered at Harwich by the presence of caesium-137 in a consignment of food being brought into the UK. The sample of blueberries from Lithuania was analysed and the activity concentration was 157 Bq kg^{-1}. At this concentration, FSA considered that there was no food safety requirement to limit placement of the consignment on the market for human consumption.

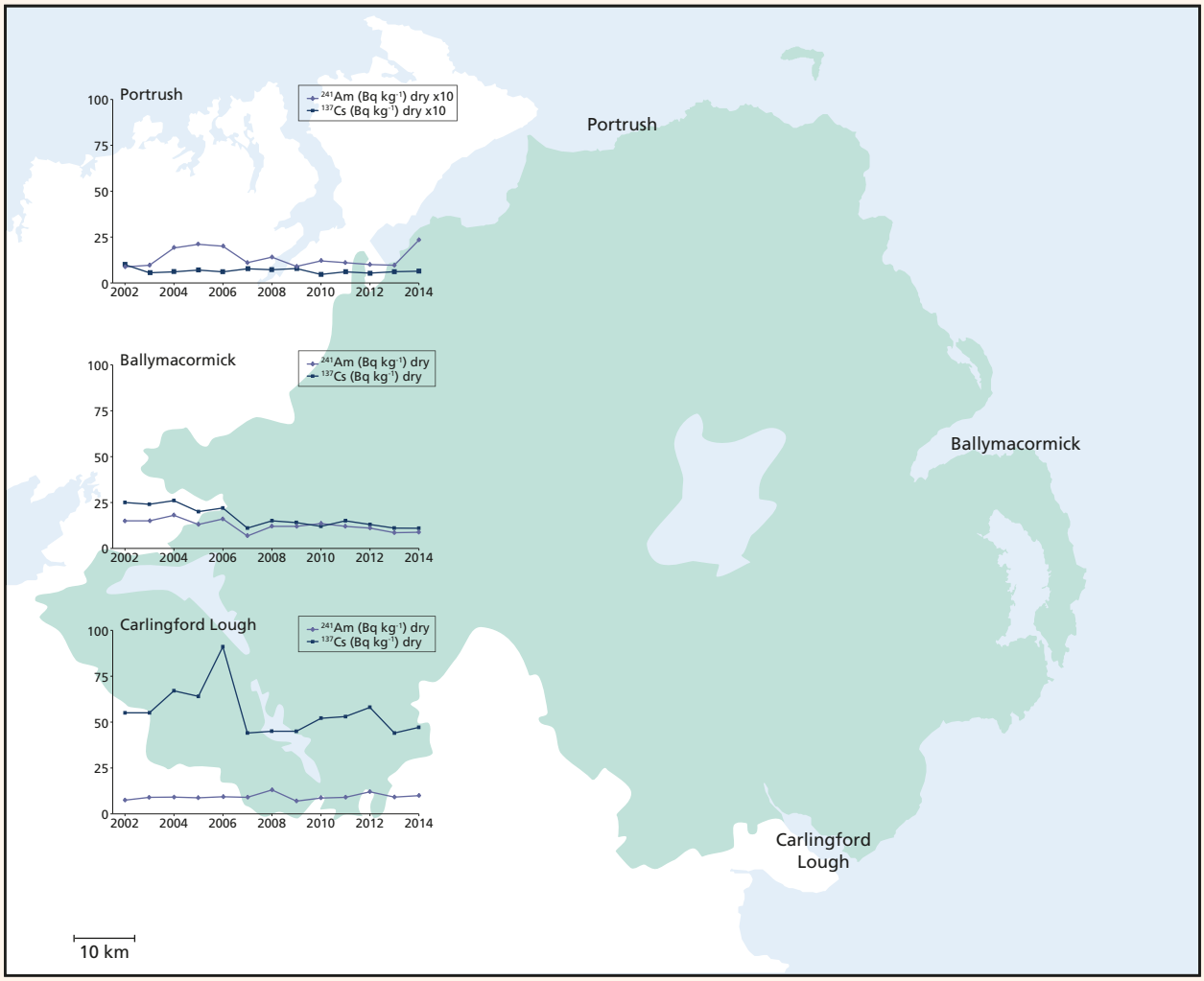


Figure 8.2. Concentrations of americium-241 and caesium-137 in coastal sediments in Northern Ireland, 2002-2014

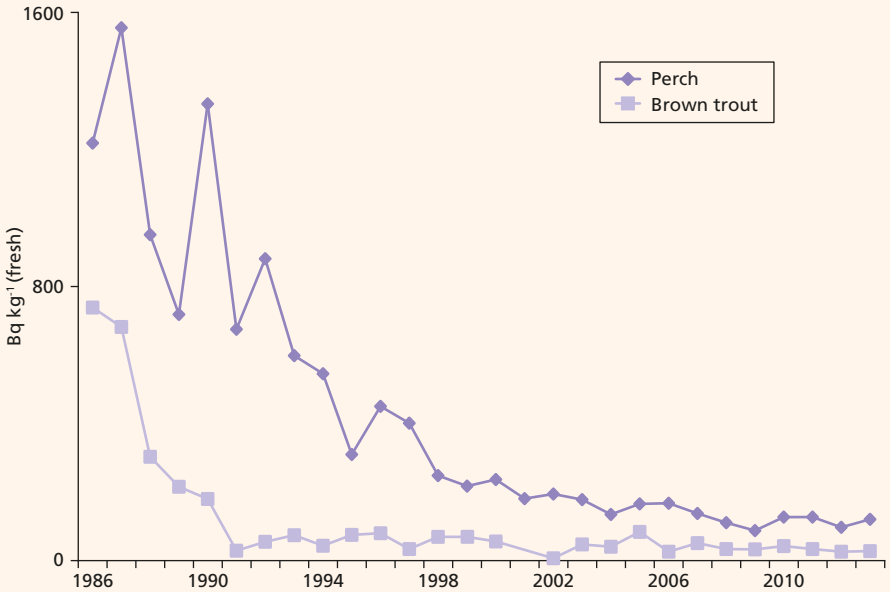


Figure 8.3. Caesium-137 concentrations in freshwater fish from Devoke Water, Cumbria 1986-2013

8.5 General diet

As part of the UK governments' general responsibility for food safety, concentrations of radioactivity are determined in regional diets. These data (and data on other dietary components in Sections 8.6 and 8.7) form the basis of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with data from other EU member states (for example, Joint Research Centre, 2009). Concentrations of radioactivity in the general diet are reported to the EC by the FSA (for England, Northern Ireland and Wales), and by SEPA (for Scotland).

In 2014, the concentrations found in a survey of radioactivity in canteen meals and mixed diet collected across the UK were very low or typical of natural sources (Table 8.5). Where comparisons can be made, similar values were observed in 2013.

8.6 Milk

The programme of milk sampling across dairies in the UK continued in 2014. Its aim is to collect and analyse samples on a monthly basis for their radionuclide content. This programme provides useful information with which to compare data from farms close to nuclear licensed sites and other establishments that may enhance concentrations above background levels. Milk data is reported by FSA (for England, Northern Ireland and Wales) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (for example, Joint Research Centre, 2009).

The results are summarised in Table 8.2. The majority of measurements, where comparable, are similar to those in previous years. Carbon-14 concentrations are very close to the expected background concentration in milk (see Appendix 1, Annex 4). Tritium results were again below detection limits. The mean concentration of strontium-90 detected was about 0.04 Bq l^{-1}. In the past, the concentrations of radiocaesium in milk were highest from those regions that received the greatest amounts of Chernobyl fallout. However, the concentrations are now very low and it is not possible to distinguish this trend.

Radiation dose from consuming milk at average rates was assessed for various age groups. In 2014, the maximum dose was to a one-year-old infant. For the range of radionuclides analysed, the dose was less than 0.005 mSv. Previous surveys (for example, FSA and SEPA, 2002) have shown that if a full range of nuclides are analysed and assessed, the dose is dominated by naturally occurring lead-210 and polonium-210, whereas man-made radionuclides contribute less than 10 per cent.

8.7 Crops

The programme of monitoring naturally occurring and man-made radionuclides in crops (in England, Wales and the Channel Islands) as a check on general food contamination (remote from nuclear sites) ceased in 2014 following a risk-based review by FSA. In the last year of sampling in 2013, there were no significant trends in concentrations of radionuclides in crops (Environment Agency, FSA, NIEA, NRW and SEPA, 2014). Tritium concentrations are reported as less than values in most samples. Carbon-14 was generally detected at levels close to those expected to occur through natural processes. Levels of other naturally occurring radionuclides varied from region to region and plutonium isotopes and americium-241 were detected at trace levels in some samples.

8.8 Airborne particulate, rain, freshwater and groundwater

Radioactivity in rainwater and air was monitored at several UK locations as part of the programme of background sampling managed by the Environment Agency and SEPA. These data are reported on behalf of DECC, NIEA and the Scottish and Welsh Governments, as part of the UK submission to the EC under Article 36 of the Euratom Treaty (for example, Joint Research Centre, 2009). The results are given in Table 8.6. The routine programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an *ad hoc* basis by gamma-ray spectrometry. Caesium-137 concentrations are reported as less than values. These levels in air, typical of recent years, remain less than 0.01 per cent of those observed in 1986, the year of the Chernobyl reactor accident.

Concentrations of beryllium-7, a naturally occurring radionuclide formed by cosmic ray reactions in the upper atmosphere, were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in recent years. Activity concentrations in air and rainwater were very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2014 (Figure 8.4). These water data are reported by the Environment Agency (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (for example, Joint Research Centre, 2009). Sampling was designed to represent the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples were representative of natural waters before

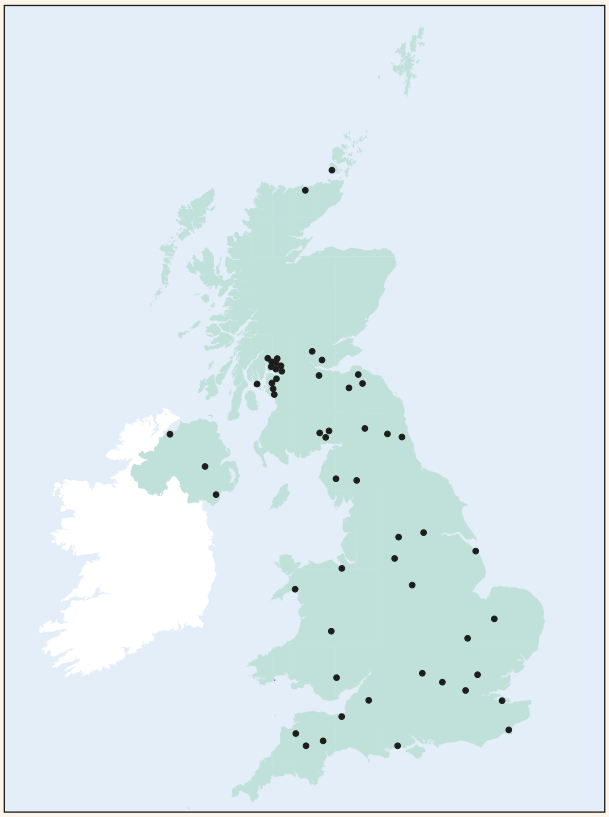


Figure 8.4. Drinking water sampling locations, 2014

treatment and supply to the public water system. The results in Tables 8.7, 8.8 and 8.9 show that concentrations of tritium were all substantially below the EU indicator limit of 100 Bq l^{-1}. The highest value in Scotland was found at Gullielands Burn, which is near to the Chapelcross nuclear licensed site. Concentrations of gross alpha and gross beta were all below the WHO screening levels for drinking water of 0.5 and 1.0 Bq l^{-1}, respectively.

The mean annual dose from consuming drinking water in the UK was assessed as 0.054 mSv in 2014 (Table 8.10). The estimated doses were dominated by naturally occurring radionuclides. The annual dose from artificial radionuclides in drinking water was less than 0.001 mSv. The highest annual dose was estimated to be 0.11 mSv due to radionuclides, including naturally occurring polonium-210, in a source of drinking water from Silent Valley in County Down.

Separately, in 2014, SEPA took a series of groundwater samples from across Scotland and the results are displayed in Table 8.11. All samples contained levels below or near the LoD and are generally consistent with those in recent years. A single positive measurement of tritium in groundwater from Annan could conceivably be due to the operation of the nearby Chapelcross nuclear site. Regardless of the source, at the levels detected there are no radiological protection implications.

8.9 Seawater surveys

The UK Governments are committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally occurring radioactive substances, and close to zero for artificial radioactive substances (DECC, Department of the Environment Northern Ireland, the Scottish Government and Welsh Assembly Government, 2009). Therefore, a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling.

The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (for example, OSPAR, 2010b). A third periodic evaluation of progress towards internationally agreed objectives have been published by OSPAR (OSPAR, 2009b). The programme of radiological surveillance work provides the source data and, therefore, the means to monitor and make an assessment of progress in line with the UK's commitments towards OSPAR's 1998 Strategy for Radioactive Substances objectives for 2020 (part of the North-east Atlantic Environment Strategy adopted by OSPAR for the period 2010-2020). The surveys also provide information that can be used to distinguish different sources of man-made radioactivity (for example, Kershaw and Baxter, 1995) and to derive dispersion factors for nuclear licensed sites (Baxter and Camplin, 1994). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Evidence to help gauge progress towards achieving the Government's vision for radionuclides and other hazardous substances is set out in a report (Defra, 2010).

The research vessel programme on radionuclide distribution currently comprises annual surveys of the western English Channel and biennial surveys of the Irish Sea and the North Sea. The results obtained in 2014 are given in Figures 8.5 – 8.8.

A seawater survey of the North Sea was carried out in 2014. Caesium-137 data (given in Figure 8.5) show that the concentrations were very low (up to 0.006 Bq l^{-1}) throughout the survey area, and these were only slightly above those observed for global fallout levels in surface seawaters (0.0001-0.0028 Bq l^{-1}, Povinec *et al*., 2005). The overall distribution in the North Sea is characteristic of that observed in previous surveys. Typically higher concentrations were observed at two stations close to the Norwegian coast, possibly due to the input of Chernobyl-derived caesium-137 from the Baltic (via the Skaggerak) or the distant effects from historic Sellafield discharges. The 2014 survey (as in 2012), also showed higher levels at some locations in the central North Sea. These were likely to be the outcome of complex water circulation (also possibly Sellafield or Chernobyl-derived).

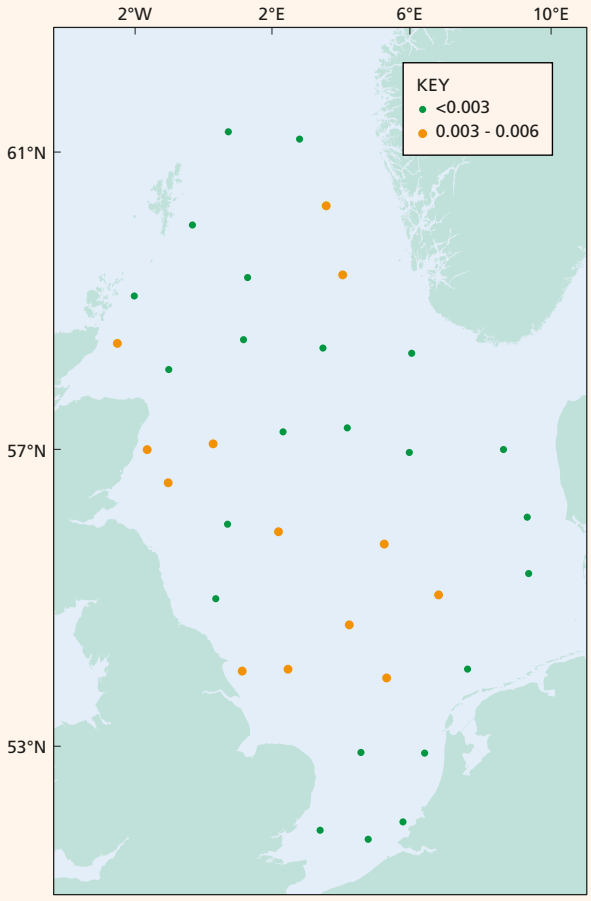


Figure 8.5. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the North Sea, September 2014

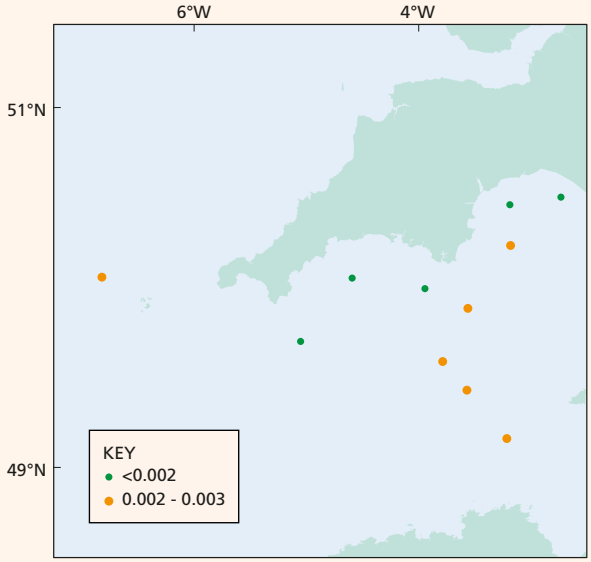


Figure 8.6. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the English Channel, February-March 2014

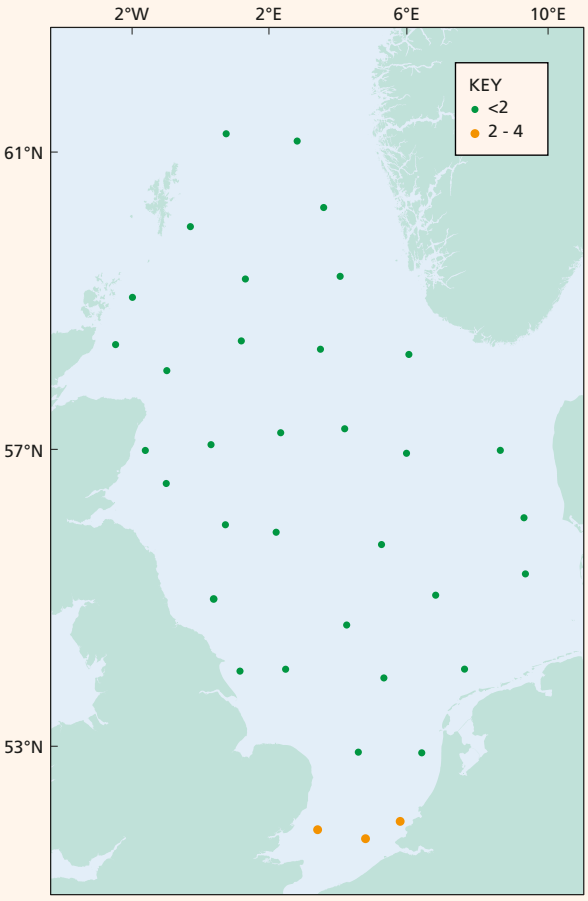


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, September 2014

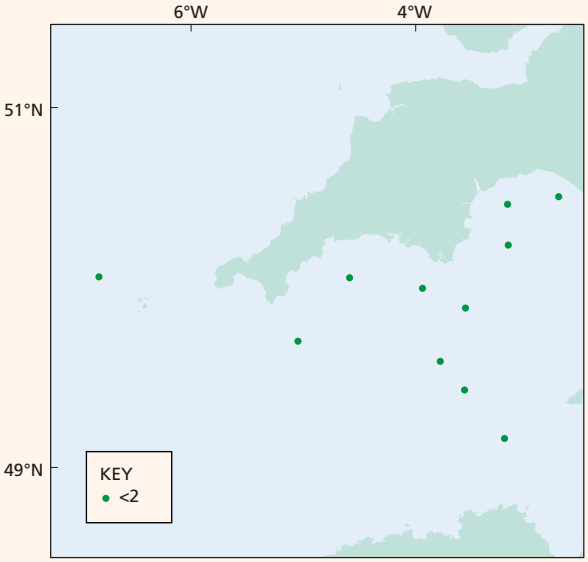


Figure 8.8. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September 2014

In the previous three decades the impact of discharges from the reprocessing plants at Sellafield and La Hague has been readily apparent, carried by the prevailing residual currents from the Irish Sea and the Channel, respectively (Povinec *et al*., 2003). The activity of caesium-137 in the North Sea has tended to follow the temporal trends of the discharges, albeit with a time lag. The maximum discharge of caesium-137 occurred at Sellafield in 1975, with up to 0.5 Bq l^{-1} caesium-137 in the North Sea surface waters in the late 1970's. Due to significantly decreasing discharges after 1978, remobilisation of caesium-137 from contaminated sediments in the Irish Sea was considered to be the dominant source of water contamination for most of the North Sea (McCubbin *et al*., 2002).

Caesium-137 concentrations in the Irish Sea were only a small percentage of those prevailing in the late 1970's (typically up to 30 Bq l^{-1}, Baxter *et al*., 1992), when discharges were substantially higher. The 2013 seawater survey recorded concentrations of up to 0.09 Bq l^{-1} in the eastern Irish Sea, elsewhere concentrations were generally below 0.03 Bq l^{-1}. A recent study has re-confirmed that the predominant source of caesium-137 to the Irish Sea was due to the remobilisation into the water column from activity associated with seabed sediment (Hunt *et al*., 2013). Discharges from Sellafield have decreased substantially since the commissioning of the SIXEP waste treatment process in the mid 1980s, and this has been reflected in a near exponential decrease in shoreline seawater concentrations at St Bees (Figure 8.9). In more recent years, the rate of decline of caesium-137 concentrations with time has been decreasing at St Bees. Longer time series showing peak concentrations in the Irish Sea and, with an associated time-lag, the North Sea are also shown in Figure 8.9.

Concentrations of caesium-137 (up to 0.003 Bq l^{-1}) in the western English Channel (Figure 8.6) were not distinguishable from the background levels of global fallout (within experimental error) in 2014. Activity concentrations near the Channel Islands were generally similar to those in previous years and lower than concentrations in both the Irish and North Seas.

A full assessment of long-term trends of caesium-137 in surface waters of Northern European seas is provided elsewhere (Povinec *et al*., 2003).

Tritium concentrations in North Sea seawater (in 2014) are shown in Figure 8.7, and were generally lower than those observed in the Irish Sea in 2013 (Environment Agency, FSA, NIEA, NRW and SEPA, 2014) due to the influence of discharges from Sellafield and other nuclear licensed sites. As in previous North Sea surveys, tritium concentrations were slightly elevated (but still very low) in a few water samples taken from the most southerly sampling locations of the North Sea. The most probable source of this is from the authorised discharges of tritium from the French nuclear power plants located on the coast of the English Channel. Tritium concentrations in the western English Channel were also very low (Figure 8.8).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed from 1994 to their most recent peak in 2003. The results of research cruises to study this radionuclide have been published by Leonard *et al*., (1997a, b; 2004) and McCubbin *et al*., (2002; 2008). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*., (1999). Full reviews of the quality status of the North-east Atlantic and a periodic evaluation of progress towards internationally agreed objectives have been published by OSPAR (2000b; 2009b; 2010b). A research study, commissioned by the Food Standards Agency, determined the depth distributions of technetium-99 concentrations in sea-bed cores to produce an estimate of the total inventory residing in the sub-tidal sediments of the Irish Sea (Jenkinson *et al*., 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.

Shoreline sampling was also carried out around the UK, as part of routine site and regional monitoring programmes. Much of the shoreline sampling was directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, these are reported in the relevant sections of this report, and the analysis results are collated in Table 8.12. Most radionuclides are below limits of detection, and tritium and caesium-137 levels remote from site discharge points are consistent with those in Figures 8.5 – 8.9. The effects of discharges of tritium from AGR sites can often be detected when sampling coincides with the periodic discharges. This was the case in 2014 at Heysham.

In 2014, SEPA took a series of marine sediment samples from across Scotland and the results are displayed in Table 8.13. Various radionuclides were detected. The results are generally consistent with those to be expected from measurements at nuclear licensed sites in this report (see, for example, Section 2), and are similar to those sampled in 2013. Overall, the results support the concept of a reducing trend in concentration with distance from the Sellafield site, albeit confounded by natural variability due to sediment type.

8.10 Bottled water

The EC published Council Directive 2013/51/EURATOM on 22 October 2013, laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption (EC, 2013b). This legislation requires the testing, by drinking water companies, of drinking water

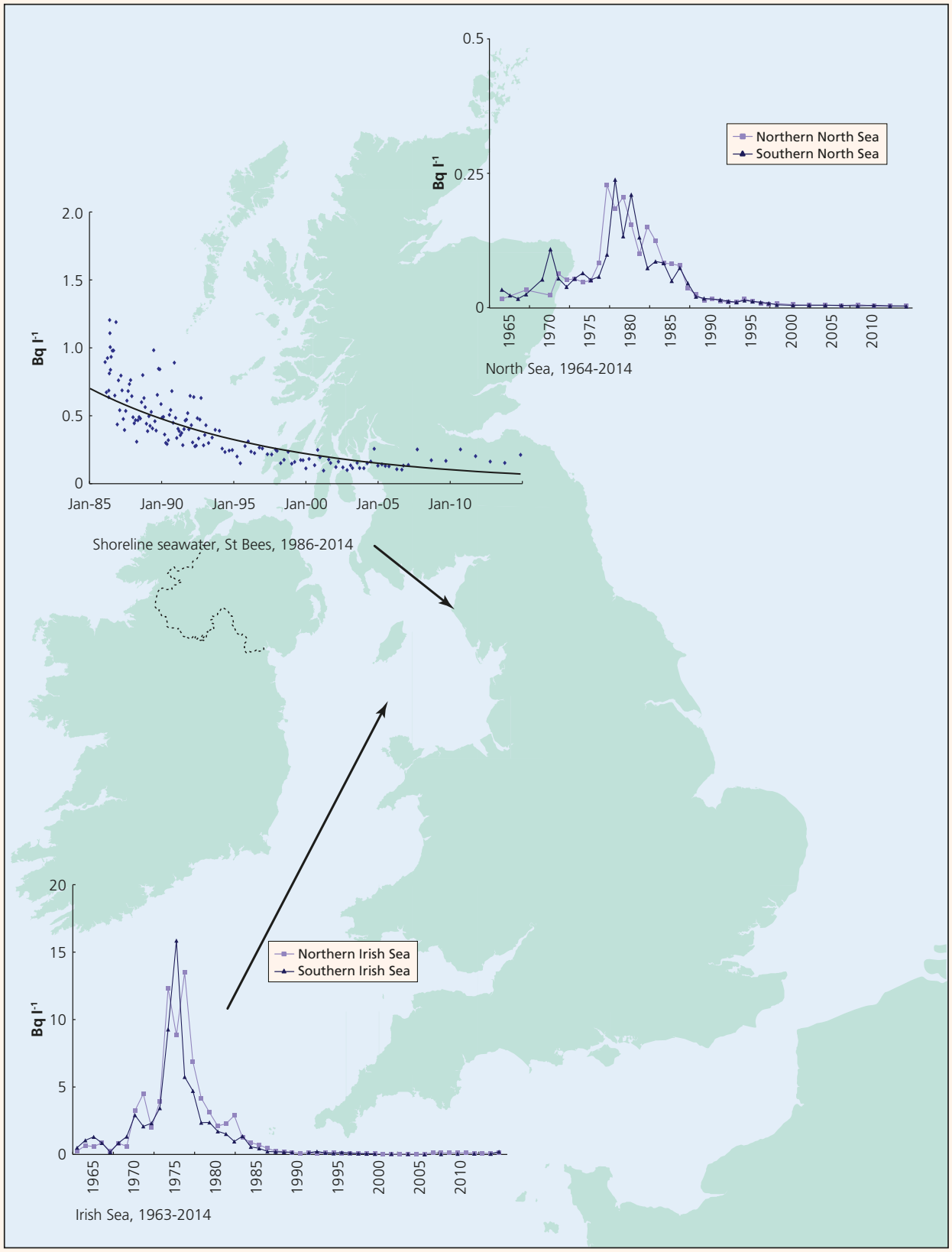


Figure 8.9. Concentration of caesium-137 in the Irish Sea, North Sea and in shoreline seawater close to Sellafield at St. Bees
(Note different scales used for activity concentrations)

and bottled water for certain radionuclides and will be implemented into UK law during 2015.

Legally, bottled water is considered a food and hence is within the remit of the FSA, whilst drinking water is the responsibility of the Drinking Water Inspectorate in England, Wales and Northern Ireland and the Drinking Water Quality Regulator in Scotland. As food regulations are a devolved responsibility, the regulation covering composition and standards of bottled drinking water are the responsibility of Defra in England and FSA in the rest of the UK (from 1st April 2015, FSS has responsibility in Scotland).

In autumn 2013, FSA commissioned a survey of bottled water. Samples were collected between January and February 2014. PHE was commissioned to analyse the samples for levels of radionuclides.

Naturally occurring radionuclides uranium-234 and uranium-238 were detected in 9 of the 28 samples. From these results the subsequent doses were calculated. The calculated doses are very low, less than 0.005 mSv, and can be attributed to low activity concentrations in water of naturally occurring radionuclides.

Full results of this survey have been published as a Food Information Sheet on FSA website:

http://www.food.gov.uk/science/research/surveillance/food-surveys/food-survey-information-sheets-2014/radioactivity

Table 8.1. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2014

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I
Guernsey										
	Mackerel	1				<0.08			<0.67	*
	Bass	1				<0.07			<0.53	*
	Limpets	1				<0.06			<0.50	*
	Ormers	1				<0.14			<1.4	*
Fermain Bay	*Porphyra*	2				<0.11			<0.77	<2.1
Fermain Bay	*Fucus serratus*	1				<0.05	<0.046	0.71	<0.35	*
St. Sampson's Harbour	Mud and sand	1				<0.22			<2.1	*
Jersey										
	Pollack	2				<0.06			<0.48	<0.79
	Mackerel	1				<0.08			<0.75	<0.42
	Bass	1				<0.07			<0.69	*
	Crabs	1				<0.04			<0.43	<0.65
	Spiny spider crabs	1				<0.06			<0.52	*
	Lobsters	1				<0.05		0.51	<0.49	*
	Scallops[b]	2				<0.05			<0.38	<0.15
La Rocque	Oysters	1				<0.06			<0.49	<1.3
La Rozel	Limpets	1				<0.04			<0.31	*
Plemont Bay	Porphyra	2				<0.06			<0.54	*
La Rozel	*Fucus vesiculosus*	1				<0.08		5.4	<0.55	<1.2
Gorey	*Fucus vesiculosus*	3				<0.06			<0.47	<0.76
La Rozel	*Ascophyllum nodosum*	3				<0.06	<0.060		<0.42	<0.80
Gorey	*Ascophyllum nodosum*	1				<0.08			<0.58	*
St Helier	Mud	1				1.7			<2.1	*
Alderney										
	Crabs	1	<25	<25	47	<0.07		<0.90	<0.56	<1.1
	Lobsters	1				<0.05			<0.42	<0.84
	Toothed winkles	1	<25	<25	33	<0.13	<0.20		<0.97	*
	Fucus vesiculosus	2								0.95
Quenard Point	*Fucus serratus*	4				<0.10	<0.036	0.80	<0.74	<0.53
Quenard Point	*Laminaria digitata*	4				<0.09			<0.76	*
Little Crabbe Harbour	Sand	1				<0.26			<2.8	*
	Seawater	4		<4.7						

Table 8.1. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Guernsey										
	Mackerel	1	0.08	<0.18	<0.000035	0.000022	0.000045	*	*	120
	Bass	1	0.20	<0.11	<0.000018	0.000022	0.000073	*	*	150
	Limpets	1	<0.06	<0.15			<0.15			86
	Ormers	1	<0.13	<0.32			<0.30			100
Fermain Bay	*Porphyra*	2	<0.08	<0.12	0.0024	0.0077	0.011	*	0.00072	31
Fermain Bay	*Fucus serratus*	1	<0.04	<0.10	0.0026	0.011	0.0049	*	0.00031	110
St. Sampson's Harbour	Mud and sand	1	0.70	<0.77	0.034	0.13	0.17	*	0.016	520
	Seawater	2	0.002							
Jersey										
	Pollack	2	<0.13	<0.11			<0.11			140
	Mackerel	1	<0.08	0.14	0.000043	0.00011	0.00012	*	*	
	Bass	1	0.13	<0.11			<0.07			120
	Crabs	1	<0.04	<0.13	0.00030	0.00074	0.0022	*	0.00017	120
	Spiny spider crabs	1	<0.05	<0.10			<0.06			76
	Lobsters	1	<0.05	<0.12	0.00047	0.0014	0.011	*	0.0010	64
	Scallops[b]	2	<0.04	<0.09	0.0095	0.033	0.033	0.00081	0.0018	120
La Rocque	Oysters	1	<0.06	<0.14	0.0016	0.0043	0.0052	0.00014	0.00044	84
La Rozel	Limpets	1	<0.03	<0.06	0.0019	0.0057	0.0085	0.000090	0.00061	82
Plemont Bay	Porphyra	2	<0.05	<0.10			<0.07			100
La Rozel	*Fucus vesiculosus*	1	<0.07	<0.13			<0.08			160
Gorey	*Fucus vesiculosus*	3	<0.05	<0.14			<0.17			190
La Rozel	*Ascophyllum nodosum*	3	<0.05	<0.11	0.0055	0.017	0.0086	0.000099	0.00056	160
Gorey	*Ascophyllum nodosum*	1	<0.07	<0.18			<0.22			190
St Helier	Mud	1	1.2	<0.56	0.25	0.85	1.6	0.030	0.10	580
St Catherine's Bay	Seawater	1	0.001							
Alderney										
	Crabs	1	<0.06	<0.12	0.000062	0.00037	0.015	*	0.00016	96
	Lobsters	1	0.04	<0.12	0.00015	0.00059	0.0051	*	0.00051	97
	Toothed winkles	1	<0.11	<0.19	0.0040	0.017	0.021	*	0.0014	50
	Fucus vesiculosus	2								
Quenard Point	*Fucus serratus*	4	<0.08	<0.16	0.0035	0.012	0.0051	*	0.00050	240
Quenard Point	*Laminaria digitata*	4	<0.08	<0.14			<0.13			210
Little Crabbe Harbour	Sand	1	1.7	<0.57			0.52			710
	Seawater	4	0.002							

* *Not detected by the method used*

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

[b] *The concentration of ^{108m}Ag was 0.11 Bq kg^{-1}*

Table 8.2. Concentrations of radionuclides in milk remote from nuclear sites, 2014

Location	Selection[a]	No. of farms/ dairies[b]	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{14}C	^{90}Sr	Total Cs
Milk						
Co. Antrim		1		16	<0.023	<0.06
Co. Armagh		1			<0.021	<0.05
Ceredigion		1			<0.025	<0.05
Cheshire		1		15	<0.021	<0.05
Clwyd		1		16	<0.023	<0.04
Cornwall		1		17	<0.021	<0.04
Devon		1		15	<0.023	<0.05
Dorset		1		15	<0.020	<0.04
Co. Down		1			<0.022	<0.05
Dumfriesshire		1	<5.0	<15	<0.10	<0.05
Essex		1		9.9	<0.022	<0.05
Co. Fermanagh		1			<0.025	<0.05
Gloucestershire		1		9.7	<0.020	<0.05
Gwynedd		1		19	<0.021	<0.05
Hampshire		1		12	<0.023	<0.04
Humberside		1		21	<0.021	<0.05
Kent		1		15	<0.021	<0.04
Lanarkshire		1	<5.0	<15	<0.049	0.02
Lancashire		1		14	<0.021	<0.05
Leicestershire	max	2		11	<0.022	<0.04
Middlesex		1		16	<0.021	<0.05
Midlothian		1	<5.0	<15	<0.12	<0.05
Nairnshire		1	<5.0	<15	<0.10	<0.05
Norfolk		1		10	<0.023	<0.05
North Yorkshire		1		12	<0.021	<0.05
Renfrewshire		1	<5.0	<15	<0.10	<0.05
Co. Tyrone	max	2		20	<0.022	<0.05
Mean Values						
England				14	<0.021	<0.05
Northern Ireland				18	<0.023	<0.05
Wales				18	<0.023	<0.05
Scotland			<5.0	<15	<0.094	<0.04
United Kingdom			<5.0	<15	<0.035	<0.05

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

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

Table 8.3. Concentrations of radionuclides in food and the environment from the Isle of Man, 2014[a]

Material	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{60}Co	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Seaweed	3	<0.92	<0.62	<1.2	41	<5.4	<3.3	<0.82	<0.71
Sediment	1	<0.32	<0.22	<0.48		<1.8	<0.99	<0.29	6.3

Material	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
		^{144}Ce	^{241}Am	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Aquatic samples								
Seaweed	3	<2.2	<0.77	2.2	<0.16	2.0		
Sediment	1	<1.3	1.5				<130	480

[a] *The gamma dose rate in air at 1m over sand and stones at Ramsey was 0.092 mGy h^{-1}*

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

Table 8.4(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2014[a]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Cod	Kilkeel	4	34	<0.06		<0.12	<0.06	0.92
Plaice	Kilkeel	4		<0.05		<0.12	<0.05	0.26
Haddock	Kilkeel	4		<0.06		<0.14	<0.06	0.34
Herring	Ardglass	2		<0.10		<0.25	<0.10	0.29
Lesser spotted dogfish	North coast	4		<0.12		<0.25	<0.12	1.0
Skates / rays	Kilkeel	4		<0.07		<0.17	<0.07	0.72
Crabs	Kilkeel	4		<0.07		<0.16	<0.07	<0.09
Lobsters	Ballycastle	2		<0.05	5.5	<0.11	<0.05	0.07
Lobsters	Kilkeel	4		<0.06	11	<0.14	<0.06	0.14
Nephrops	Kilkeel	4		<0.07	1.5	<0.19	<0.08	0.37
Winkles	Minerstown	4		<0.08		<0.19	<0.09	<0.14
Mussels	Carlingford Lough	2		<0.10	3.4	<0.23	<0.10	0.26
Scallops	Co. Down	2		<0.07		<0.14	<0.07	0.20
Ascophyllum nodosum	Carlingford Lough	2		<0.09		<0.19	<0.09	0.26
Ascophyllum nodosum	Ardglass	1		<0.11		<0.22	<0.11	0.27
Fucus serratus	Portrush	1		<0.06		<0.12	<0.06	<0.53
Fucus spp.	Carlingford Lough	1		<0.05	70	<0.11	<0.06	0.39
Fucus spp.	Portrush	3		<0.05		<0.12	<0.05	0.10
Fucus vesiculosus	Carlingford Lough	1		<0.18		<0.32	<0.18	0.32
Fucus vesiculosus	Ardglass	3		<0.10	12	<0.19	<0.10	0.35
Rhodymenia spp.	Portaferry	4		<0.09	<0.26	<0.21	<0.09	<0.28
Mud	Carlingford Lough	2		<0.56		<1.5	<0.74	47
Mud	Carrichue	1		<0.19		<0.49	<0.26	2.7
Mud	Ballymacormick	1		<0.24		<0.74	<0.32	11
Mud	Dundrum Bay	1		<0.38		<1.2	<0.59	23
Mud	Oldmill Bay	2		<0.41		<1.0	<0.51	18
Mud	Strangford Lough-Nicky's point	2		<0.50		<1.5	<0.70	20
Mud and sand	Carrichue	1		<0.23		<0.71	<0.34	2.1
Mud and sand	Ballymacormick	1		<0.39		<1.0	<0.51	11
Mud and shell	Dundrum Bay	1		<0.41		<1.2	<0.62	4.2
Sand	Portrush	2		<0.22		<0.65	<0.28	0.66
Seawater	North of Larne	12			0.0013		*	0.01

Table 8.4(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{155}Eu	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm + ^{244}Cm
Cod	Kilkeel	4	<0.10			<0.09		
Plaice	Kilkeel	4	<0.11			<0.09		
Haddock	Kilkeel	4	<0.14			<0.14		
Herring	Ardglass	2	<0.23			<0.25		
Lesser spotted dogfish	North coast	4	<0.20			<0.16		
Skates / rays	Kilkeel	4	<0.18			<0.18		
Crabs	Kilkeel	4	<0.15			<0.17		
Lobsters	Ballycastle	2	<0.09			<0.10		
Lobsters	Kilkeel	4	<0.12			<0.09		
Nephrops	Kilkeel	4	<0.17	0.0030	0.019	0.049	*	*
Winkles	Minerstown	4	<0.16	0.025	0.17	0.13	*	*
Mussels	Carlingford Lough	2	<0.19			<0.15		
Scallops	Co. Down	2	<0.11			<0.08		
Ascophyllum nodosum	Carlingford Lough	2	<0.21			<0.24		
Ascophyllum nodosum	Ardglass	1	<0.18			<0.12		
Fucus serratus	Portrush	1	<0.13			0.30		
Fucus spp.	Carlingford Lough	1	<0.13			<0.16		
Fucus spp.	Portrush	3	<0.13			<0.18		
Fucus vesiculosus	Carlingford Lough	1	<0.23			<0.12		
Fucus vesiculosus	Ardglass	3	<0.15			<0.23		
Rhodymenia spp.	Portaferry	4	<0.16	0.032	0.21	0.41	*	*
Mud	Carlingford Lough	2	<1.4	1.9	13	9.8	*	*
Mud	Carrichue	1	<0.51	0.18	1.2	2.3	*	*
Mud	Ballymacormick	1	<0.97			12		
Mud	Dundrum Bay	1	<1.4			7.5		
Mud	Oldmill Bay	2	<0.96			<7.5		
Mud	Strangford Lough-Nicky's point	2	<1.7			6.2		
Mud and sand	Carrichue	1	<0.92			1.9		
Mud and sand	Ballymacormick	1	<0.94			8.7		
Mud and shell	Dundrum Bay	1	<1.1			2.4		
Sand	Portrush	2	<0.80			<2.2		

* *Not detected by the method used*

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

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

Table 8.4(b). Monitoring of radiation dose rates in Northern Ireland, 2014[a]

Location	Ground type	No. of sampling observ-ations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lisahally	Mud	1	0.068
Donnybrewer	Shingle	1	0.053
Carrichue	Mud	1	0.067
Bellerena	Mud	1	0.058
Benone	Sand	1	0.060
Castlerock	Sand	1	0.055
Portstewart	Sand	1	0.057
Portrush, Blue Pool	Sand	1	0.056
Portrush, White Rocks	Sand	1	0.056
Portballintrae	Sand	1	0.055
Giant's Causeway	Sand	1	0.054
Ballycastle	Sand	1	0.055
Cushendun	Sand	1	0.063
Cushendall	Sand and stones	1	0.062
Red Bay	Sand	1	0.071
Carnlough	Sand	1	0.060
Glenarm	Sand	1	0.058
Half Way House	Sand	1	0.058
Ballygally	Sand	1	0.059
Drains Bay	Sand	1	0.059
Larne	Sand	1	0.061
Whitehead	Sand	1	0.063
Carrickfergus	Sand	1	0.061
Jordanstown	Sand	1	0.062
Helen's Bay	Sand	1	0.060
Groomsport	Sand	1	0.061
Millisle	Sand	1	0.071
Ballywalter	Sand	1	0.068
Ballyhalbert	Sand	1	0.067
Cloghy	Sand	1	0.067
Portaferry	Shingle and stones	1	0.091
Kircubbin	Sand	1	0.080
Greyabbey	Sand	1	0.080
Ards Maltings	Mud	1	0.086
Island Hill	Mud	1	0.070
Nicky's Point	Mud	1	0.076
Strangford	Shingle and stones	1	0.090
Kilclief	Sand	1	0.074
Ardglass	Mud	1	0.079
Killough	Mud	1	0.080
Ringmore Point	Sand	1	0.077
Tyrella	Sand	1	0.079
Dundrum	Sand	1	0.096
Newcastle	Sand	1	0.11
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.081
Mill Bay	Sand	1	0.11
Greencastle	Sand	1	0.086
Rostrevor	Sand	1	0.12
Narrow Water	Mud	1	0.099

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

Table 8.5. Concentrations of radionuclides in diet, 2014[a]

Region	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
Canteen meals					
England	8		79	<0.028	<0.07
Northern Ireland	5		90	0.033	<0.06
Scotland	12	<37	85	0.028	<0.03
Wales	5		87	<0.034	<0.08
	No. of farms/dairies				
Mixed diet in Scotland[b]					
Dumfriesshire					
Dumfries	4		89	<0.10	<0.05
East Lothian					
North Berwick	4		89	<0.078	<0.05
Renfrewshire					
Paisley	4		87	<0.10	<0.05
Ross-shire					
Dingwall	4		78	<0.10	<0.05

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

[b] *Mixed diet samples comprise food from the following food groups in the ratios specified in brackets: domestic fruit (1), green vegetables (1), pig meat (1), cattle meat (1), potatoes (2) and cereals (3)*

Table 8.6. Concentrations of radionuclides in rainwater and air, 2014

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]					
				^{3}H	^{7}Be	$^{7}Be^{d}$	^{90}Sr	^{137}Cs	$^{137}Cs^{d}$
Ceredigion									
	Aberporth	Rainwater	4	<0.89	<0.45			<0.014	
		Air	4		0.0021			$<7.3\ 10^{-7}$	
Co. Down									
	Conlig	Rainwater	4		<0.84			<0.0094	
		Air	4		0.0021			$<7.4\ 10^{-7}$	
Dumfries and Galloway									
	Eskdalemuir	Rainwater	12	<1.0	<0.27		<0.0056	<0.010	
		Air	12		0.0010			$<1.0\ 10^{-5}$	
North Lanarkshire									
	Holytown	Rainwater	8	<1.0	<0.90		<0.028	<0.019	
		Air	12		0.0011			$<1.0\ 10^{-5}$	
North Yorkshire									
	Dishforth	Rainwater	4		<0.41			<0.011	
		Air	4		0.0017			$<5.4\ 10^{-7}$	
Oxfordshire									
	Chilton	Rainwater	4		<0.69	<0.21	<0.00032[b]	<0.015	<0.0020
		Air	12			0.0014			$<2.9\ 10^{-7}$
Shetland									
	Lerwick	Rainwater	12	<1.0	<0.40		<0.0051	<0.010	
		Air	12		0.0014			$<1.0\ 10^{-5}$	
Suffolk									
	Orfordness	Rainwater	4	<1.0	<0.54			<0.012	
		Air	4		0.0023			$<5.1\ 10^{-7}$	

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]				
				$^{238}Pu^{c}$	$^{239}Pu+\ ^{240}Pu^{c}$	$^{241}Am^{c}$	Gross alpha	Gross beta
Ceredigion								
	Aberporth	Rainwater	4	$<2.0\ 10^{-5}$	$<2.0\ 10^{-5}$	<0.00024		
		Air	4	$<3.0\ 10^{-9}$	$<3.0\ 10^{-9}$	$<3.0\ 10^{-9}$		
Dumfries and Galloway								
	Eskdalemuir	Air	12					<0.00020
North Lanarkshire								
	Holytown	Air	12					<0.00020
Oxfordshire								
	Chilton	Rainwater	4				<0.0078[d]	<0.014[d]
Shetland								
	Lerwick	Air	12					<0.00020

[a] *Bq l^{-1} for rainwater and Bq kg^{-1} for air. 1.2 kg air occupies 1m^3 at standard temperature and pressure*
[b] *Bulked from 4 quarterly samples*
[c] *Separate annual sample for rain, annual bulked sample for air*
[d] *Bulked from 12 monthly samples*

Table 8.7. Concentrations of radionuclides in sources of drinking water in Scotland, 2014

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}				
			^{3}H	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Angus	Loch Lee	4	<1.0	<0.0050	<0.01	<0.0092	0.027
Argyll and Bute	Auchengaich	1	<1.0		<0.01	<0.010	0.015
Argyll and Bute	Helensburgh Reservoir	1	<1.0		<0.01	<0.0091	0.059
Argyll and Bute	Loch Ascog	1	<1.0		<0.01	<0.010	0.10
Argyll and Bute	Loch Eck	1	<1.0		<0.05	<0.0075	0.039
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.0		<0.01	<0.010	0.020
Argyll and Bute	Loch Finlas	1	<1.0		<0.01	<0.010	0.037
Clackmannanshire	Gartmorn Dam	1	<1.0		<0.01	<0.011	0.10
Dumfries and Galloway	Black Esk	1	<1.0		<0.01	<0.010	0.027
Dumfries and Galloway	Gullielands Burn	1	19		<0.01	<0.010	0.26
Dumfries and Galloway	Purdomstone	1	1.2		<0.01	<0.010	0.044
Dumfries and Galloway	Winterhope	1	1.7		<0.01	<0.010	0.075
East Lothian	Hopes Reservoir	1	<1.0		<0.01	<0.0080	0.040
East Lothian	Thorters Reservoir	1	<1.0		<0.01	<0.0097	0.056
East Lothian	Whiteadder	1	<1.0		<0.01	<0.011	0.095
East Lothian	Thornton Loch Burn	1	<1.0		<0.01	<0.0079	0.033
Fife	Holl Reservoir	1	<1.0		<0.01	<0.013	0.063
Highland	Loch Baligill	1	<1.0		<0.05	0.014	0.076
Highland	Loch Calder	1	<1.0		<0.01	<0.010	0.041
Highland	Loch Glass	4	<1.0	<0.0052	<0.01	<0.010	<0.032
Highland	Loch Shurrerey	1	<1.0		<0.01	<0.010	0.041
North Ayrshire	Camphill	1	<1.0		<0.01	<0.010	0.061
North Ayrshire	Knockendon Reservoir	1	1.1		<0.01	<0.010	0.020
North Ayrshire	Munnoch Reservoir	1	<1.0		<0.01	<0.010	0.060
North Ayrshire	Outerwards	1	1.1		<0.01	<0.010	0.030
Orkney Islands	Heldale Water	1	<1.0		<0.05	<0.011	0.079
Perth and Kinross	Castlehill Reservoir	1	<1.0		<0.01	<0.012	0.050
Scottish Borders	Knowesdean	4	<1.0	<0.0057	<0.01	<0.010	0.032
Stirling	Loch Katrine	12	<1.0	<0.0028	<0.001	<0.0089	<0.025
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.0		<0.01	<0.0077	0.032
West Lothian	Morton No 2 Reservoir	1	1.2		<0.05	<0.011	0.11

Table 8.8. Concentrations of radionuclides in sources of drinking water in England and Wales, 2014

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}							
			^{3}H	^{40}K	^{90}Sr	^{125}I	^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England										
Buckinghamshire	Bourne End, Groundwater	3	<4.0	<0.048	<0.0013		<0.0029	0.020	0.053	<0.048
Cambridgeshire	Grafham Water	4	<4.0	0.25	0.0029		<0.0010	0.028	0.41	0.27
Cheshire	River Dee, Chester	2	<4.0	0.073	0.0043	<0.0029	<0.0012	<0.020	0.11	0.068
Cornwall	River Fowey	4	<4.0	0.045	0.0028	<0.0022	<0.0010	0.023	0.080	0.053
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.058	0.0037		0.0027	0.082	0.18	0.11
County Durham	River Tees, Darlington	4	<4.0	0.040	0.0038	<0.0020	<0.0010	0.019	0.067	0.046
Cumbria	Ennerdale Lake	4	<4.0	<0.036	0.0035		<0.0010	<0.020	<0.049	<0.050
Cumbria	Haweswater Reservoir	4	<4.0	<0.011	0.0034		<0.0010	<0.020	<0.050	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	0.033	0.0015		<0.0010	<0.020	<0.051	<0.050
Derbyshire	Matlock, Groundwater[a]	2	<4.0	0.045	<0.0010		<0.0012	0.12	0.12	0.076
Devon	River Exe, Exeter	4	<4.0	0.12	0.0031	<0.0093	<0.0043	0.068	0.17	0.10
Devon	Roadford Reservoir, Broadwoodwidger	4	<4.0	0.061	0.0032		<0.0010	<0.020	0.092	0.059
Greater London	River Lee, Chingford	4	<4.0	0.23	0.0018	0.0018	<0.0010	0.025	0.37	0.24
Hampshire	River Avon, Christchurch	4	<4.0	0.090	0.0014	<0.0020	<0.0010	0.018	0.10	0.069
Humberside	Littlecoates, Groundwater	4	<4.0	0.088	0.0010		<0.0010	0.024	0.13	0.083
Kent	Chatham, Deep Groundwater	4	<4.0	0.036	<0.0011		<0.0012	<0.020	0.060	<0.051
Kent	Denge, Shallow Groundwater	4	<4.0	0.086	0.0051		<0.0010	<0.020	0.15	0.10
Lancashire	Corn Close, Groundwater	4	<4.0	0.084	<0.0010		<0.0010	0.023	0.13	0.084
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.10	0.0021	0.0019	<0.0010	0.026	0.14	0.093
Northumberland	Kielder Reservoir	4	<4.0	<0.053	0.0041		<0.0011	<0.037	0.063	0.050
Oxfordshire	River Thames, Oxford	4	<4.0	0.12	0.0016	<0.0020	<0.0010	0.019	0.18	0.12
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.048	<0.0011		<0.0012	0.020	0.11	0.073
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.13	0.0026		<0.0010	0.022	0.16	0.10
Surrey	River Thames, Chertsey	4	<4.0	0.17	0.0014	0.0021	<0.0010	<0.020	0.23	0.16
Surrey	River Thames, Walton	4	<4.0	0.17	0.0019	<0.0019	<0.0010	0.020	0.24	0.16
Yorkshire	Chellow Heights, Bradford	2	<4.0	<0.023	0.0038		<0.0014	<0.020	0.051	<0.050
Wales										
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.016	0.0043		<0.0012	<0.020	<0.052	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.024	0.0026		<0.0010	<0.020	<0.053	<0.050
Powys	Elan Valley Reservoir	4	<4.0	<0.018	0.0042		<0.0010	<0.020	<0.050	<0.050

[1] *Using ^{137}Cs standard*
[2] *Using ^{40}K standard*
[a] *The concentrations of ^{210}Po, ^{226}Ra, ^{234}U, ^{235}U and ^{238}U were <0.010, 0.012, 0.045, <0.010 and 0.020 Bq l^{-1} respectively*

Table 8.9. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2014

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}									
			^{3}H	^{90}Sr	^{137}Cs	^{210}Po	^{226}Ra	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Co. Londonderry	R Faughan	4	<1.0	0.0033	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	0.020	0.082
Co. Antrim	Lough Neagh	4	<1.0	0.0022	<0.05	0.020	<0.010	<0.010	<0.010	<0.010	0.024	0.10
Co. Down	Silent Valley	4	<1.0	0.0025	<0.05	0.047	<0.010	<0.010	<0.010	<0.010	0.024	0.061

Table 8.10. Doses from radionuclides in drinking water, 2014[a]

Region	Mean exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides[b,c]	Naturally occurring radionuclides[b]	All radionuclides	Location	All radionuclides
England	<0.001	0.029	0.029	Matlock, Groundwater, Derbyshire	0.029
Wales[d]	<0.001			Cwm Ystradllyn Treatment Works, Gwynedd	<0.001[d]
Northern Ireland	<0.001	0.062	0.063	Silent Valley, Co. Down	0.11
Scotland[d]	<0.001			Gullielands Burn, Dumfries and Galloway	0.001[d]
UK	<0.001	0.054	0.054	Silent Valley, Co. Down	0.11

[a] *Assessments of dose are based on some concentration results at limits of detection. Exposures due to potassium-40 content of water are not included here because they do not vary according to the potassium-40 content of water. Levels of potassium are homeostatically controlled*

[b] *Average of the doses to the most exposed age group at each location*

[c] *Including tritium*

[d] *Analysis of naturally occurring radionuclides was not undertaken*

Table 8.11. Analysis of groundwater – background survey in Scotland, 2014

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Scottish Borders	Selkirk	1	<1.0	<0.10	<0.034	<0.81
East Lothian	Dunbar	1	<1.0	<0.10	<0.0093	0.040
Fife	Kingsbarns	1	<1.0	<0.10	0.077	0.28
Fife	Falkland	1	<1.0	<0.10	<0.0090	0.040
Angus	Brechin	1	<1.0	<0.10	<0.010	0.030
Aberdeenshire	Stonhaven	1	<1.0	<0.10	<0.012	0.057
Aberdeenshire	Lumsden	1	<1.0	<0.10	0.015	0.027
Aberdeenshire	Peterhead	1	<1.0	<0.10	<0.010	0.072
Aberdeenshire	Turriff	1	<1.0	<0.10	<0.010	0.060
Moray	Fochabers	1	<1.0	<0.10	0.12	0.24
Highlands	Torridon	1	<1.0	<0.10	<0.0080	0.020
Highlands	Cromarty	1	<1.0	<0.10	0.018	0.092
East Dunbartonshire	Campsie Fells	1	<1.0	<0.10	<0.039	0.068
Ayrshire	Girvan	1	<1.0	<0.10	0.017	0.090
Dumfries and Galloway	Stranraer	1	<1.0	<0.10	<0.038	0.15
Dumfries and Galloway	Dumfries	1	<1.0	<0.10	0.020	0.040
Dumfries and Galloway	Annan	1	1.9	<0.10	0.079	<0.059

Table 8.12. Concentrations of radionuclides in seawater, 2014

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}						
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag
Dounreay (Sandside Bay)	2[S]	<1.0		<0.10			<0.72	<0.11
Dounreay (Brims Ness)	2[S]	<1.0		<0.10			<0.60	<0.10
Rosyth	2[S]	<1.0		<0.10			<0.47	<0.10
Torness[a]	2[S]	4.0		<0.10			<0.58	<.10
Hartlepool (North Gare)	2	<3.1		<0.28			<2.1	<0.31
Sizewell	2	<3.5		<0.29			<2.2	<0.34
Bradwell	2			<00.32			<2.1	<0.35
Dungeness south	2	<3.1		<0.30			<2.1	<0.36
Winfrith (Lulworth Cove)	1			<0.23			<1.7	<0.29
Alderney	4[F]	<4.7						
Devonport (Millbrook Lake)	2	<2.8	<3.2	<0.22				
Devonport (Tor Point South)	2	<2.9	<2.9	<0.32				
Hinkley	2			<0.27	<0.025		<1.9	<0.30
Berkeley and Oldbury	2			<0.25			<1.9	<0.31
Cardiff (Orchard Ledges)[b]	2	<9.0	<2.4	<0.31				
Wylfa (Cemaes Bay)	2	<3.1		<0.23			<1.8	<0.31
Wylfa (Cemlyn Bay West)	2			<0.24			<1.9	<0.32
Heysham (inlet)	2	46		<0.34			<2.4	<0.40
Seascale (Particulate)	2			<0.06	<0.0070		<0.39	<0.06
Seascale (Filtrate)	2			<0.29	<0.030	<0.12	<2.3	<0.36
St. Bees (Particulate)	2			<0.04	<0.0070		<0.33	<0.05
St. Bees (Filtrate)	2	<3.3		<0.24	<0.035	<0.35	<1.9	<0.31
Seafield	2[S]	<1.4		<0.10			<0.64	<0.10
Southerness	2[S]	5.0		<0.10			<0.66	<0.10
Auchencairn	2[S]	1.7		<0.10			<0.61	<0.10
Port Patrick	2[S]	<1.0		<0.10			<0.34	<0.10
Hunterston[c]	2[S]	6.9		<0.10			<0.76	<0.10
North of Larne	12[N]					0.0013		
Faslane (Carnban)	2[S]	<1.1		<0.10			<0.56	<0.10

Table 8.12. continued

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}					
		^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	2[S]	<0.10	<0.10	<0.47	<0.11		
Dounreay (Brims Ness)	2[S]	<0.10	<0.10	<0.37	<0.10		
Rosyth	2[S]	<0.10	<0.10	<0.34	<0.11		
Torness[a]	2[S]	<0.10	<0.10	<0.38	<0.11		
Hartlepool (North Gare)	2	<0.28	<0.23	<0.93	<0.28	<4.0	17
Sizewell	2	<0.30	<0.25	<0.97	<0.29	<3.7	14
Bradwell	2	<0.30	<0.24	<0.98	<0.28	<3.3	14
Dungeness south	2	<0.31	<0.25	<1.2	<0.34	<3.7	13
Winfrith (Lulworth Cove)	1	<0.26	<0.20	<0.92	<0.30	<5.4	15
Alderney	4[F]	*	0.0020				
Jersey	1[F]	*	0.0010				
Guernsey	2[F]	*	0.0020				
Hinkley	2	<0.26	<0.21	<0.88	<0.27	<3.0	11
Berkeley and Oldbury	2	<0.26	<0.21	<1.2	<0.36	<1.6	7.0
Cardiff (Orchard Ledges)[b]	2		<0.26				
Wylfa (Cemaes Bay)	2	<0.25	<0.20	<0.96	<0.30	<1.4	7.9
Wylfa (Cemlyn Bay West)	2	<0.26	<0.20	<1.0	<0.30	<3.1	14
Heysham (inlet)	2	<0.34	<0.26	<1.3	<0.36	<3.4	13
Seascale (Particulate)	2	<0.05	<0.05	<0.14	<0.08	0.12	0.057
Seascale (Filtrate)	2	<0.32	<0.24	<1.0	<0.30	<3.6	13
St. Bees (Particulate)	2	<0.04	<0.04	<0.14	<0.05	0.046	0.031
St. Bees (Filtrate)	2	<0.27	<0.21	<0.85	<0.25	<2.3	10
Seafield	2[S]	<0.10	<0.10	<0.45	<0.10		
Southerness	2[S]	<0.10	<0.10	<0.42	<0.15		
Auchencairn	2[S]	<0.10	<0.10	<0.41	<0.11		
Port Patrick	2[S]	<0.10	<0.10	<0.22	<0.10		
Hunterston[c]	2[S]	<0.10	<0.10	<0.44	<0.12		
North of Larne	12[N]	*	0.008				
Faslane (Carnban)	2[S]	<0.10	<0.10	<0.39	<0.10		

* *Not detected by the method used*

[a] *The concentration of ^{35}S was <0.50 Bq l^{-1}*

[b] *The concentrations of ^{3}H as tritiated water and ^{125}I were <3.1 Bq l^{-1} and <0.27 Bq l^{-1} respectively*

[c] *The concentration of ^{35}S was <0.50 Bq l^{-1}*

Results are made on behalf of the Environment Agency unless indicated otherwise

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency and the Channel Islands States*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 8.13. Concentrations of radionuclides in marine sediments – background survey in Scotland, 2014[a]

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1} (dry)								
			^{3}H	^{60}Co	^{110}Ag	^{125}Sb	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Firth of Clyde	NW Cloch Point	1	<5.0	0.17	<0.21	0.63	49	1.7	8.8	210	1600
Firth of Clyde	Lunderston Bay	1	<5.0	<0.10	<0.15	0.43	25	1.1	4.6	140	1100
Firth of Clyde	Wemyss Point	1	<5.0	<0.10	<0.19	0.33	38	1.1	5.7	170	1500
Firth of Clyde	East of Toward	1	<5.0	<0.10	0.73	<0.28	23	1.2	3.7	120	1300
Firth of Clyde	East of Strone Point	1	<5.0	0.25	1.1	1.1	89	1.6	15	170	2000
Firth of Clyde	East of Brodick	1	<5.0	<0.10	<0.25	<0.39	100	3.0	21	220	2200
Firth of Clyde	7km off Whiting Bay	1	<5.0	0.17	<0.29	<0.47	71	1.7	31	220	2100
Firth of Clyde	5km SW of Lady Isle	1	<5.0	<0.11	<0.25	<0.21	49	1.2	25	130	2100
Firth of Clyde	Middle at offshore	1	<5.0	<0.16	1.5	<0.55	70	2.0	32	150	2300
Firth of Clyde	Middle at offshore south	1	<5.0	<0.10	<0.19	<0.26	51	1.8	23	200	1900

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

9. References

(Includes references from Appendix 1: CD supplement; sorted in order of first author and then date)

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APPENDIX 1. Sampling, measurement, presentation and assessment methods and data

This Appendix contains information on the methods of sampling, measurement, presentation and assessment used in the Radioactivity in Food and the Environment report. It is provided in a separate file to the main report at https://www.gov.uk/government/policies/radioactive-and-nuclear-substances-and-waste?page=2

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2014

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014 Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (CNS Ltd)	Alpha	BAT	4.09E+06	NA
Other authorised outlets	Beta	BAT	7.24E+05	NA
Capenhurst	Uranium	7.50E+06	3.32E+05	4.4
(Urenco UK Ltd)	Other alpha	2.40E+06	Nil	Nil
	Technetium-99	1.00E+08	Nil	Nil
	Others	2.25E+09	Nil	Nil
	Alpha (Incinerator)	2.00E+08	Nil	Nil
	Beta (Incinerator)	2.50E+08	Nil	Nil
Sellafield[c]	Alpha	8.80E+08	8.43E+07	9.6
	Beta	4.20E+10	7.07E+08	1.7
	Tritium	1.10E+15	9.47E+13	8.6
	Carbon-14	3.30E+12	3.40E+11	10
	Krypton-85	4.40E+17	5.62E+16	13
	Strontium-90	7.10E+08	3.37E+07	4.7
	Ruthenium-106	2.30E+10	7.76E+08	3.4
	Antimony-125	3.00E+10	8.83E+09	29
	Iodine-129	7.00E+10	1.19E+10	17
	Iodine-131	3.70E+10	3.48E+08	<1
	Caesium-137	5.80E+09	1.54E+08	2.7
	Radon-222	5.00E+11	4.26E+10	8.5
	Plutonium alpha	1.90E+08	1.69E+07	8.9
	Plutonium-241	3.00E+09	2.02E+08	6.7
	Americium-241 and curium-242	1.20E+08	1.28E+07	11
Springfields	Uranium	5.30E+09	5.58E+08	11
Springfields	Tritium	1.00E+08	5.49E+06	5.5
(National Nuclear Laboratory)	Carbon-14	1.00E+07	4.65E+04	<1
	Other alpha radionuclides	1.00E+06	Nil	Nil
	Other beta radionuclides	1.00E+07	2.22E+03	<1
Research establishments				
Dounreay	Alpha[e,f]	9.80E+08	4.57E+06	1.4
(Fuel Cycle Area)[d, 1]	Beta[f,g]	4.50E+10	3.90E+07	<1
(January to April 2014)[2]	Tritium	2.00E+12	1.78E+10	2.7
	Krypton-85[h]	4.36E+13	Nil	Nil
	Strontium-90	4.20E+09	3.45E+06	<1
	Ruthenium-106	3.90E+09	6.90E+05	<1
	Iodine-129	1.10E+09	8.96E+06	2.4
	Iodine-131	1.50E+08	1.40E+06	2.8
	Caesium-134	8.40E+08	8.38E+04	<1
	Caesium-137	7.00E+09	1.09E+05	<1
	Cerium-144	7.00E+09	5.62E+05	<1
	Plutonium-241	3.30E+09	2.45E+05	<1
	Curium-242	2.70E+08	3.40E+03	<1
	Curium-244[i]	5.40E+07	3.51E+02	<1
Dounreay	Alpha[f,j]	1.00E+07	1.83E+03	<1
(Fast Reactor)[d, 1]	Beta[f,g,k]	1.50E+09	7.01E+03	<1
(January to April 2014)[2]	Tritium	4.50E+12	5.41E+08	<1
	Krypton-85[h]	4.00E+08	7.89E+07	59
Dounreay	Alpha[f,j]	6.00E+06	9.30E+03	<1
(Prototype Fast Reactor)[d, 1]	Beta[f,g,k]	5.10E+07	6.08E+04	<1
(January to April 2014)[2]	Tritium	1.05E+13	7.62E+11	22
	Krypton-85[h]	5.25E+14	7.51E+12	4.3

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Dounreay	Alpha[f,j]	6.00E+04	8.63E+01	<1
(PFR minor sources)[d,1]	Beta[f,g,k]	5.00E+05	3.46E+02	<1
(January to April 2014)[2]	Tritium	2.00E+11	1.47E+08	<1
Dounreay	Alpha[f,j]	1.37E+07	2.48E+04	<1
(East minor sources)[d,1]	Beta[f,g,k]	3.71E+08	1.33E+05	<1
(January to April 2014)[2]	Krypton-85[h]	1.00E+12	Nil	Nil
Dounreay	Alpha[f,j,k]	3.00E+05	4.68E+02	<1
(West minor sources)[d,1]	Beta[g,k]	7.50E+07	3.03E+03	<1
(January to April 2014)[2]	Tritium	1.00E+10	4.83E+07	1.4
Dounreay[d,1]	Alpha[s]	3.10E+07	4.55E+06	22
(May to December 2014)[2]	Non-alpha[t]	1.70E+09	8.06E+07	7.1
	Tritium	1.72E+13	3.24E+11	2.8
	Krypton-85	5.69E+14	2.79E+12	<1
	Iodine-129	1.08E+08	2.24E+07	31
Harwell				
(Research Sites Restoration Ltd)	Alpha	8.00E+05	2.00E+04	2.5
	Beta	2.00E+07	5.50E+05	2.8
	Tritium	1.50E+13	3.60E+11	2.4
	Krypton-85	2.00E+12	Nil	Nil
	Radon-220	1.00E+14	5.80E+12	5.8
	Radon-222	3.00E+12	2.40E+11	8.0
	Iodines	1.00E+10	Nil	Nil
	Other radionuclides	1.00E+11	Nil	Nil
Winfrith	Alpha	1.00E+05	Nil	Nil
(Inutec)	Tritium	1.95E+13	1.63E+11	<1
	Carbon-14	3.00E+10	Nil	Nil
	Other	1.00E+05	Nil	Nil
Winfrith	Alpha	2.00E+06	1.06E+03	<1
(Research Sites Restoration Ltd)	Tritium	5.00E+13	2.82E+11	<1
	Carbon-14	6.00E+09	2.39E+08	4.0
	Other	5.00E+06	1.58E+04	<1
Minor sites				
Imperial College Reactor Centre	Tritium	3.00E+08	8.86E+06	3.0
Ascot	Argon-41	1.70E+12	Nil	Nil
Nuclear power stations				
Berkeley[l]	Beta	2.00E+07	1.93E+05	1.0
	Tritium	2.00E+10	9.97E+09	50
	Carbon-14	5.00E+09	5.19E+08	10
Bradwell	Beta	6.00E+08	5.72E+05	<1
	Tritium	6.00E+12	2.78E+10	<1
	Carbon-14	9.00E+11	6.19E+08	<1
Chapelcross[3]	Tritium	2.30E+14	3.00E+13	13
	All other nuclides	5.15E+09	3.56E+08	6.9
Dungeness	Beta[f]	5.00E+08	2.92E+06	<1
A Station	Tritium	2.60E+12	1.12E+10	<1
	Carbon-14	5.00E+12	4.74E+08	<1
Dungeness	Tritium	1.20E+13	9.52E+11	7.9
B Station	Carbon-14	3.70E+12	8.08E+11	22
	Sulphur-35	3.00E+11	2.48E+10	8.3
	Argon-41	7.50E+13	8.90E+12	12
	Cobalt-60[f]	1.00E+08	3.05E+06	3.1
	Iodine-131	1.50E+09	2.77E+07	1.8

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Hartlepool	Tritium	1.00E+13	5.69E+11	5.7
	Carbon-14	4.50E+12	1.76E+12	39
	Sulphur-35	2.30E+11	1.16E+10	5.0
	Argon-41	1.50E+14	5.89E+12	3.9
	Cobalt-60[f]	1.00E+08	2.96E+07	30
	Iodine-131	1.50E+09	1.79E+08	12
Heysham Station 1	Tritium	1.00E+13	8.05E+11	8.0
	Carbon-14	4.50E+12	8.73E+11	19
	Sulphur-35	2.00E+11	2.15E+10	11
	Argon-41	1.50E+14	3.04E+12	2.0
	Cobalt-60[f]	1.00E+08	7.93E+06	7.9
	Iodine-131	1.50E+09	8.30E+07	5.5
Heysham Station 2	Tritium	1.00E+13	1.21E+12	12
	Carbon-14	3.70E+12	1.53E+12	41
	Sulphur-35	2.30E+11	9.46E+09	4.1
	Argon-41	7.50E+13	9.91E+12	13
	Cobalt-60[f]	1.00E+08	8.64E+06	8.6
	Iodine-131	1.50E+09	7.52E+07	5.0
Hinkley Point A Station	Beta	5.00E+07	2.00E+05	<1
	Tritium	7.50E+11	2.30E+10	3.1
	Carbon-14	5.00E+10	4.80E+08	1.0
Hinkley Point B Station	Tritium	1.20E+13	1.60E+12	13
	Carbon-14	3.70E+12	1.66E+12	45
	Sulphur-35	3.50E+11	7.10E+10	20
	Argon-41	1.00E+14	2.17E+13	22
	Cobalt-60[f]	1.00E+08	8.18E+06	8.2
	Iodine-131	1.50E+09	4.61E+06	<1
Hunterston A Station (January to June 2014)[4]	Beta[f]	6.00E+07	3.50E+05	<1
	Tritium	2.00E+10	4.00E+08	2.0
	Carbon-14	2.00E+09	3.60E+07	1.8
Hunterston A Station (July to December 2014)[4]	Tritium	2.00E+10	3.90E+08	2.0
	Carbon-14	2.00E+09	4.40E+07	2.2
	All other radionuclides	3.00E+06	4.10E+05	14
Hunterston B Station[d]	Particulate beta	5.00E+08	6.98E+07	14
	Tritium	1.50E+13	2.86E+12	19
	Carbon-14	4.50E+12	1.08E+12	24
	Sulphur-35	5.00E+11	7.03E+10	14
	Argon-41	1.50E+14	1.20E+13	8.0
	Iodine-131	2.00E+09	2.16E+06	<1
Oldbury[5]	Beta	1.00E+08	1.13E+06	1.1
	Tritium	9.00E+12	1.55E+11	1.7
	Carbon-14	4.00E+12	8.64E+09	<1
Sizewell A Station	Beta	8.50E+08	Nil	Nil
	Tritium	3.50E+12	2.54E+10	<1
	Carbon-14	1.00E+11	4.49E+09	4.5
Sizewell B Station	Noble gases	3.00E+13	3.07E+12	10
	Particulate Beta	1.00E+08	2.00E+06	2.0
	Tritium	3.00E+12	8.61E+11	29
	Carbon-14	5.00E+11	2.48E+11	50
	Iodine-131	5.00E+08	1.30E+07	2.6

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Torness	Particulate beta	4.00E+08	5.32E+06	1.3
	Tritium	1.10E+13	1.07E+12	9.7
	Carbon-14	4.50E+12	9.38E+11	21
	Sulphur-35	3.00E+11	3.56E+10	12
	Argon-41	7.50E+13	4.86E+12	6.5
	Iodine-131	2.00E+09	9.03E+06	<1
Trawsfynydd	Particulate Beta	5.00E+07	2.70E+06	5.4
	Tritium	3.75E+11	4.60E+10	12.3
	Carbon-14	1.00E+10	9.70E+08	9.7
Wylfa	Particulate Beta	7.00E+08	1.07E+07	1.5
	Tritium	1.80E+13	1.79E+12	9.9
	Carbon-14	2.30E+12	3.42E+11	15
	Sulphur-35	4.50E+11	4.51E+10	10
	Argon-41	1.00E+14	8.62E+12	8.6
Defence establishments				
Aldermaston[m]	Alpha	1.65E+05	2.64E+04	16
	Particulate Beta	6.00E+05	2.83E+03	<1
	Tritium	3.90E+13	3.60E+11	<1
	Carbon-14	6.00E+06	Nil	Nil
	Activation products[8]	NA	2.10E+05	NA
	Volatile beta	4.40E+06	2.80E+04	<1
Barrow[n]	Tritium	3.20E+06	Nil	Nil
	Argon-41	4.80E+10	Nil	Nil
Burghfield[m]	Tritium	1.00E+10	Nil	Nil
	Alpha	5.00E+03	1.38E+03	28
Coulport	Tritium	5.00E+10	6.69E+09	13
Derby[o,p]	Uranium[6]	3.00E+06	8.03E+05	26
	Alpha[f]	2.40E+04	4.20E+01	<1
	Beta[f]	1.80E+06	4.39E+04	2.4
Devonport[q]	Beta/gamma[f]	3.00E+05	4.06E+04	14
	Tritium	4.00E+09	8.30E+08	21
	Carbon-14	4.30E+10	1.14E+09	2.7
	Argon-41	1.50E+10	9.72E+06	<1
Dounreay[d]	Beta[f]	5.10E+06	1.00E+06	20
(Vulcan)	Noble gases	5.00E+09	6.50E+08	13
Rosyth[r]	Beta (particulate)	1.00E+05	Nil	Nil
	Tritium	2.00E+08	Nil	Nil
	Carbon-14	5.00E+08	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)[7]	Alpha	2.25E+06	3.40E+05	15
	Radionuclides T1/2<2hr	7.50E+11	2.82E+10	3.8
	Tritium	2.00E+12	1.08E+06	<1
	Radon-222	1.00E+13	2.13E+12	21
	Other including selenium-75 and iodine-131	1.60E+10	2.50E+06	<1
Cardiff (GE Healthcare)	Soluble tritium	1.56E+14	6.00E+11	<1
	Insoluble tritium	6.00E+14	4.90E+11	<1
	Carbon-14	2.38E+12	1.34E+11	5.6
	Phosphorus-32/33	5.00E+06	Nil	Nil
	Iodine-125	1.80E+08	Nil	Nil
	Other radionuclides	1.00E+09	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Industrial and landfill sites				
LLWR	Alpha	BAT	8.90E+03	NA
	Beta	BAT	5.97E+04	NA
Lillyhall (Studsvik)	Alpha (particulate)	5.00E+05	4.69E+03	<1
	Beta (particulate)	5.00E+05	1.87E+04	3.7

* *As reported to SEPA and the Environment Agency*
[a] *In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites*
[b] *Data quoted to 2 significant figures except where values are <1%*
[c] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*
[d] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection*
[e] *Excluding curium-242 and 244*
[f] *Particulate activity*
[g] *Excluding krypton-85*
[h] *Krypton-85 discharges are calculated monthly*
[i] *Data excludes any curium-243 present*
[j] *Excluding radon and daughter products*
[k] *Excluding tritium*
[l] *Combined data for Berkeley Power Station and Berkeley Centre*
[m] *Discharges were made by AWE plc*
[n] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[o] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[p] *Annual limits on beta and alpha derived from monthly and weekly notification levels*
[q] *Discharges were made by Devonport Royal Dockyard Ltd*
[r] *Discharges were made by Rosyth Royal Dockyard Ltd*
[s] *All alpha emitting radionuclides taken together*
[t] *All non-alpha emitting radionuclides, not specifically listed, taken together*
[1] *Discharge authorisation revised with effect from 24 April 2014*
[2] *Discharge authorisation active during this period (% of annual limit is calculated from the discharge and the discharge limit over the appropriate time period)*
[3] *Discharge permit revised with effect from 28 May 2013, sulphur-35 and argon-41 are no longer within the authorisation*
[4] *Discharge Authorisation revised with effect 1 July 2014*
[5] *Discharge permit revised with effect 1 May 2014, sulphur-35 and argon-41 are no longer in the permit*
[6] *Discharge permit revised with effect 1 November 2013*
[7] *Discharge permit revised with effect from September 2013, sulphur-35, iodine-125 and noble gases are no longer within the permit*
[8] *Argon-41 is reported under the Activation products total and the limit is the demonstration of Best Available Techniques*
NA Not applicable under permit
BAT Best available technology

Table A2.2. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2014

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst	Uranium	7.50E+08	2.82E+06	<1
(Urenco UK Ltd)	Uranium daughters	1.36E+09	5.98E+06	<1
(Rivacre Brook)	Non-uranic alpha	2.20E+08	1.13E+07	5.1
	Technetium-99	1.00E+09	2.74E+06	<1
Sellafield (sea pipelines)[c]	Alpha	1.00E+12	1.75E+11	18
	Beta	2.20E+14	9.75E+12	4.4
	Tritium	2.00E+16	1.35E+15	6.8
	Carbon-14	2.10E+13	5.35E+12	25
	Cobalt-60	3.60E+12	4.70E+10	1.3
	Strontium-90[2]	4.50E+13	1.63E+12	3.6
	Zirconium-95 + Niobium-95	2.80E+12	8.68E+10	3.1
	Technetium-99	1.00E+13	1.27E+12	13
	Ruthenium-106	5.10E+13	1.07E+12	2.1
	Iodine-129	2.00E+12	3.56E+11	18
	Caesium-134	1.60E+12	5.54E+10	3.5
	Caesium-137	3.40E+13	2.65E+12	7.8
	Cerium-144	4.00E+12	1.55E+11	3.9
	Neptunium-237	7.30E+11	3.51E+10	4.8
	Plutonium alpha	7.00E+11	1.51E+11	22
	Plutonium-241	2.50E+13	2.93E+12	12
	Americium-241	3.00E+11	2.15E+10	7.2
	Curium-243+244	5.00E+10	1.78E+09	3.6
	Uranium[d]	2.00E+03	3.60E+02	18
Sellafield (factory sewer)	Alpha	3.00E+08	6.04E+07	20
	Beta	6.10E+09	1.70E+09	28
	Tritium	6.80E+10	4.62E+09	6.8
Springfields	Alpha	1.00E+11	1.44E+10	14
	Beta	2.00E+13	2.94E+12	15
	Technetium-99	6.00E+11	1.78E+10	3.0
	Thorium-230	2.00E+10	2.08E+09	10
	Thorium-232	1.50E+10	1.46E+08	<1
	Neptunium-237	4.00E+10	1.99E+09	5.0
	Other transuranic radionuclides	2.00E+10	1.53E+09	7.6
	Uranium	4.00E+10	1.04E+10	26
Research establishments				
Dounreay	Alpha[f]	2.00E+10	Nil	Nil
PFR liquid metal disposal plant[e,1]	Beta[g]	1.10E+11	Nil	Nil
(January to April 2014)[2]	Tritium	1.40E+12	Nil	Nil
	Sodium-22	1.80E+12	Nil	Nil
	Caesium-137	6.60E+10	Nil	Nil
Dounreay	Alpha[f]	9.00E+10	1.22E+08	0.4
Other facilities[e,1]	Beta[h]	6.20E+11	9.43E+07	0.0
(January to April 2014)[2]	Tritium	5.50E+12	1.74E+10	0.9
	Strontium-90	7.70E+11	9.22E+09	3.6
	Caesium-137	1.00E+12	9.20E+08	0.3
Dounreay[e,1]	Alpha[u]	3.40E+09	1.80E+08	7.9
(May to December 2014)[2]	Non-alpha[v]	4.80E+10	9.82E+08	3.1
	Tritium	6.90E+12	3.55E+10	<1
	Strontium-90	1.77E+11	1.85E+10	16
	Caesium-137	6.29E+11	1.70E+09	<1
Harwell (Lydebank Brook)	Alpha	3.00E+07	9.76E+06	33
	Beta	3.00E+08	1.36E+08	45
	Tritium	2.00E+10	3.98E+09	20

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Harwell (sewer)	Alpha	1.00E+07	7.15E+05	7.2
	Beta	6.00E+08	8.39E+07	14
	Tritium	1.00E+11	6.12E+08	<1
	Cobalt-60	5.00E+06	1.64E+06	33
	Caesium-137	2.00E+08	3.50E+07	17
Winfrith (inner pipeline)[i]	Alpha	2.00E+10	1.64E+07	<1
	Tritium	2.20E+14	2.03E+12	<1
	Caesium-137	2.00E+12	1.73E+09	<1
	Other radionuclides	1.00E+12	5.55E+09	<1
Winfrith (outer pipeline)	Alpha	2.00E+09	5.43E+06	<1
	Tritium	1.50E+11	4.94E+08	<1
	Other radionuclides	1.00E+09	2.34E+07	2.3
Winfrith (River Frome)	Tritium	7.50E+11	Nil	Nil
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	4.00E+07	Nil	Nil
	Other radioactivity	1.00E+06	Nil	Nil
Nuclear power stations				
Berkeley	Tritium	1.00E+12	3.73E+08	<1
	Caesium-137	2.00E+11	2.39E+09	1.2
	Other radionuclides	2.00E+11	4.45E+08	<1
Bradwell	Tritium	7.00E+12	2.48E+09	<1
	Caesium-137	7.00E+11	3.80E+08	<1
	Other radionuclides	7.00E+11	3.13E+09	<1
Chapelcross[3]	Alpha	1.00E+09	2.02E+06	<1
	Non-alpha[j]	1.00E+12	1.52E+09	<1
	Tritium	6.50E+12	1.81E+09	<1
Dungeness A Station	Tritium	8.00E+12	5.13E+10	<1
	Caesium-137	1.10E+12	1.14E+10	1.0
	Other radionuclides	8.00E+11	4.55E+09	<1
Dungeness B Station	Tritium	6.50E+14	1.54E+14	24
	Sulphur-35	2.00E+12	1.81E+11	9.1
	Cobalt-60	1.00E+10	3.16E+08	3.2
	Caesium-137	1.00E+11	1.40E+09	1.4
	Other radionuclides	8.00E+10	2.06E+09	2.6
Hartlepool	Tritium	6.50E+14	2.38E+14	37
	Sulphur-35	3.00E+12	1.03E+12	34
	Cobalt-60	1.00E+10	2.40E+08	2.4
	Caesium-137	1.00E+11	1.84E+09	1.8
	Other radionuclides	8.00E+10	3.86E+08	<1
Heysham Station 1	Tritium	6.50E+14	1.69E+14	26
	Sulphur-35	2.00E+12	1.72E+11	8.6
	Cobalt-60	1.00E+10	1.44E+08	1.4
	Caesium-137	1.00E+11	1.00E+09	1.0
	Other radionuclides	8.00E+10	2.89E+09	3.6
Heysham Station 2	Tritium	6.50E+14	4.23E+14	65
	Sulphur-35	2.00E+12	4.03E+10	2.0
	Cobalt-60	1.00E+10	5.74E+07	<1
	Caesium-137	1.00E+11	3.02E+09	3.0
	Other radionuclides	8.00E+10	1.36E+10	17
Hinkley Point A Station	Tritium	1.00E+12	4.90E+10	4.9
	Caesium-137	1.00E+12	5.15E+10	5.1
	Other radionuclides	7.00E+11	1.43E+11	20

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Hinkley Point B Station	Tritium	6.50E+14	2.78E+14	43
	Sulphur-35	2.00E+12	4.41E+11	22
	Cobalt-60	1.00E+10	2.45E+08	2.5
	Caesium-137	1.00E+11	9.77E+08	1.0
	Other radionuclides	8.00E+10	4.97E+09	6.2
Hunterston A Station (January to June 2014)[4]	Alpha	4.00E+10	3.80E+08	<1
	Beta	6.00E+11	1.65E+09	<1
	Tritium	7.00E+11	5.60E+08	<1
	Plutonium-241	1.00E+12	9.90E+07	<1
Hunterston A Station (July to December 2014)[4]	Alpha	2.00E+09	3.10E+07	1.6
	All other non-alpha	6.00E+10	2.40E+08	<1
	Tritium	3.00E+10	6.80E+07	<1
	Caesium-137	1.60E+11	1.30E+08	<1
	Plutonium-241	2.00E+09	2.10E+07	1.1
Hunterston B Station	Alpha	1.00E+09	2.67E+07	2.7
	All other non-alpha	1.50E+11	8.17E+09	5.4
	Tritium	7.00E+14	2.79E+14	40
	Sulphur-35	6.00E+12	6.90E+11	12
	Cobalt-60	1.00E+10	3.80E+08	3.8
Oldbury	Tritium	1.00E+12	1.68E+11	17
	Caesium-137	7.00E+11	1.18E+11	17
	Other radionuclides	7.00E+11	8.39E+10	12
Sizewell A Station	Tritium	5.00E+12	5.10E+10	1.0
	Caesium-137	1.00E+12	1.78E+11	18
	Other radionuclides	7.00E+11	4.79E+10	6.8
Sizewell B Station	Tritium	8.00E+13	6.20E+13	78
	Caesium-137	2.00E+10	1.00E+09	5.0
	Other radionuclides	1.30E+11	1.10E+10	8.5
Torness	Alpha	5.00E+08	2.69E+06	<1
	All other non-alpha	1.50E+11	2.92E+09	1.9
	Tritium	7.00E+14	2.93E+14	42
	Sulphur-35	3.00E+12	8.89E+11	30
	Cobalt-60	1.00E+10	3.47E+08	3.5
Trawsfynydd	Tritium	3.00E+11	1.77E+10	5.9
	Caesium-137	1.50E+10	5.00E+08	3.3
	Other radionuclides[k]	3.00E+10	4.11E+09	14
Wylfa	Tritium	1.50E+13	2.58E+12	17
	Other radionuclides	1.10E+11	5.75E+09	5.2
Defence establishments				
Aldermaston (Silchester)[l]	Alpha	1.00E+07	2.16E+06	22
	Other beta emitting radionuclides	2.00E+07	2.82E+06	14
	Tritium	2.50E+10	1.40E+08	<1
Aldermaston (to Stream)[m, l]	Tritium	NA	5.30E+08	NA
Barrow[n]	Tritium	1.20E+10	Nil	Nil
	Carbon-14	2.70E+07	Nil	Nil
	Other gamma emitting radionuclides	3.50E+06	Nil	Nil
Derby[o]	Alpha[p]	2.00E+09	4.86E+07	2.4
	Alpha[q]	3.00E+05	4.17E+04	14
	Beta[q]	3.00E+08	1.21E+06	<1
Devonport (sewer)[r]	Tritium	2.00E+09	6.89E+07	3.4
	Cobalt-60	3.50E+08	3.93E+06	1.1
	Other radionuclides	6.50E+08	1.52E+08	23

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a], Bq	Discharges during 2014	
			Bq	% of annual limit[b]
Devonport (estuary)[r]	Tritium	7.00E+11	2.24E+10	3.2
	Carbon-14	1.70E+09	1.12E+08	6.6
	Cobalt-60	8.00E+08	2.12E+07	2.7
	Other radionuclides	3.00E+08	2.71E+07	9.0
Faslane	Alpha	2.00E+08	2.30E+04	<1
	Beta[s,j]	5.00E+08	2.50E+05	<1
	Tritium	1.00E+12	3.81E+09	<1
	Cobalt-60	5.00E+08	1.20E+05	<1
Rosyth[t]	Tritium	3.00E+09	8.78E+06	<1
	Cobalt-60	3.00E+08	1.63E+06	<1
	Other radionuclides	3.00E+08	1.25E+06	<1
Radiochemical production				
Amersham (GE Healthcare)[s,5]	Alpha	3.00E+08	3.98E+06	1.3
	Tritium	1.41E+11	1.30E+06	<1
	Other radionuclides	6.50E+10	4.23E+08	<1
Cardiff (GE Healthcare)	Tritium	1.30E+14	1.91E+09	<1
	Carbon-14	9.10E+11	9.51E+08	<1
	Phosphorus-32/33	8.50E+07	Nil	Nil
	Iodine-125	3.00E+08	Nil	Nil
	Others	1.20E+08	Nil	Nil
Industrial and landfill sites				
LLWR	Alpha	BAT	8.04E+07	NA
	Beta	BAT	1.08E+09	NA
	Tritium	BAT	8.76E+10	NA
Lillyhall (Studsvik)	Alpha	5.00E+05	1.20E+03	<1
	Beta	5.00E+05	1.03E+04	2.1

[a] *In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[d] *The limit and discharge data are expressed in kg*
[e] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 2 decimal places*
[f] *All alpha emitting radionuclides taken together*
[g] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[h] *All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together*
[i] *Discharges reported include those from INUTEC*
[j] *Excluding tritium*
[k] *Including strontium*
[l] *Discharges were made by AWE plc*
[m] *The discharge limit has been replaced by an activity notification level of 30 Bq l^{-1}*
[n] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[o] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[p] *Discharge limit is for Nuclear Fuel Production Plant*
[q] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[r] *Discharges were made by Devonport Royal Dockyard Ltd*
[s] *Excluding cobalt-60*
[t] *Discharges were made by Rosyth Royal Dockyard Ltd*
[u] *All alpha emitting radionuclides taken together*
[v] *All non-alpha emitting radionuclides, not specifically listed, taken together*
[1] *Discharge authorisation revised with effect from 24 April 2014*
[2] *Discharge authorisation active during this period (% of annual limit is calculated from the discharge and the discharge limit over the appropriate time period)*
[3] *Discharge authorisation revised with effect from 28 May 2013*
[4] *Discharge authorisation revised with effect from 1 July 2014*
[5] *Discharge permit revised with effect from September 2013, iodine-125 and caesium-137 are no longer within the permit*

NA Not applicable under permit
BAT Best available technology

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2014

Establishment	Radioactivity	Disposal limit	Disposals during 2014	
		Bq	Bq	% of limit[a]
LLWR[b]	Tritium	1.00E+13	Nil	Nil
	Carbon-14	5.00E+10	Nil	Nil
	Cobalt-60	2.00E+12	Nil	Nil
	Iodine-129	5.00E+10	Nil	Nil
	Radium-226 plus thorium-232	3.00E+10	Nil	Nil
	Uranium	3.00E+11	Nil	Nil
	Other alpha[c]	3.00E+11	Nil	Nil
	Others[c,d]	1.50E+13	Nil	Nil
Dounreay[e]	Alpha		Nil	NA
	Beta/gamma		Nil	NA

[a] *Data quoted to 2 significant figures except where values are less than 1%*
[b] *Under current planning permission at the LLWR near to Drigg, certain wastes are temporarily stored, as opposed to being disposed, pending disposal/storage elsewhere or permission for disposal in-situ*
[c] *With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232*
[d] *Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table*
[e] *The current authorisation includes limits on concentrations of activity. At no time did the concentrations exceed the limits*
NA Not applicable

Table A2.4. Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2014

Site	Month	Summary of incident	Consequences and action taken
Chapelcross	June 2014	The operator contacted SEPA regarding an unscheduled increase in gaseous tritium discharges from a number of outlets which discharge at a height higher than 5 metres above ground level. This excludes the Chapelcross Processing Plant stack.	The authorised limit for this discharge route is 50 GBq of gaseous tritium and this is a sub-limit of the total site limit for gaseous discharge of tritium which is 750,000 GBq. The operator contacted SEPA in September 2014 to report that they have exceeded the sub-limit. On the basis of the activity of the sub-limit compared to the site limit, SEPA is confident that this increase does not present an impact on the public or the environment. The source of the increase in tritium discharges was identified as a number of Temporary Storage Vessels which contain tritiated pellet waste. The site has undertaken action to contain the tritium and reduce the associated discharges to the environment. The site has since reported a downward trend in discharges via the stacks at a height higher than 5 metres above ground level.
Dounreay	March 2014	DSRL notified SEPA about a potential issue in relation to gaseous discharges arising from fuel repackaging work that was being undertaken in the Prototype Fast Reactor (PFR) facility. It was believed that a fuel can that was being stored within a pond had been damaged and there was a potential loss of radionuclides into the pond water and for gaseous discharges of krypton-85 and tritium to have taken place from the facility's authorised discharge stack.	During the interim period between the initial releases of gas from the fuel can (in March) and the removal of the fuel can from the pond (in June) small increases in radiation readings above the pond occurred, indicative of further releases of gas from the fuel can. This indicated that the gaseous discharges from the fuel can did not all occur within the month of March and as a result DSRL considered it was appropriate to assign a portion of the discharges to several months. Based on DSRL's information on the maximum activity of krypton-85 and tritium present within the fuel can and the allocation of these discharges, the reported discharges of tritium in May and June exceeded a sub-limit for gaseous disposals from the site. The assessed tritium discharges arising from the fuel can are well below the annual authorised site limit. On the basis of the sub-limit compared to the actual authorised site limit and the risk assessments made against the authorised limits, SEPA is confident that there is no risk to the public or the environment. SEPA wrote to DSRL to request that DSRL undertake a detailed review of the site's arrangements for the sampling of authorised discharges.
Dounreay	April 2014	DSRL notified SEPA about a small spill of bund water (approx. 250 ml) to the non-active drainage system.	Sample analysis of the water indicated the presence of very low levels of activity. The radiological consequences are also considered to be very low. As a result SEPA undertook inspections of DSRL's arrangements for the consignment of wastes into the non-active drainage system. The inspections identified some shortcomings in DSRL's processes and arrangements and as a result DSRL produced a Forward Action Plan which has been incorporated into DSRL's Environmental Improvement Programme.
Dounreay	July 2014	DSRL notified SEPA of the detection of a small quantity of radioactivity in a sample of sludge.	The sample was taken from a manhole within a foul drain system, outwith and upstream of the Dounreay site. Subsequent analysis work was undertaken which demonstrated that the radioactivity detected in the sludge is due to naturally occurring radionuclides and is not associated with Dounreay site activities.
Dounreay	October 2014	DSRL notified SEPA about a fire that occurred in the Sodium Tank Farm building at the PFR facility.	SEPA investigated the circumstances surrounding the decommissioning work that was being undertaken at the time in the tank farm. Having looked at the highest estimate of the amount of tritium released, and the environmental monitoring results, the environmental impact is considered to be very low. However, SEPA's investigation identified failings in the arrangements in place for ensuring radioactive gaseous waste was disposed of in accordance with DSRL's authorisation and identified a number of non-compliances with the conditions contained in DSRL's authorisation. As a result (in December), SEPA issued a Notice of Variation to the authorisation to include the requirement for DSRL to undertake a range of improvements within the authorisation. These improvements relate to the design and testing of temporary containment and ventilation systems and to the management and supervision of decommissioning activities.
Hinkley Point A	March 2014	A small quantity (<1 litre) of sludge supernatant leaked from a broken pipe into a containment trench within the fuel pond building. The containment trench did not hold the liquid and it migrated through the building structure and leaked to ground outside the building.	The release was quickly identified and the liquid contained and remediated. No liquid entered the local drains and the impact to the environment was insignificant. A Warning Letter was issued to the site and a number of actions were undertaken by the site as a result of this. These actions included: adding secondary containment to the pipe which had originally broken, a site review of other potentially vulnerable assets and maintenance requirements, repairs to the trench, etc.

Table A2.4. continued

Site	Month	Summary of incident	Consequences and action taken
Sellafield	March 2014	Failure of the Fuel Handling Plant Pond Hall extract fan gaiters led to the discharge of aerial effluent from a release point other than the permitted stack outlet.	Any release via the non-permitted route had the potential of causing only a minor environmental effect. A Warning Letter was served for three breaches of the Environmental Permit. Recommendations were placed to ensure future compliance.
Sellafield	August 2014	Bolted flange on a by-pass duct dripping active condensate.	Any release via the non permitted route is considered to have been minor. We have reviewed the circumstances surrounding this event and provided regulatory advice.
Winfrith	December 2014	On 2nd December 2014, a failure of a component in the final valve housing of the Winfrith sea pipeline resulted in a loss of very dilute effluent from the pipeline onto the foreshore at Arish Mell, Dorset. The pipeline would normally discharge from the Valve House to an outfall beyond the mean low water springs limit. The investigation identified a failure in an air release valve which led to the flooding of an inspection pit within the building which overflowed resulting in the release of effluent.	Approximately 75 cubic metres of dilute site effluent was discharged from the Valve House building, some of which escaped from the building onto surrounding land and foreshore. RSRL were able to recover a proportion of the effluent that was retained within the building sump. Radiological monitoring of the area of the leak conducted by RSRL found no radiological contamination. The concentrations of radioactivity in the effluent released were below the World Health Organisation's (WHO) drinking water limits. There was no identified environmental consequence and no persistent land contamination. There was little potential for public contact with the effluent as the area affected lies within an operational MoD firing range and is subject to public access restrictions. RSRL conducted an internal review and have improved asset management procedures and staff training arrangements.

APPENDIX 3. Abbreviations and glossary

ABL	AWE plc, Babcock and Lockheed Martin UK
ABWR	Advanced Boiling Water Reactor
AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques or Best Available Technology
BNFL	British Nuclear Fuels plc
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
BSS	Basic Safety Standards
CCFE	Culham Centre for Fusion Energy
CEC	Commission of the European Communities
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
CNLS	Cardiff Nuclear Licensed Site
CNS	Capenhurst Nuclear Services Limited
COMRE	Committee on Medical Aspects of Radiation in the Environment
COS	Carbonyl Sulphide
CoRWM	Committee on Radioactive Waste Management
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DH	Department of Health
DPAG	Dounreay Particles Advisory Group
DSRL	Dounreay Site Restoration Limited
DSTL	Defence Science and Technology Laboratory
Euratom	European Atomic Energy Community
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EDF	Electricité de France
EPR 10	Environment Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
ESC	Environmental Safety Case
ESG	Environmental Scientifics Group
EU	European Union
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
FSS	Food Standards Scotland
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GDL	Generalised Derived Limit
GE	General Electric
GES	Good Environmental Status
GOCO	Government Owned Contractor Operator
HMIP	Her Majesty's Inspectorate of Pollution
HMNB	Her Majesty's Naval Base
HMSO	Her Majesty's Stationery Office
HPA	Health Protection Agency
HSE	Health & Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILW (FED)	Intermediate Level Waste (Fuel Element Debris)
IRPA	International Radiation Protection Association
ISO	International Standards Organisation
JET	Joint European Torus
LGC	Laboratory of the Government Chemist
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LoD	Limit of Detection
MAC	Medium Active Concentrate
MAFF	Ministry of Agriculture, Fisheries & Food
MCAA	Marine and Coastal Act 2009
MMO	Marine Management Organisation
MoD	Ministry of Defence
MRF	Metals Recycling Facility
MRL	Minimum Reporting Level
MRWS	Managing Radioactive Waste Safely
ND	Not Detected
NDA	Nuclear Decommissioning Authority
NFPP	Nuclear Fuel Production Plant
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NMP	Nuclear Management Partners Limited
NNB Genco	NNB Generation Company Limited
NORM	Naturally Occurring Radioactive Material
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
NPS	National Policy Statement
NRTE	Naval Reactor Test Establishment
OBT	Organically Bound Tritium
OECD	Organisation for Economic Co-operation and Development
OMAD	Old Main Active Drain
ONR	Office for Nuclear Regulation
OSPAR	Oslo and Paris Convention
PBO	Parent Body Organisation
PRAG (D)	Particles Retrieval Advisory Group (Dounreay)
PHE	Public Health England
PWR	Pressurised Water Reactor
RAPs	Reference Animals and Plants
REP	RSR Environmental Principle
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Limited
RRMPOL	Rolls-Royce Marine Power Operations Limited
RNAS	Royal Naval Air Station

RSA 93	Radioactive Substances Act 1993
RSR	Radioactive Substances Regulation
RSRL	Research Sites Restoration Limited
RSS	Radioactive Substances Strategy
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Limited
SIXEP	Site Ion Exchange Plant
SLC	Site Licence Company
SRP	Society for Radiological Protection
STW	Sewage Treatment Works
SWIMMER	Sustainable Water Integrated Management and Ecosystem Research
THORP	Thermal Oxide Reprocessing Plant
TNORM	Technologically enhanced Naturally Occurring Radioactive Material
TRAMP	Terrestrial Radioactive Monitoring Programme
UCP	Urenco ChemPlants Limited
UKAEA	United Kingdom Atomic Energy Authority
UKNWM	UK Nuclear Waste Management Limited
UOC	Uranium Ore Concentrate
UUK	Urenco UK Limited
VLLW	Very Low Level Waste
WFD	Water Framework Directive
WHO	World Health Organisation
WWTW	Waste Water Treatment Works
YP	Ystradyfodwg and Pontypridd

Absorbed dose	The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J kg^{-1}.
Authorised Premises	This is a premises that has been authorised by the environment agencies to discharge to the environment.
Becquerel	One radioactive transformation per second.
Bioaccumulation	Excretion may occur, however the rate of excretion is less than the rate of intake + accumulation.
Biota	Flora and fauna.
Committed effective dose	The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.
Direct shine	Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.
Dose	Shortened form of 'effective dose' or 'absorbed dose'.
Dose limits	Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv per year for the UK.
Dose rates	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the sievert (Sv).
Environmental materials	Environmental materials include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.
Equivalent dose	The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the sievert (Sv).

External dose	Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.
Fragments	'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.
Generalised Derived Limit	A convenient reference level against which the results of environmental monitoring can be compared. GDLs are calculated using deliberately cautious assumptions and are based on the assumption that the level of environmental contamination is uniform over the year. GDLs relate the concentrations of a single radionuclide in a single environmental material to the dose limit for members of the public.
Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the food chain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Millisievert	The millisievert is a 1/1000 of a sievert. A sievert is one of the International System of Units used for the measurement of dose equivalent.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative person	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
TNORM	Naturally occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue weighting factors	Factor used to weight the equivalent dose in a tissue or organ to takes account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01.
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation.

APPENDIX 4. Research in support of the monitoring programmes

FSA and the environment agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

- To evaluate the significance of potential sources of radionuclide contamination of the food chain and the environment
- To identify and investigate specific topics or pathways not currently addressed by the routine monitoring programmes and the need for their inclusion in future routine monitoring
- To develop and maintain site-specific habit and agricultural practice data, in order to improve the realism of dose assessment calculations
- To develop more sensitive and/or efficient analytical techniques for measurement of radionuclides in natural matrices
- To evaluate the competence of laboratories' radiochemical analytical techniques for specific radionuclides in food and environmental materials
- To develop improved methods for handling and processing monitoring data

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (for example, Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002b). A review of research funded by FSA was published in 2004 (FSA, 2004).

Information on recently completed extramural research is presented in Table A4.1. Those sponsored by the Environment Agency and FSA are also listed on their websites (www.environment-agency.gov.uk, www.food.gov.uk, respectively). Copies of the final reports for each of the projects funded by the FSA are available from Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by SEPA and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.environment-agency.gov.uk. A charge may be made to cover costs.

Table A4.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Soil and herbage survey	UKRSR01 and SCO00027	E, S	In press
Measurement of radioactivity in canteen meals for Euratom (2005-2013)	R03025	F	In press

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

Environment Agency
Monitoring Assessment and New Reactor Permitting Nuclear Regulation (North)
Lutra House, Off Seedlee Road, Walton Summit, Bamber Bridge, Preston PR5 8BX

Food Standards Agency
Chemical Safety Division
Aviation House, 125 Kingsway, London WC2B 6NH

Food Standards Scotland
4th Floor, Pilgrim House,
Old Ford Road, Aberdeen, AB11 5RL

Cyfoeth Naturiol Cymru / Natural Resources Wales
Ty Cambria, 29 Newport Road, Cardiff CF29 0TP

Northern Ireland Environment Agency
Industrial Pollution and Radiochemical Inspectorate
Klondyke Building, Cromac Avenue, Lower Ormeau Road, Belfast BT7 2JA

Scottish Environment Protection Agency
Radioactive Substances Unit
Strathallan House, Castle Business Park, Stirling FK9 4TZ

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