RIFE - 16

Radioactivity in Food and the Environment, 2010

Environment Agency

Food Standards Agency
food.gov.uk

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

SEPA Scottish Environment Protection Agency

2011

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

Radioactivity in Food and the Environment, 2010

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October 2011

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

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Preface

April 2011 marked the 25th anniversary of the Chernobyl accident. The results of the monitoring programmes given in this report continue to show the effects from this accident, albeit now at much lower concentrations. As a result, the risks in the UK from the aftermath of Chernobyl have also reduced substantially. There are still controls in place for some farms in upland areas but the requirement for these controls is under review.

The deposition from the Chernobyl accident was the last significant deposition of radionuclides in the UK. In 2011, minute quantities of radioactive material from the accident at the Fukushima-Daiichi nuclear power station in Japan reached the UK. The Environment Agency (EA), Northern Ireland Environment Agency (NIEA) and the Scottish Environment Protection Agency (SEPA) (collectively referred to as environment agencies in this report) and the Food Standards Agency were able to show this was the case by direct monitoring of air, rain and food in the UK made possible by using the established routine monitoring programmes. Updates of monitoring results were hosted on the Health Protection Agency and the Food Standards Agency website. Additionally, the results of monitoring in Scotland are provided in a single report which is available on the SEPA website. All the UK monitoring data will be published in RIFE -17.

The continuation of our routine monitoring programmes allow us to demonstrate that radioactivity in food is well within safe levels, and the exposure of members of the public from authorised discharges and direct radiation around the 39 nuclear sites in the UK has remained within legal limits. The data from the programmes will also act as a baseline against which future discharges from any new or existing nuclear power stations can be judged. It is important that the structure and content of both our and site operators programmes remain fit for purpose and be flexible enough to adjust for new demands. To this end, in 2010, the EA, Food Standards Agency and SEPA published their Environmental Monitoring Guidance document for radioactivity. This sets out guidance on planning and implementing environmental radiological monitoring programmes as well as objectives and principles to consider when designing such programmes.

This report is for sampling conducted in 2010 and is the product of collaboration between the environment agencies and the Food Standards Agency. The monitoring programmes conducted by these agencies are independent of, and also used as a check on, the site operators' programmes. The Food Standards Agency is responsible for food safety in the UK whilst the environment agencies are responsible for environmental protection and regulation in their respective countries.

Technical summary

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

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

Radiation exposure around nuclear sites

This report uses the results of monitoring of radioactivity in food and the environment near nuclear sites to make an assessment of doses to the public. Monitoring results are supplemented by modelling where appropriate. The assessments use radionuclide concentrations, dose rates and information on the habits of people living near the sites. Changes in the doses received by people can occur from year to year and are mostly caused by variations in radionuclide concentrations and dose rates. However, in some years doses are affected by changes in people's habits, in particular the food they eat, which is reported in habits surveys. The dose quantity presented in this summary is known as the 'total dose' and is made up of contributions from all sources. This year's report places more emphasis on *total dose* than previous reports which have also detailed source specific doses. This is because *total dose* provides a more definitive measure of exposure for comparison with dose limits. Source specific dose assessments were also performed in some case as a check on the *total dose* assessment method. *Total dose* was confirmed as a robust measure of exposure.

Figure S and Table S show the assessed *total doses* due to the effects of authorised waste discharges and direct radiation for those people most exposed to radiation near all major nuclear licensed sites in the UK. In 2010, radiation doses from permitted (authorised) releases of radioactivity, to adults and children living around nuclear sites, remained well below the national and European limit of 1 millisievert (mSv, a measure of dose) per year (see Appendix 3 for explanation of reference to dose).

This year, those sites receiving the highest doses changed from those reported in previous years. This change is due to the choice of *total dose* as the primary dose quantity. Capenhurst, Amersham and Sellafield doses were 0.26, 0.22 and 0.18 mSv, respectively. With the exception of Sellafield, the dose was largely determined by direct radiation from sources on the sites. Permitted discharges were the source of most of the dose at the Sellafield site. A small number of people in Cumbria who consumed a large amount of molluscan shellfish represented those who received the highest dose of radiation there. Their dose was estimated to be 0.18 mSv in 2010, which was well within the EU and UK limit for members of the public of 1 mSv per year. This dose included the effects of current and past liquid discharges from Sellafield and from past liquid discharges from a phosphate processing plant at Whitehaven. Sellafield discharges were estimated to have contributed 0.14 mSv to this dose in 2010, a reduction of 0.01 mSv from the 0.15 mSv reported in 2009 (this contribution includes a dose from external radiation). Most of the dose at Sellafield was due to the accumulation of caesium-137, plutonium isotopes and americium-241 in seafood and the environment from past liquid discharges. The reduction in dose due to Sellafield discharges was largely due to the reduction in mollusc consumption rates. Doses from technetium-99 have been falling for several years as a result of decreasing discharges from Sellafield. In 2010, technetium-99 in seafood contributed 0.001 mSv (about 1 per cent) to the 0.14 mSv dose.

Most liquid radioactive discharges from Sellafield have fallen in recent years. Concentrations of some radionuclides in fish and shellfish have also reduced or are unchanged. Some people in the area have consumed more fish and shellfish since 2000, which has led to an increase in doses, but this trend was not seen in 2010.

As well as the radiation exposure from Sellafield discharges, the people who consumed seafood also received a dose of 0.047 mSv in 2010 from the legacy of past discharges from a phosphate processing works at Whitehaven (which was decommissioned in 2002). This was a man-made practice that generated what is sometimes known as 'technologically enhanced naturally-occurring radioactive material' (TNORM). Where discharges of TNORM occur, this can lead to an increase in the concentrations of naturally-occurring radionuclides in the environment. Near Whitehaven, concentrations of TNORM have fallen in recent years, and so it is now difficult to distinguish between the total naturally-occurring radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. However, using an approach based on average concentrations, small increases of some naturally-occurring radionuclides (in particular polonium-210) are observed above expected concentrations from naturally sourced radioactivity. The dose from naturally-occurring radionuclides in 2010 was 0.047 mSv, and this was much lower than the dose of 0.14 mSv in 2009. The reduction was largely due to decreases in polonium-210 concentrations in seafood in 2010, though changes in consumption rates also had an effect.

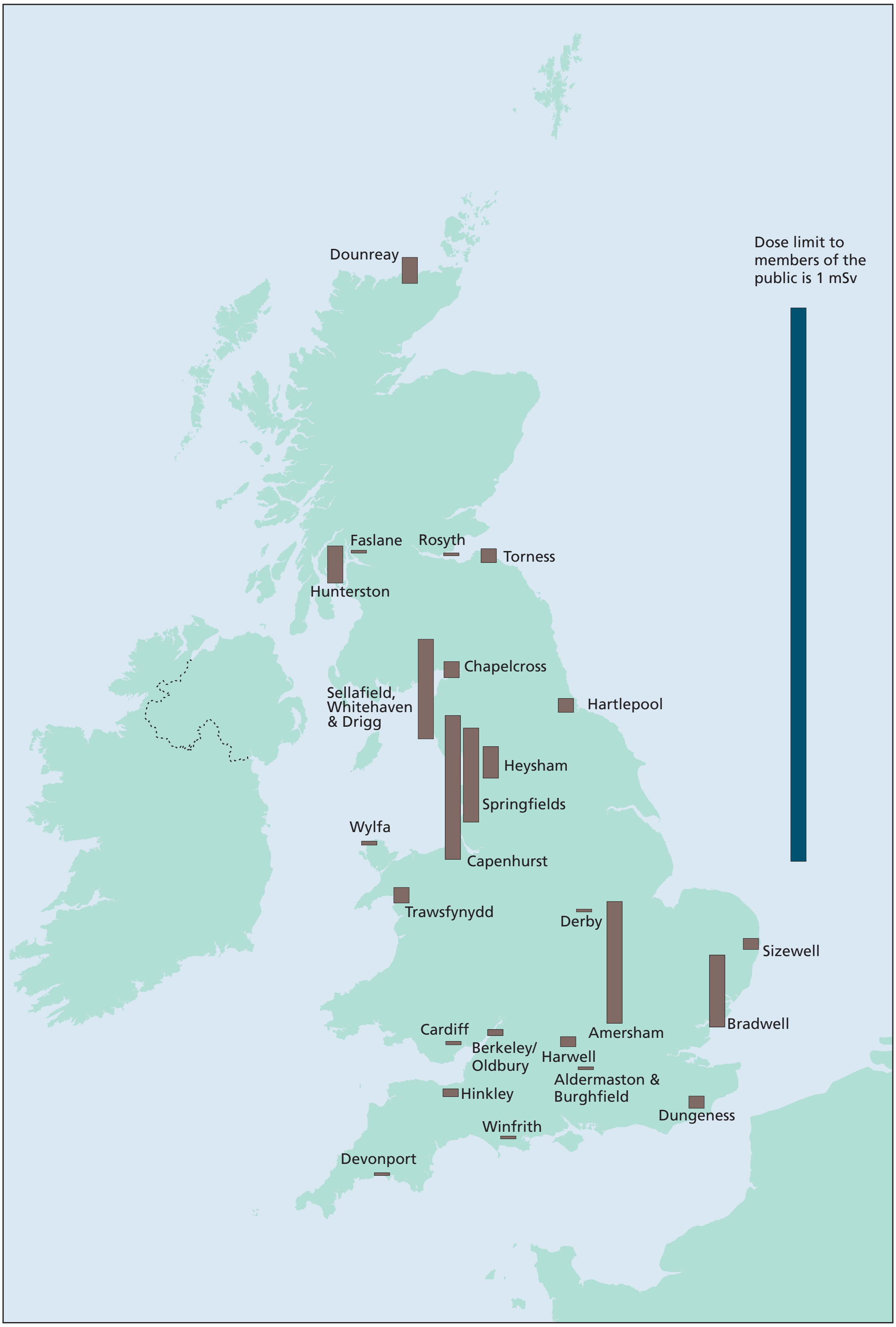


Figure S. Total radiation exposures in the UK due to radioactive waste discharges and direct radiation, 2010 (Exposures at Sellafield, Whitehaven and Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Summary Table S. Radiation doses due to all sources at major UK sites, 2010[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.26	Direct radiation
Springfields	0.17	Gamma dose rate over sediment
Sellafield[d]	0.18	Crustaceans, fish, molluscs, ^{210}Po, $^{239/240}Pu$, ^{241}Am
Research establishments		
Dounreay	0.047	Game meat, ^{137}Cs
Harwell	0.018	Direct radiation
Winfrith	<0.005	Gamma dose rate over sediment
Nuclear power stations		
Berkeley and Oldbury	0.011	Direct radiation, external and inhalation close to site
Bradwell	0.13	Direct radiation
Chapelcross	0.029	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Dungeness	0.022	Direct radiation
Hartlepool	0.025	Direct radiation, gamma dose rate over sediment
Heysham	0.057	Gamma dose rate over sediment
Hinkley Point	0.014	Gamma dose rate over sediment
Hunterston	0.067	Direct radiation
Sizewell	0.020	Direct radiation
Torness	0.025	Direct radiation, ^{241}Am
Trawsfynydd	0.028	Direct radiation
Wylfa	0.007	Fish, gamma dose rate over sediment, ^{137}Cs
Defence establishment		
Aldermaston and Burghfield	<0.005	Gamma dose rate over riverbank
Derby	<0.005	Water, ^{60}Co
Devonport	<0.005	Gamma dose rate over sediment
Faslane	<0.005	Gamma dose rate over mud
Rosyth	<0.005	Gamma dose rate over sediment
Radiochemical production		
Amersham	0.22	Direct radiation
Cardiff	0.006	Gamma dose rate over sediment, fish, ^{3}H
Industrial and landfill		
LLWR near Drigg[d]	0.18	Crustaceans, fish, molluscs, ^{210}Po, $^{239/240}Pu$, ^{241}Am
Whitehaven[d]	0.18	Crustaceans, fish, molluscs, ^{210}Po, $^{239/240}Pu$, ^{241}Am

[a] *Includes the effects of waste discharges and direct radiation from the site. May also include the far-field effects of discharges of liquid waste from Sellafield*

[b] *Committed effective dose calculated using methodology of ICRP-60 to be compared with the dose limit of 1 mSv*

[c] *Pathways and radionuclides that contribute more than 10% of the total dose. Some radionuclides are reported as being at the limits of detection*

[d] *The doses from man-made and naturally occurring radionuclides were 0.13 and 0.047 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*

The highest dose at Sellafield was most affected by historic liquid discharges. The maximum dose at Sellafield for those people most affected by pathways related to gaseous discharge and direct radiation sources was 0.011 mSv in 2010 compared with 0.045 mSv in 2009. The people most exposed in 2010 were high-rate infant consumers of milk. In 2009 the most exposed were high rate consumers of game meat and their dose reduced due to reductions of radionuclide concentrations in their diet.

The next highest dose was received by people living on houseboats in the Ribble Estuary. In 2010, their dose was 0.17 mSv. Most of this exposure was due to external dose from radionuclides from Sellafield deposited in intertidal sediments. Their dose in 2009 was 0.15 mSv and the increase was due to a small increase in dose rates near the boats. The dose at Springfields was the highest in the UK due to nuclear industry waste discharges.

In Scotland, the people who received the highest dose from authorised releases of radioactivity were those who lived near the Hunterston site. It was estimated that they received 0.067 mSv in 2010, the same as in 2009. Most of this dose was due to direct radiation from the site.

Relatively high concentrations of tritium have previously been found in food and the environment near GE Healthcare's Maynard Centre, at Cardiff, where radiochemicals for life science research are produced. In 2010, the most exposed people received an estimated dose of 0.006 mSv. Their dose in 2009 was 0.012 mSv. The dose was due to (i) eating fish from the Severn Estuary that contained tritium and carbon-14 and (ii) external radiation that was not derived from operations at the Maynard Centre. Doses at this site have been steadily falling since 2000 in line with lower discharges.

Habits surveys near nuclear sites

In 2010, the regular programmes of habits surveys around nuclear sites continued. These give site-specific information on diets and occupancy habits of people near nuclear sites. In 2010, surveys were carried out at Dungeness, Hinkley Point, Sellafield and Sizewell in England, and at Chapelcross and Rosyth in Scotland. The findings were used to strengthen and update monitoring programmes and to improve the assessment of doses to members of the public near nuclear sites.

Radioactivity concentrations in samples collected around nuclear sites

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

A revised UK Radioactive Discharge Strategy was published in 2009, extending and strengthening the scope of the earlier Strategy published in 2002. Both describe how the UK will implement the commitments in the OSPAR Radioactive Substances Strategy on radioactive discharges to the marine environment of the North-East Atlantic. One of the aims of the UK Strategy is to progressively and substantially reduce liquid radioactive discharges. This means that nuclear sites need action plans to achieve reductions in discharges. In 2010, the Environment Agency and SEPA issued new permits (authorisations), or varied existing ones, at five sites (Cardiff, Hinkley Point A, Hunterston A, Sellafield and Sizewell A), resulting in strengthened conditions, reduced limits or new routes for disposing of radioactive waste.

During the past decade, discharges from GE Healthcare at Cardiff have continued to fall. This has led to a downward trend in concentrations of tritium in fish and molluscs. Similarly, lower discharges of technetium-99 from Sellafield have led to a fall in technetium-99 in local food and the environment since the peaks seen in 1997. There were no major variations in concentrations of radioactivity in 2010 compared to those in 2009.

During 2010, discharges of technetium-99 from Sellafield continued at the lowest level seen since new abatement technology was introduced. Discharges are expected to remain low in the future. Technetium-99 from Sellafield can be detected in the Irish Sea, in Scottish waters and in the North Sea. Concentrations of technetium-99 have shown a strong trend downward from their most recent peak in 2003, though concentrations in 2010 were similar to those in 2009. Technetium-99 has been found in seaweed, and our monitoring has shown a small-scale transfer of technetium-99 from sea to land where seaweed has been used as a soil conditioner.

Marine sediment samples are a useful indicator of trends in the environment. People who spend time on beaches can be exposed to radiation through the radionuclide content of the sediments. Near Sellafield, the environmental concentrations of most radionuclides have declined substantially over the last 20 years. In some recent years, concentrations of caesium-137, plutonium isotopes and americium-241 in mud samples from the Ravenglass estuary near Sellafield have increased, but this was not the case in 2010. These trends are unlikely to be associated with changes in discharges. Concentrations of americium-241 will have increased due to radioactive 'in-growth' from the decay of the parent radionuclide plutonium-241 in the environment. Higher activity concentrations can occur in sediments as a result of their containing radioactivity from discharges in earlier decades and then being remobilised, or due to the differences in their particle size. There were small decreases in concentrations of plutonium isotopes and americium-241 in fish and shellfish samples from Cumbria.

On occasion, the effects of non-nuclear sites discharge are detected by the monitoring programme for nuclear sites. In 2010, iodine-131 was detected at several nuclear sites. The source of the iodine-131 is not known with certainty but a likely cause is the therapeutic use of this radionuclide in a local hospital. The concentrations were of low radiological significance.

Dose rates from around nuclear sites

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

There were no major changes in external dose rates in intertidal areas in 2010 compared with 2009. At most locations, the external dose rates were close to background levels. Levels were higher in some estuaries near Sellafield (up to twice the background rate) and in the Ribble Estuary.

Nuclear site incidents and non-routine surveys

During 2010, as a result of an ongoing programme of monitoring by the operator, radioactive items were detected on beaches on the Cumbrian coastline, where 386 particles* and contaminated pebbles/stones from Sellafield were removed. An update on further progress of the enhanced beach monitoring was provided by the Environment Agency in March 2010 (Environment Agency, 2010b). The Health Protection Agency has recently offered advice that, based on information available in March 2011, the overall health risks for beach users from radioactive objects on beaches near Sellafield are very low and significantly lower than other risks that people accept when using the beaches. Monitoring, removal and research into the origins, fate and effects of the particles by Sellafield Limited will continue.

At Chapelcross, a programme of work to reline and grout sections of the discharge pipeline has mitigated the potential release of limescale particles, with no particles being detected on the foreshore during 2010. At Dounreay, the comprehensive beach monitoring programme for fragments of irradiated nuclear fuel (particles) continued and recovered further particles from local beaches. Offshore particles which could pose significant harm were recovered from the seabed, where fishing restrictions under the Food and Environment Protection Act 1985 are still in force.

'Special' (or *ad hoc*) sampling related to nuclear operation was undertaken at three sites (Chapelcross, Dounreay and Hunterston) in 2010 to further investigate specific issues.

Radiation doses and levels at other locations in the UK

Food and drinking water in people's general diet and sources of public drinking water were analysed across the United Kingdom. Results showed that artificial radionuclides only contributed a small proportion of the total public radiation dose in people's general diet.

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

In the past, liquid slurry containing thorium and uranium was discharged into the Irish Sea from a phosphate plant near Whitehaven. This site stopped operating at the end of 2001 and the plant has subsequently been demolished. Concentrations of naturally-occurring radionuclides in fish and shellfish near Whitehaven have been found to be higher than the maximum expected ranges due to natural sources. Concentrations of natural radionuclides have declined in the last 10 years so that by 2010 the concentrations were very close to natural background, making any increase due to the past discharges difficult to distinguish. Estimates of the concentrations of naturally-occurring radionuclides in seafood caused by past discharges from the site have been made by subtracting the expected natural concentration of these radionuclides in UK seafood from the measured levels. Polonium-210, which is naturally-occurring, is present in some seafood samples at slightly above background levels. People in the Sellafield area who consume large amounts of molluscs were estimated to receive a dose of 0.18 mSv, with about 20% from polonium-210.

Discrete radioactive items have been detected on Dalgety Bay since at least 1990. In 2010, SEPA conducted further work on the potential solubility and doses which could be received from a source present on the beach at Dalgety Bay should it be ingested, together with work on the potential doses which could occur from skin contact. This study reports that there is low potential of a skin burn being received following exposure to a source, although if a source were to be ingested, it could result in a significant dose in excess of 100 mSv to young infants.

The scheduled monitoring programme undertaken by Defence Estates (now the Defence Infrastructure Organisation (DIO)) came to a conclusion in 2010 and SEPA considered, in the absence of such a programme, whether further actions were needed to protect the public from the radioactive sources present on the beach. As sources which could give significant doses to members of the public were still being recovered from the beach, SEPA concluded that a further programme of monitoring and retrieval was needed coupled with the continued presence of signs to provide information to the public on the hazards present. Following discussions with SEPA, the DIO has agreed to undertake a further programme of monitoring and recovery. The DIO has also agreed to support the work of SEPA in attempting to determine the primary source of the contamination which continues to re-populate the beach; this work will be reported next year.

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

Food imported into the UK may contain radioactive contamination. A monitoring system is in place to detect radioactivity in consignments. In 2010, the Food Standards Agency analysed a sample of blueberries that had been imported into Dover. The concentration found was 110 Bq kg^{-1} of caesium-137. By law the concentration in the final food product has to be compared with the maximum level permissible under EC Regulations, which is 600 Bq kg^{-1} (fresh weight). In this case the UK authorities therefore did not need to take any further action.

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

The environmental effects of the Chernobyl accident continued to be monitored in 2010. There are still restrictions on moving, selling and slaughtering sheep in some upland areas of the UK. These were limited to 340 farms in 2010, compared with 9,700 farms following the accident in 1986. In Scotland, restrictions for the two remaining farms were lifted during 2010.

The distribution of radionuclides in coastal seas away from nuclear sites continues to be monitored. This supports the UK's marine environmental policies and international treaty commitments. Government research vessels are used in the sampling programme and the results have been used to show trends in the quality of the UK's coastal seas. These surveys, together with the results of monitoring at nuclear sites, contribute to the data collected by the OSPAR Commission. They also help to measure progress towards the UK Government's targets for improving the state of the marine environment.

Disposal of dredge spoil from harbours and other areas is licensed under the Food and Environment Protection Act, 1985. In 2010, the Department for Environment, Food and Rural Affairs (Defra) considered a proposal for the disposal of sediment from two locations in south west England. Samples of the dredge spoil were analysed for radioactivity and an assessment of potential radiation doses was made. Doses to members of the public were all less than the International Atomic Energy Agency (IAEA) *de minimis* criterion of 0.010 mSv per year, and a licence was issued.

The monitoring programmes and further research

The monitoring programmes in this report involved six specialist laboratories working together, each with rigorous quality assurance audits, and a wide range of sample collectors throughout the United Kingdom. They were organised by the Environment Agency, the Food Standards Agency, NIEA and SEPA and they are independent of the industries discharging radioactive effluents. The programmes include monitoring on behalf of the Scottish Government, Channel Island States, the Department of Energy and Climate Change, the Department for Environment, Food and Rural Affairs, the Manx Government and the Welsh Government. Overall, around 12,000 analyses and dose rate measurements were completed in 2010.

The accident at Fukushima-Daiichi nuclear power station in Japan in March 2011 resulted in significant quantities of radioactivity being released to air and sea. At the end of March 2011, elevated iodine-131 levels were detected in the UK. The Environment Agency, the Food Standards Agency, the Health Protection Agency (HPA), NIEA and SEPA increased the scrutiny of their environmental monitoring programmes and took additional samples where appropriate. The levels detected in the UK environment mean that there is minimal risk to public health in the UK from the release of radioactive material at the Fukushima-Daiichi nuclear power plant. Regular updates of monitoring data where hosted on the HPA website, and additionally SEPA have compiled a data report of all monitoring undertaken in Scotland. The report is available at http://www.sepa.org.uk/radioactive_substances/publications/other_reports.aspx . Full monitoring data results for the UK will be published in RIFE next year.

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

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

1. Introduction

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 2010 and (iii) gives an overview of the main sources of radiation in a regulatory context.

Key points

- The report represents collaboration by Government regulatory bodies across the UK, independent of industry
- Provides an open check on food safety and the public's exposure to radiation
- Monitoring programme results support the UK meeting its international treaty obligations
- Dose results are summarised for major industrial sites; all doses were within the legal limit in 2010

1.1 Purpose and scope of the monitoring programmes

This report gives the results of programmes that monitored food and environmental materials for radioactivity in the UK during 2010. In England and Wales, the Food Standards Agency conducts food monitoring, whilst the Environment Agency carries out environmental and dose rate monitoring. In Scotland, the Scottish Environment Protection Agency (SEPA) carries out food and environmental monitoring, working closely with the Food Standards Agency on its programme, and in Northern Ireland this is carried out by the Northern Ireland Environment Agency (NIEA). The Food Standards Agency continues to monitor some upland areas in England, Wales and Scotland for caesium-137, arising from the 1986 Chernobyl accident. Drinking water, air and rain are monitored on behalf of the Department of Energy and Climate Change (DECC), NIEA and the Scottish Government. The Food Standards Agency and SEPA also carry out nationwide monitoring of foodstuffs (including milk, animals, crops and canteen meals) that are remote from nuclear sites. The marine environment of the whole of the British Isles away from nuclear sites is monitored for the Department for Environment, Food and Rural Affairs (Defra).

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

The monitoring programmes have several purposes. Ongoing monitoring helps to establish the long-term trends in concentrations of radioactivity over time and at distance from nuclear licensed sites. The results are also used to confirm the safety of the food chain. Monitoring the environment provides indicators of radionuclide dispersion around each site. Environmental and food results are used to assess dose to the public which can then be compared with the UK statutory dose limits. Most of the monitoring carried out and presented in this report concerns the local effects of discharges from nuclear licensed sites in the UK. Other work includes the Chernobyl monitoring, which provides the authorities with information on caesium-137 concentrations in affected areas and helps them decide if restrictions are still needed. Monitoring of food and the environment remote from nuclear licensed sites is also carried out, giving information on background concentrations of radionuclides; these data are reported to the European Commission. Guidance on planning and implementing routine environmental programmes has been published (Environment Agency, Food Standards Agency and Scottish Environmental Protection Agency, 2010).

An explanatory section giving details of methods of sampling and analysis and explaining how results are interpreted in terms of public radiation exposures is provided in Appendix 1 on the CD accompanying the main report. A summary of recent trends in monitoring data and doses for 2004 – 2008 has been published (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

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

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

The routine monitoring programmes operated in 2010 are supported by a capability funded by the UK and Devolved Governments which also provides resilience to respond to radioactive emergencies. In 2011 the Fukushima-Daiichi nuclear power station incident resulted in enhanced monitoring and other actions to ensure the safety of UK citizens. The results of this additional monitoring work will be published separately; however there is a summary of the UK response in Section 8.2.

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 2010, using monitoring results for that year. The radioactivity concentrations and dose rates reported include the consequences of all discharges made up to the time of sampling.

In this report, two main types of retrospective dose assessment are made. The first type of assessment takes precedence since it is more complete. It considers the effects of discharges of radioactive waste and additionally includes exposure to direct radiation from nuclear sites. This gives an estimate of *total dose* to people around the nuclear sites. Direct radiation can be significant close to operating power stations or close to where radioactive materials are stored. The regulation of direct radiation is the responsibility of the Health & Safety Executive (HSE) working through their agency, the Office of Nuclear Regulation (ONR)*. Nuclear site operators provide estimates of direct radiation doses to HSE which are made available for use in these assessments (Table 1.1). The *total dose* assessments use recent habit survey data which has been profiled using an agreed method (Camplin et al., 2005).

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

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

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

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

Collective doses are beyond the scope of this report. They are derived using modelling techniques. The European Commission has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for the gaseous and liquid waste disposals in the years 1997 to 2004 (Harvey *et al*., 2008).

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

1.2.2 *Total dose* results for 2010

The results of the assessment are summarised in Table 1.2 for each site (see also Figure and Table S in the Technical Summary). The data are presented in three parts. The people receiving the highest dose from the pathways predominantly relating to gaseous discharges and direct radiation are shown in part A and those for liquid discharges in part B. Occasionally the people receiving the highest dose from all pathways are different from those in A and B. Therefore we have also presented this case in part C. The major contributions to dose are also presented. The use of radionuclide concentrations reported at the limits of detection provide an upper estimate of doses calculated for pathways based on these measurements. The full output from the assessment is provided for each site on the CD accompanying this report.

In all cases, doses estimated for 2010 were less than the limit of 1 mSv for members of the public. The most affected people from gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation where it was applicable. The most affected people from liquid discharges were generally adult seafood consumers or occupants over contaminated substrates. The highest dose in 2010 from all sources was to local inhabitants near the Capenhurst site; this dose was almost entirely due to direct radiation emanating from the site. The next highest doses were due to direct radiation and mollusc consumption (Amersham and Sellafield, respectively).

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

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

1.2.3 *Total dose* trends

A time-series of *total dose* from 2004 - 2010 is shown in Figure 1.1 (Table 1.3 gives numerical values), with doses not originally calculated for RIFE reports (due to a lack of suitable habits data at the time) retrospectively added according to the monitoring data for that year. Many sites show little by way of a trend in *total dose* over this period. Changes in direct radiation dominate the inter-annual variation at most of the power station sites, and small fluctuations in external dose rates can have relatively large effects at sites where high rates of intertidal occupancy have been recorded. One site where there has been an upward trend in *total dose*, indicated by measurement data, is Capenhurst. The explanation for this trend is the statistical uncertainty associated with measurements of radiation fields that are barely above natural background levels. There have been no significant changes in source holdings or operations on site which would have generated such a trend. The effects of decreases in direct radiation were observed at Dungeness and Sizewell where cessation of power production by Magnox reactors was the cause. The most significant trends in *total dose* due to discharges of waste were seen for high-rate mollusc consumers on the Cumbrian coast near Sellafield, Whitehaven and Drigg. This is largely due to reductions in the effects of polonium-210 discharges from Whitehaven though changes in consumption rates also had an effect.

At Cardiff, there has been a downward trend in *total dose* which is partly due to reductions in discharges of tritium and carbon-14 to sea. The increase in *total dose* observed at Dounreay in 2007 and 2008 was reversed in 2009 and 2010, as caesium-137 concentrations in game meat (venison) decreased. The high consumption rate of game meat recorded during the 2008 habits survey makes this pathway more prominent than in the routine assessments earlier in this report. The reduction in *total dose* at Hinkley Point was largely due to findings from a new habits survey in 2010.

1.2.4 Source specific dose results for 2010

The results of the source specific assessments for the main industrial sites in the UK are summarised in Table 1.4 and Figure 1.2. The focus for these assessments is the effect of gaseous or liquid waste discharges, unlike that for *total dose* which also includes all sources including the effect of direct radiation.

The most significant exposures are found at Whitehaven and Sellafield and at Springfields. At Whitehaven and Sellafield the majority of the dose was from the legacy of historic discharges from Sellafield and from non-nuclear industrial operations resulting in technologically enhanced levels of natural radionuclides. The most important pathways and radionuclides at each site are similar to those found for *total dose* if the effect of direct radiation is taken into account. At Springfields the dose was also largely due to historic discharges from Sellafield.

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

1.2.5 Protecting the environment

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

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

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

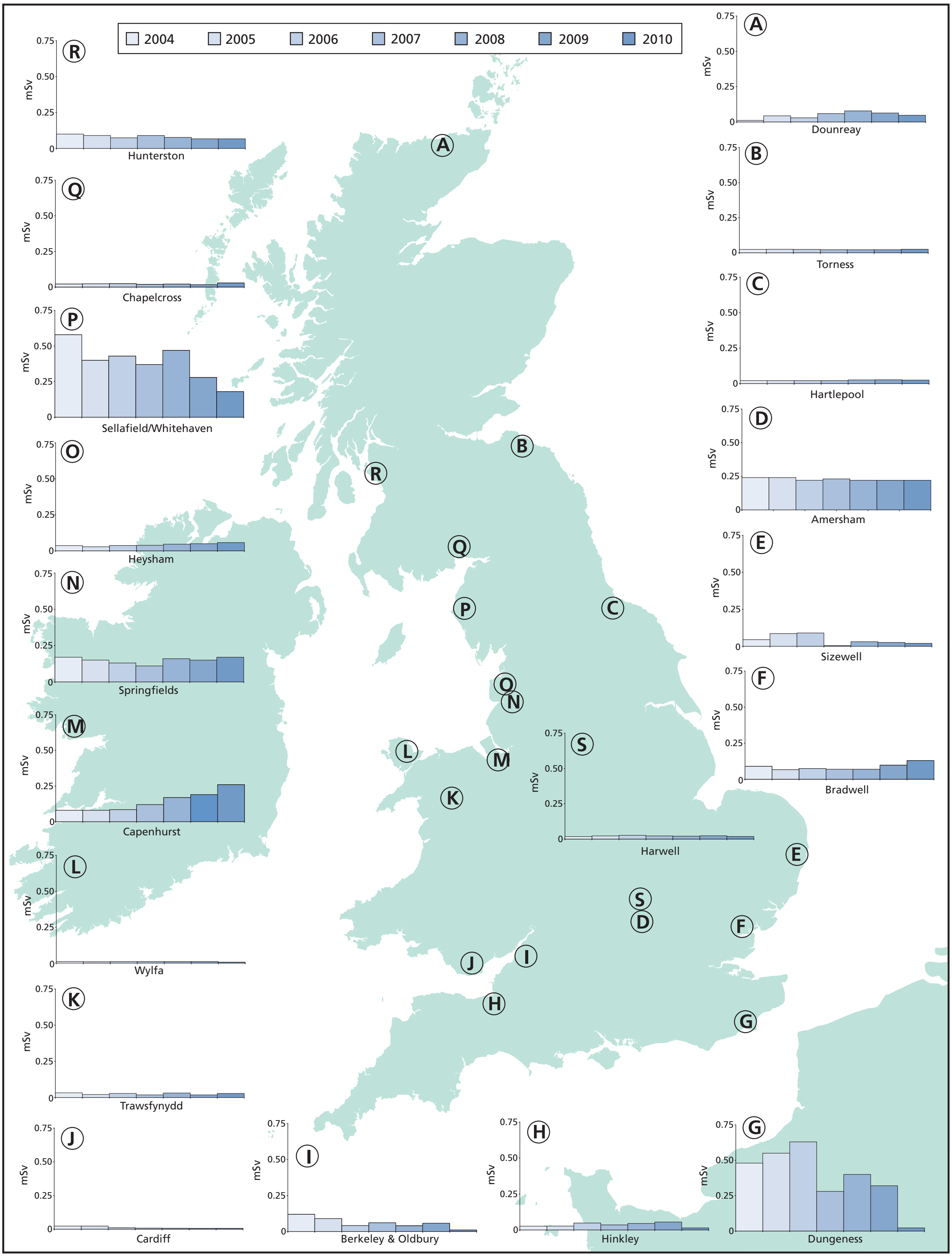


Figure 1.1. Total radiation exposures around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2004-2010). (Exposures at Sellafield/Whitehaven receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)

Figure 1.2. Radiation exposures in the UK due to radioactive waste discharges, 2010 (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

and implementing monitoring programmes to reflect the results of the initial characterisation, reviewing environmental quality using the results from the monitoring programmes, developing standards and producing management plans to improve the environmental status of the UK aquatic environment.

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

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

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

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

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

1.2.6 Food irradiation

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

Irradiation may be used to eliminate or reduce food-borne pathogenic organisms, extend shelf life by delaying food from rotting or developing mould, and prevent certain food products from ripening, germinating or sprouting. Irradiation may also be used as a phytosanitary measure to rid plants or plant products of harmful organisms which may be harmful to domestic flora.

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

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

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

1.3 Sources of radiation exposure

1.3.1 Radioactive waste disposal from nuclear sites

Nuclear licensed sites in the UK discharge radioactive waste as liquid and/or gas as part of their operations. In addition, solid low level waste (LLW) from nuclear sites can be transferred to the LLWR near Drigg for disposal. Solid LLW from Dounreay will be transferred to the new Dounreay Low Level Waste Facility (due to be operational by 2014). These discharges and disposals are regulated by the environment agencies under RSA 93 or EPR 10*.

Figure 1.3 shows the nuclear sites that produce waste containing artificial radionuclides. Nuclear licensed sites are authorised to dispose of radioactive waste (United Kingdom - Parliament, 1993). They are also subject to the Nuclear

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

Figure 1.3. Principal sources of radioactive waste disposal in the UK, 2010 (Showing main initial operation. Some operations are undergoing decommissioning)

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

Appendix 2 gives a summary of the discharges of liquid and gaseous radioactive waste and disposals of solid radioactive waste from nuclear establishments in the UK during 2010. The tables also list the discharge and disposal limits that are specified or, in the case of the Ministry of Defence (MoD), administratively agreed. In 2010 discharges and disposals were below the limits. The tables show the percentage of the limit actually discharged in 2010. Section 7 gives information on discharges from non-nuclear sites.

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

The discharges and disposals made by sites are generally regular throughout the year. However, from time to time there may be unplanned events that cause unintended leakages, spillages or other emissions that are different to the normal or expected pattern of discharges. These events must be reported to the environment agencies and may lead to follow up action, including reactive monitoring by the site, the environment agencies or the Food Standards Agency. In cases where there has been a breach of limits, or if appropriate actions have not been undertaken to ensure discharges are as low as possible, regulatory action may be taken. Where monitoring took place because of these events, the results are presented and discussed in the relevant site text later in this report. Appendix Table A2.4 summarises the types of events that took place in 2010.

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

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

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

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

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

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

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

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

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

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

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

The expected outcomes of the UK Strategy are:

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

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

Information on work in progress within the OSPAR Convention can be found on the OSPAR website www.ospar.org. The basis for OSPAR's approach is the Radioactive Substances Strategy whose primary objective is to prevent marine pollution (OSPAR, 2003), 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, 2011). It also considers the relationship between OSPAR and its work on radioactivity and the separate initiative to develop a European Marine Strategy. 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, 2009a, b). The UK submission concerning the implementation of the principle of using Best Available Technology (BAT) has also been published (OSPAR, 2009c). Progress by Contracting Parties towards meeting the objectives in the Radioactive Substances Strategy has been reviewed (OSPAR, 2009d), as has the quality status of the Convention area (OSPAR, 2010b). The Quality Status Report considers radioactivity in food and the environment and refers to results of the monitoring programmes published in earlier issues of this report. The overall conclusions of the review were that there is evidence of:

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

The European Commission (EC) has considered various options for a new policy instrument concerning the protection and conservation of the marine environment and has now issued a Marine Strategy Directive (Commission of the European Communities, 2008). The Directive has been transposed into UK law (United Kingdom - Parliament, 2010b) and is supported by measures to improve management of the marine environment covering the UK, Scotland and Northern Ireland (United Kingdom - Parliament, 2009; Scotland - Parliament, 2010; Department of the Environment Northern Ireland, 2010). It requires Member States to achieve Good Environmental Status (GES) in waters under their jurisdiction by 2020. At the time of writing it is unclear whether the European Commission considers that radioactive substances are involved in the determination of GES. This is because the Euratom Treaty is seen to be the relevant regulatory instrument (OSPAR, 2011).

The importance of an integrated approach to stewardship of the marine environment has been recognised in the UK, and a strategy to achieve this has been published (Department for Environment, Food and Rural Affairs, Scottish Executive and Welsh Assembly Government, 2002). The report "Safeguarding Our Seas" considers conservation and sustainable development of the marine environment and sets out how the UK is addressing those issues in relation to radioactive and other substances and effects. The UK completed a fully integrated assessment of the marine environment in 2005 (Department for Environment, Food and Rural Affairs, 2005a, b; Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005) and has completed a new assessment in 2010 (Department for Environment, Food and Rural Affairs, 2010).

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

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

In October 2010, DECC published for consultation revised draft National Policy Statements (NPS), for Nuclear Power Generation and other energy sources. The nuclear NPS listed eight sites assessed as potentially suitable for the development of new nuclear power stations and stated that any new nuclear power station would play a vitally important role in providing reliable electricity supplies and a secure and diverse energy mix as the UK makes the transition to a low carbon economy. The consultation of NPSs closed in January 2011. These were approved by Parliament on 18 July 2011 and designated under the Planning Act 2008 on 19 July 2011. The Scottish Government is opposed to the development of new nuclear power stations in Scotland. It is committed to enhancing Scotland's generation advantage based on renewables and fossil fuel with carbon capture and storage, as well as energy efficiency as the best long term solution to Scotland's energy security.

During 2010, the Health & Safety Executive and the Environment Agency continued to assess the design of potential new nuclear power stations. The assessment process, called "'Generic Design Assessment" (GDA), allows the safety, security and environmental implications of new power station designs to be assessed, and is commenced before an application is made to build that design at a particular site in England and Wales. The designs being assessed are AP1000 (Westinghouse) and UK-EPR (EDF and AREVA) nuclear plants. The Environment Agency's assessment of the two new nuclear power station designs is to make sure that, if they were built here, their environmental impact, including the radioactive wastes they create and the discharges they make, should be acceptable.

In June 2010, the Environment Agency began public consultation on the outcome of its assessment (Environment Agency, 2010c). Reports summarising the responses to the consultation have been published (Environment Agency, 2011a and b). Future plans now include a period to take account of the analysis of the unprecedented events in Japan (Allars, K. and McHugh, J., 2011). This analysis will include the reports from the Office of Nuclear Regulation (ONR) and the implications and lessons learnt for the UK from the Japanese incident (see, for example, Weightman, 2011). The radiological monitoring results reported in the RIFE report series will provide a baseline against which future discharges from any new or existing nuclear power stations can be judged.

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

1.3.3 Managing radioactive liabilities in the UK

The UK Government and Devolved Administrations have ratified the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (International Atomic Energy Agency, 1997). This agreement aims to ensure that individuals, society and the environment are protected from the harmful effects of ionising radiation as a result of the management of spent nuclear fuel and radioactive waste. The UK's first national report, demonstrating compliance with the Convention, was provided to the International Atomic Energy Agency (IAEA) in May 2003 (Department for Environment, Food and Rural Affairs, 2004a). An updated UK national report was submitted to the IAEA in October 2005 (Department for Environment, Food and Rural Affairs, 2005c). A third Joint Convention report was published by the UK in May 2008. A fourth report is due for publication in Autumn 2011.

The UK Government has radically altered the existing arrangements for managing civil public sector nuclear clean up. The Energy Act 2004, which became law in 2004, led to the establishment of the Nuclear Decommissioning Authority (NDA) in April 2005. The NDA is responsible for nuclear sites formerly owned by British Nuclear Fuels Ltd (BNFL), including ownership of its assets and liabilities, and United Kingdom Atomic Energy Authority (UKAEA). It is responsible for developing and implementing an overall strategy for cleaning up the civil public sector nuclear legacy safely, securely, and in ways that protect the environment. The current strategy was published in 2011 (Nuclear Decommissioning Authority, 2011a) and the plan for 2011/14 is available (Nuclear Decommissioning Authority, 2011b). The NDA published an up-to-date inventory and forecast of radioactive wastes in the UK jointly with DECC in 2011 (Department of Energy and Climate Change, 2011).

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

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

- The NDA creating a UK-wide strategy for managing LLW from the nuclear industry, including considering whether a replacement(s) of the national disposal facility near Drigg in Cumbria might be needed
- Initiating a UK-wide strategy for managing LLW from non-nuclear industries
- Minimising waste

Complementing the low-level waste policy, the UK Government published its policy for managing higher activity radioactive waste in the White Paper 'Managing Radioactive Waste Safely (MRWS): A Framework for Implementing Geological Disposal' in June 2008 (Department for Environment, Food and Rural Affairs, Department for Business, Enterprise and Regulatory Reform, Welsh Assembly Government and Northern Ireland Assembly, 2008). This followed from the independent Committee on Radioactive Waste Management's (CoRWM) recommendations that geological disposal, preceded by safe and secure interim storage, was the best available approach for the long-term management of higher activity radioactive waste (Department for Environment, Food and Rural Affairs, 2007b). The UK Government takes a volunteer and partnership approach to siting a facility, and communities were invited to discuss with Government the possibility of hosting a geological disposal facility at some point in the future. The UK Government and the Devolved Administrations of Northern Ireland, Scotland and Wales have published their response to CoRWMs recent report on national research and development for the long term management of higher activity radioactive waste (Department of Energy and Climate Change, Department of Environment (Northern Ireland), the Scottish Government and the Welsh Assembly Government, 2010).

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

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

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

1.3.4 Solid radioactive waste disposal at sea

In the past, packaged solid waste of low specific activity was disposed of deep in the North Atlantic Ocean. The last disposal of this type was in 1982. The UK Government announced at the OSPAR Ministerial meeting in 1998 that it was stopping disposal of this material at sea. At that meeting, Contracting Parties agreed that there would no longer be any exception to prohibiting the dumping of radioactive substances, including waste (OSPAR, 1998). The environmental impact of the deep ocean disposals was predicted by detailed mathematical modelling and has been shown to be negligible (Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985). Disposals of small amounts of waste also took place from 1950 to 1963 in a part of the English Channel known as the Hurd Deep. The results of environmental monitoring of this area in 2010 are presented in Section 8. They confirm that the radiological impact of these disposals was insignificant.

In the UK, Defra, the Department of the Environment, Northern Ireland, Scottish Government and Welsh Government issue licences under the Food and Environment Protection Act (FEPA), 1985 (United Kingdom - Parliament, 1985) to operators disposing of dredge material. The protection of the marine environment is considered before a licence is issued. Since dredge materials will contain varying concentrations of radioactivity from natural and artificial sources, assessments are carried out, when appropriate, to provide reassurance that there is no significant risk to the food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the IAEA (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003) and which has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2010, specific assessments were carried out for the disposal of dredged material in south-west England. Consistent with results for previous operations at other locations, the impact of the radioactivity associated with the disposal operation was very low. Individual doses to members of the crew and the public were both less than 0.005 mSv per year and within de minimis criteria of 0.010 mSv per year. Further details are provided in Appendix 5.

1.3.5 Other sources of radioactivity

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

The Environmental Protection Act 1990 provides the basis, through the Environment Act 1995, for a regulatory regime for identifying and remediating contaminated land. The regime provides a system for identifying and remediating land, where contamination is causing people to be exposed to lasting exposure to radiation resulting from the after-effects of a radiological emergency, past practice or post work activity; and where intervention is liable to be justified. A profile of industries which may have caused land contamination has been published (Department for Environment, Food and Rural Affairs, 2006a). Dose criteria for the designation of contaminated land have been determined for England and Wales (Smith *et al*., 2006). A report giving an overview of the progress made by local authorities and the Environment Agency in identifying and remediating contaminated land was published in 2009 (Environment Agency, 2009a). Defra has consulted on proposals for revising Statutory Guidance on contaminated land, including the separation of guidance for radioactive and non-radioactive contamination into separate documents. No substantive changes are planned for the rules on radioactivity. The consultation closed in March 2011 and new Statutory Guidance is planned to be issued before the end of 2011. 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 clear criteria are set for discrete point sources for the designation of radioactive contaminated land.

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

All sources of ionising radiation exposure to the UK population are reviewed, the most recent being in 2005 (Watson *et al*., 2005). Sources of naturally-occurring radiation and man-made radiation produced for medical use predominate. The average annual dose from naturally-occurring radiation was found to be 2.2 mSv and about half of this was from radon exposure indoors. The average annual dose from artificial radiation was 0.42 mSv, mainly derived from medical procedures, such as x-rays. The overall average annual dose was 2.7 mSv. Exposures from non-medical man-made sources were very low and discharges of radioactive wastes contributed less than 0.1 per cent of the total. These figures represent the exposure of the average person. Much of the information in this RIFE report is directed at establishing the exposure of people who might receive the highest doses due to radioactive waste discharges as a result of their age, diet, location or habits. It is the exposure of these people which forms the basis for comparisons with dose limits in EU and UK law.

Table 1.1. Individual radiation exposures - direct radiation pathway, 2010

Site	Exposure, mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.26
Sellafield	0.002
Springfields	<0.028
Research establishments	
Dounreay	0.004
Harwell	0.018
Winfrith	Bgd[a]
Nuclear power stations	
Berkeley	<0.010
Bradwell	0.13
Chapelcross	0.001
Dungeness	<0.020[b]
Hartlepool	<0.020
Heysham	<0.020
Hinkley Point	0.010[c]
Hunterston	<0.066[d]
Oldbury	Bgd[a]
Sizewell	<0.020[e]
Torness	<0.020
Trawsfynydd	0.027
Wylfa	Bgd[a]
Defence establishments	
Aldermaston	Bgd[a]
Burghfield	Bgd[a]
Derby	Bgd[a]
Devonport	Bgd[a]
Faslane	Bgd[a]
Rosyth	Bgd[a]
Radiochemical production	
Amersham	0.22
Cardiff	Bgd[a]
Industrial and landfill sites	
LLWR near Drigg	0.031

[a] *Doses not significantly different from natural background*
[b] *Datum for Dungeness B. Dungeness A (0.009) not used*
[c] *Datum for Hinkley B. Hinkley A (Bgd[a]) not used*
[d] *Datum for Hunterston A. Hunterston B (<0.020) not used*
[e] *Datum for Sizewell B. Sizewell A (Bgd[a]) not used*

Table 1.2. *Total dose* integrated across pathways, 2010			
Site	Most exposed people[a]	Exposure, mSv	
		Total	Dominant contributions[b]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Milk consumers aged 1y	<0.005	Milk, ^{3}H, ^{137}Cs
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Prenatal children of local inhabitants (0 - 0.25km)	0.011	Direct radiation, external and inhalation close to site
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.13	Direct radiation
Capenhurst	Local adult inhabitants (0 - 0.25km)	0.26	Direct radiation
Cardiff	Milk consumers aged 1y	<0.005	Milk, ^{32}P, ^{35}S, ^{137}Cs
Chapelcross	Milk consumers aged 1y	0.029	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Derby	Domestic fruit consumers aged 1y	<0.005	Domestic fruit ^{106}Ru, ^{241}Am
Devonport	Prenatal children of green vegetable consumers	<0.005	Green vegetables, domestic fruit, ^{3}H
Dounreay	Adult consumers of game meat	0.047	Game meat, ^{137}Cs
LLWR near Drigg	Local adult inhabitants (0.25 - 0.5km)	0.038	Direct radiation, fish
Dungeness	Local adult inhabitants (0 - 0.25km)	0.022	Direct radiation
Faslane	Adult consumers of cattle meat	<0.005	Cattle meat, ^{137}Cs
Hartlepool	Local adult inhabitants (0.5 - 1km)	0.020	Direct radiation
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.018	Direct radiation
Heysham	Local adult inhabitants (0.25 - 0.5km)	0.021	Direct radiation
Hinkley Point	Local adult inhabitants (0.5 - 1km)	0.011	Direct radiation
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.067	Direct radiation
Rosyth	-	-	
Sellafield and Whitehaven	Milk consumers aged 1y	0.011	Milk, potatoes, ^{60}Co, ^{90}Sr, ^{106}Ru. ^{137}Cs
Sizewell	Local adult inhabitants (0 - 0.25km)	0.020	Direct radiation
Springfields	Adult mushroom consumers	0.029	Direct radiation
Torness	Adult root vegetable consumers	0.025	Direct radiation, ^{241}Am
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.028	Direct radiation
Winfrith	Adult consumers of green vegetables	<0.005	Domestic fruit, gamma dose rate over sediment, milk, green vegetables, potatoes, ^{137}Cs
Wylfa	Local inhabitants aged 1y (0.25 - 0.5km)	<0.005	Milk, ^{14}C, ^{35}S, ^{137}Cs
B Liquid releases from the site			
Aldermaston and Burghfield	Adult occupants over riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Adult occupants over riverbank	<0.005	Gamma dose rate over riverbank
Berkeley and Oldbury	Adult occupants over sediment	0.009	Gamma dose rate over sediment
Bradwell	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Capenhurst	Occupants over riverbank aged 10y	0.010	Gamma dose rate over sediment
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment, fish, ^{3}H
Chapelcross	Adult occupants over sediment	0.010	Gamma dose rate over sediment, ^{241}Am
Derby	Consumers of locally sourced water aged 1y	<0.005	Water, ^{60}Co
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult occupants over sediment	0.006	Gamma dose rate over sediment
Dungeness	Adult occupants over sediment	0.014	Gamma dose rate over sediment, direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Adult occupants over sea coal/sand	0.007	Gamma dose rate over sea coal/sand
Harwell	Adult occupants of riverbank	0.006	Gamma dose rate over riverbank
Heysham	Adult occupants over sediment	0.057	Gamma dose rate over sediment
Hinkley Point	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Hunterston	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and LLWR near Drigg[d]	Adult mollusc consumers	0.18[c]	Crustaceans, fish, molluscs, ^{210}Po, $^{239/240}Pu$, ^{241}Am
Sizewell	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Springfields	Adult occupants on houseboats	0.17	Gamma dose rate over sediment
Torness	Adult occupants over sediment	0.012	Direct radiation, gamma dose rate over sediment
Trawsfynydd	Adult occupants over sediment	0.006	Fish, gamma dose rate over sediment, direct radiation
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult consumers of marine plants and algae	0.007	Fish, gamma dose rate over sediment, ^{137}Cs

Table 1.2. continued

Site	Most exposed people[a]	Exposure, mSv	
		Total	Dominant contributions[b]
C All sources			
Aldermaston and Burghfield	Adult occupants over riverbank	<0.005	Gamma dose rate over riverbank
Amersham	Local adult inhabitants (0 - 0.25km)	0.22	Direct radiation
Berkeley and Oldbury	Prenatal children of local inhabitants (0 - 0.25km)	0.011	Direct radiation, external and inhalation close to site
Bradwell	Prenatal children of local inhabitants (0 - 0.25km)	0.13	Direct radiation
Capenhurst	Local adult inhabitants (0 - 0.25km)	0.26	Direct radiation
Cardiff	Prenatal children of occupants over sediment	0.006	Gamma dose rate over sediment, fish, ^{3}H
Chapelcross	Milk consumers aged 1y	0.029	Milk, ^{14}C, ^{90}Sr, ^{241}Am
Derby	Consumers of locally sourced water aged 1y	<0.005	Water, ^{60}Co
Devonport	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Dounreay	Adult consumers of game meat	0.047	Game meat, ^{137}Cs
Dungeness	Local adult inhabitants (0.5 - 1km)	0.022	Direct radiation
Faslane	Adult occupants over sediment	<0.005	Gamma dose rate over mud
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.025	Direct radiation, gamma dose rate over sediment
Harwell	Prenatal children of local inhabitants (0 - 0.25km)	0.018	Direct radiation
Heysham	Adult occupants over sediment	0.057	Gamma dose rate over sediment
Hinkley Point	Adult occupants over sediment	0.014	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.25 - 0.5km)	0.067	Direct radiation
Rosyth	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Sellafield, Whitehaven and LLWR near Drigg[d]	Adult mollusc consumers	0.18[c]	Crustaceans, fish, molluscs, ^{210}Po, $^{239/240}Pu$, ^{241}Am
Sizewell	Local adult inhabitants (0 - 0.25km)	0.020	Direct radiation
Springfields	Adult occupants on houseboats	0.17	Gamma dose rate over sediment
Torness	Adult root vegetable consumers	0.025	Direct radiation, ^{241}Am
Trawsfynydd	Local inhabitants aged 1y (0.25 - 0.5km)	0.028	Direct radiation
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult consumers of marine plants and algae	0.007	Fish, gamma dose rate over sediment, ^{137}Cs

[a] *Selected on the basis of providing the highest dose from the pathways associated with the sources as defined in A, B or C*

[b] *Pathways and radionuclides that contribute more than 10% of the total dose. Some radionuclides are reported as being at the limits of detection and based on these measurements, an upper estimate of dose is calculated*

[c] *The doses from man-made and naturally occurring radionuclides were 0.13 and 0.047 mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR near Drigg site into the same area*

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

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

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

[a] *Where no data is given, no assessment was undertaken due to a lack of suitable habit data at the time. Data in italics signify assessments performed to show trends in total dose over the five-year period from 2004 - 2008, using subsequently obtained habit data*

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[g]	L	0.012	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005[h]	^{234}U
Springfields	External (skin) to fishermen	L	0.050[f]	Beta
	Fish and shellfish consumption	L	0.017	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site	G	<0.005[h]	^{129}I ^{234}U
	External in intertidal areas (children playing)[g,a]	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	0.16	Ext
	External in intertidal areas (farmers and wildfowlers)	L	0.032	Ext
Sellafield[e]	Fish and shellfish consumption and external in intertidal areas (2006-2010 surveys) (excluding naturally occurring radionuclides)[k]	L	0.18	$^{239/240}Pu$ ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2006-2010 surveys) (including naturally occurring radionuclides)[l]	L	0.26	^{210}Po ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2010 surveys) (excluding naturally occurring radionuclides)[k]	L	0.16	Ext ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[i]	G	0.022	^{90}Sr
	Terrestrial foods at Ravenglass[i]	G/L	0.038	
	External in intertidal areas (Ravenglass)[a]	L	0.044	Ext ^{241}Am
	Occupancy of houseboats (Ribble estuary)	L	0.16	Ext
	External (skin) to bait diggers	L	0.037[f]	Beta
	Handling of fishing gear	L	0.10[f]	Beta
	Porphyra/laverbread consumption in South Wales	L	<0.005	^{241}Am
	Seaweed/crops at Sellafield	L	0.012	^{99}Tc
Research establishments				
Culham	Water consumption[n]	L	<0.005	
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	0.006	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.028	^{241}Am
Harwell	Fish consumption and external to anglers	L	0.006	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{3}H ^{222}Rn
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site	G	<0.005	^{137}Cs
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	0.012	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Bradwell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	^{3}H ^{14}C
Chapelcross	Wildfowl and fish consumption and external in intertidal areas	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.021	^{14}C
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.014	Ext ^{241}Am
	Occupancy of houseboats	L	0.015	Ext
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{137}Cs
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	0.008	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{35}S
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.046	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.005	
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.020	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{137}Cs
Hunterston	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.008	^{14}C ^{90}Sr

Table 1.4. Radiation doses due to discharges of radioactive waste in the United Kingdom, 2010

Table 1.4. continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[d]	Exposure, mSv[b] per year	Contributors[c]
Nuclear power production *continued*				
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{241}Am
	Occupancy of houseboats	L	0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{35}S
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{137}Cs ^{241}Am
	Terrestrial foods, external and inhalation near site[i]	G	0.014	^{90}Sr ^{241}Am
Trawsfynydd	Fish consumption and external to anglers	L	0.006	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{90}Sr ^{137}Cs
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.009	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	^{14}C ^{35}S
Defence establishments				
Aldermaston	Fish consumption and external to anglers	L	<0.005[h]	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	<0.005[h]	^{235}U
Derby	Water consumption, fish consumption and external to anglers[n]	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[i]	G	<0.005	
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{14}C
	Terrestrial foods, external and inhalation near site[o]	G	<0.005	
Faslane	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
Holy Loch	External in intertidal areas	L	0.007	Ext
Rosyth	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext ^{137}Cs
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext ^{137}Cs
	Terrestrial foods, external and inhalation near site[i]	G	0.012	^{222}Rn
Cardiff	Fish and shellfish consumption and external in intertidal areas[o]	L	0.010	Ext ^{3}H
	Terrestrial foods, external and inhalation near site[i]	G	0.005	^{32}P ^{137}Cs
	Inadvertent ingestion and riverbank occupancy (River Taff)	L	<0.005	Ext
Industrial and landfill				
LLWR near Drigg	Terrestrial foods[i]	G	0.012	^{90}Sr
	Water consumption[n]	L	<0.005	
Whitehaven	Fish and shellfish consumption[j]	L	0.082	^{210}Po ^{210}Pb
	Fish and shellfish consumption[m]	L	0.26	^{210}Po ^{241}Am

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

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

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

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

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

[f] *Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see Appendix 1)*

[g] *10 y old*

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

[i] *1 y old*

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

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

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

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

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

[o] *Prenatal children*

2. Nuclear fuel production and reprocessing

Key points

- There was one minor revision of radioactive waste permits in 2010 at Sellafield
- Doses, discharges, environmental concentrations and dose rates in 2010 were broadly similar to those in 2009

Capenhurst, Cheshire

- Public radiation doses from all sources were less than 26 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Transfer initiated of NDA-owned site to Urenco UK Limited, under a long lease and services contract
- Liquid discharges of uranium decreased

Springfields, Lancashire

- Public radiation doses from all sources were less than 17 per cent of the dose limit. People living on houseboats received the highest exposure
- Doses to wildfowlers/anglers and fishermen were lower
- Responsibility for the commercial fuel manufacturing business and Springfields Fuels Limited was transferred from NDA to Westinghouse
- Liquid discharges of uranium increased
- Gamma dose rates were generally lower over marsh but increased in the vicinity of the houseboats in 2010

Sellafield, Cumbria

- Public radiation doses from all sources (*total dose*) were less than 18 per cent of the public dose limit
- The highest doses were from seafood affected by historic discharges from Sellafield and from phosphate processing at Whitehaven
- Radiation dose to seafood consumers from natural radionuclides was much lower than in 2009, mostly due to a decrease in polonium-210 in shellfish from past phosphate processing at Whitehaven. The dose from Sellafield discharges also reduced due to the revision in mussel consumption rate
- Gaseous discharges were generally similar to 2009, except tritium and antimony-125 which decreased
- Liquid discharges of carbon-14, technetium-99, americium-241 and uranium radionuclides were lower in 2010
- Concentrations and dose rates were generally similar to those in 2010. Caesium-137 concentrations in milk decreased and antimony-125 remained below the limit of detection (LoD); total caesium in deer muscle decreased; caesium-137, plutonium radionuclides and americium-241 generally declined in fish and shellfish
- The project to strip asbestos cladding from Calder Hall was completed

This section considers the results of monitoring by the Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and the Scottish Environment Protection Agency of four sites in the UK associated with civil nuclear fuel production and reprocessing. The sites are at:

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

Both the Springfields and Sellafield sites are owned by the NDA. In November 2008, the NDA confirmed that the programme to secure a new Parent Body Organisation (PBO) for the Sellafield Site Licence Company (SLC), Sellafield Limited, had been completed, by the site management contract being transferred to the consortium, Nuclear Management Partners Ltd (NMP). The NDA's Capenhurst site was also included in the contract. The Windscale nuclear site, also owned by the NDA, is located on the Sellafield site and holds its own nuclear licence, which was transferred to Sellafield Ltd in April 2008. An integrated environment permit was also issued for the Windscale and Sellafield sites in April 2008. Windscale is discussed in Section 2.4. The Low Level Waste Repository LLWR near Drigg is discussed in Section 7.1.

Gaseous and liquid discharges from each of the sites are regulated by the Environment Agency. In 2010, gaseous and liquid discharges were below permit limits for each of the sites (see Appendix 2). The medium-term trends in doses, discharges and environmental concentrations at these sites were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

2.1 Capenhurst, Cheshire

There are two adjacent nuclear licensed sites at Capenhurst, near Ellesmere Port, one owned by the NDA and one by Urenco UK Limited (UUK). The NDA site, operated by Sellafield Limited, comprises of uranic material storage facilities and activities associated with decommissioning redundant plant. The UUK site operates three plants producing enriched uranium for nuclear power stations. In October 2010, the NDA and UUK signed a set of non-binding commercial principles to support a potential transfer of the NDA-owned Capenhurst site to UUK. The proposal would transfer the NDA-owned land and operations to UUK under a long lease and services contract. The most recent habits survey was conducted in 2008 (Tipple *et al.*, 2009).

Doses to the public

In 2010, the *total dose* from all pathways and sources was assessed to have been 0.26 mSv (Table 2.1), or 26 per cent of the dose limit. This was mostly due to direct radiation from the Capenhurst site. The dose assessment identifies local adults living near to the site as the most exposed age group. The increase from 0.19 mSv in 2009 is due to an increase in the estimate of direct radiation from the site. The trend in *total dose* over the period 2004 – 2010 is given in Figure 1.1. The trend is mostly likely to have been due to the statistical uncertainty associated with measurements of radiation fields that are barely above natural background levels. There have been no significant changes in source holdings or operations on site which would have generated such a trend.

Source specific assessments indicated exposures for consumers of locally grown foods at high-rates, and for children playing in and around Rivacre Brook, were less than 0.26 mSv in 2010 (Table 2.1). As in 2009, the highest dose was 0.012 mSv in 2010 for 10 year old children (who play near the Brook and inadvertently ingest water and sediment). The dose was estimated assuming a high occupancy of the bank of the Brook, relatively high inadvertent ingestion rates of water and sediment and gamma dose rates.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges from Capenhurst, with small amounts of other radionuclides present in discharges by Sellafield Limited. The main focus for terrestrial sampling was on the content of technetium-99 and uranium in milk, fruit, vegetables, silage, grass and soil. Results for 2010 are given in Table 2.2(a). Concentrations of radionuclides in samples of milk and food around the site were very low, similar to previous years, as were concentrations of technetium-99 and uranium in soils. Figure 2.1 shows the trend of technetium-99 concentrations in grass from 2000. The trend reflects the reductions in discharges of technetium-99 from recycled uranium. In future UUK is expecting to increase the enrichment of reprocessed uranium, which may lead to increases in discharges of technetium-99 and neptunium-237. However, no increase in the discharge limits is expected.

Liquid waste discharges and aquatic monitoring

The permit held by Sellafield Limited allows liquid waste discharges (including liquid discharges from UUK) to the Rivacre Brook for tritium, uranium and daughters,

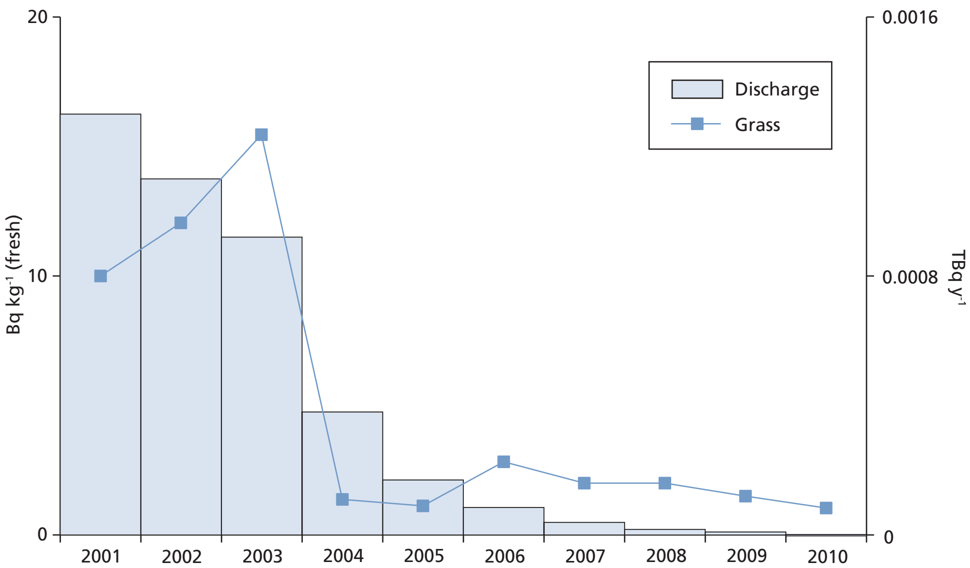


Figure 2.1. Technetium-99 annual discharges from and concentrations in grass at Capenhurst, 2001-2010

technetium-99 and non uranium alpha (mainly neptunium-237). In 2010, discharges of uranium were lower than in 2009.

Monitoring included the collection of samples of freshwater and sediments for analysis of tritium, technetium-99, gamma emitting radionuclides, uranium, neptunium-237, and gross alpha and beta. Fish and shellfish from the local marine environment were sampled and measured for a range of radionuclides. Dose rate measurements were taken on the banks of the Rivacre Brook. Results for 2010 are given in Table 2.2(a) and (b). Concentrations of radionuclides and dose rates were very low and generally similar to those in 2009. Sediment samples from the Rivacre Brook contained very low but measurable concentrations of uranium (enhanced above natural levels) and technetium-99. Some enhancement of these radionuclides was measured close to the discharge point. Variations in concentrations in sediment from the Brook are to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in freshwaters were also very low. As in 2009, measured dose rates were higher, relative to natural background, near to the discharge point. Fish and shellfish from the local marine environment showed low concentrations of a range of artificial radionuclides; these reflected the distant effects of discharges from Sellafield.

2.2 Springfields, Lancashire

The Springfields site at Salwick, near Preston, was owned by the NDA and operated by Springfields Fuels Limited (SFL), under the management of Westinghouse Electric UK Limited. On 1 April 2010, responsibility for the commercial fuel manufacturing business and SFL was transferred from the NDA to Westinghouse. The NDA retains responsibility for the historic nuclear liabilities on the site. The main function conducted is the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Other important activities include recovery of uranium from residues and decommissioning redundant plant. Monitoring around the site is carried out to check wider than just for uranium concentrations, but for other radionuclides such as daughter products from past discharges of uranium ore concentrate and for radionuclides detected from Sellafield.

The most recent habits survey was undertaken in 2006 (Tipple *et al.*, 2007). In 2010, habits information, based on a five-year rolling average (2006 – 2010) was revised, resulting in an increase in the occupancy rate for high-rate houseboat dwellers (see Appendix 1). A study commissioned by the Environment Agency considered the exposures of houseboat owners and wildfowlers in the Ribble Estuary area in relation to variables such as tidal inundation of channels and shielding from boat hulls and other materials (Punt *et al.*, 2011). Additional summary information is given in Appendix 4. The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 2.2.

Doses to the public

The *total dose* from all pathways and sources was assessed to have been 0.17 mSv (Table 2.1), or 17 per cent of the dose limit. The people most affected were adult houseboat dwellers in the Becconsall boatyard, who were exposed to external radiation from activity in muddy sediments. As in 2009, gamma dose rate measurements were not taken aboard a houseboat in 2010. Dose rates were derived by using measurements outside the houseboat, and adjusting these by the ratio of onboard and outside dose rates from results reported in earlier years. This information was directly applicable to the locations where high-rate occupancy was taking place. The increase from 0.15 mSv in 2009 was attributable to increased gamma dose rates (measured at Becconsall) in 2010. *Total doses* over the period 2004 – 2010 are given in Figure 2.4. The data indicate that *total dose* decreased over time, although there was an increase in 2008 compared with 2007. The trend at this site was primarily due to variations in gamma dose rates over sediment.

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

In 2010, the dose to people who consume seafood at high-rates, including a contribution from external exposure, was 0.017 mSv, which was less than 2 per cent of the dose limit for members of the public of 1 mSv. Of this dose, 0.012 mSv was from external exposure and the remainder was from the consumption of fish and shellfish. The dose in 2009 was 0.022 mSv. The difference between doses was mostly due to overall lower gamma dose rates at Warton Salt Marsh and Banks Marsh, and the inclusion of a lower LoD for americium-241 in fish, in comparison to those values in 2009. The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site. The dose to wildfowlers and farmers from exposure over salt marsh was 0.032 mSv, which was less than 4 per cent of the dose limit for members of the public of 1 mSv. The small increase in dose from 0.036 mSv (in 2009) was due to lower gamma dose rates over marsh in 2010. A study conducted by Rollo *et al.* (1994) showed that assessed doses to the public from inhaling Ribble Estuarine sediment re-suspended in the air were much less than 0.001 mSv, negligible in comparison with other exposure routes.

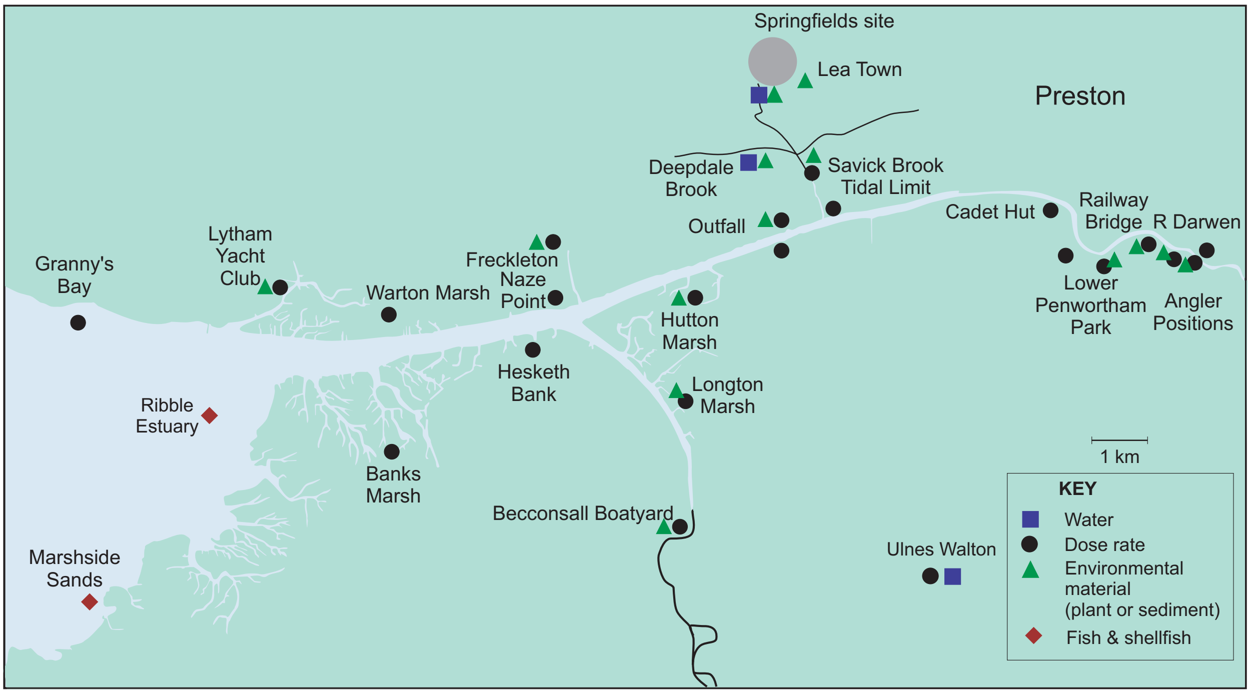


Figure 2.2. Monitoring locations at Springfields, 2010 (not including farms)

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges, with small amounts of other radionuclides present in discharges from the National Nuclear Laboratory's research and development facilities. Discharges from the site in 2010 were similar to those in 2009, albeit with small increases in tritium and carbon-14 releases from the research and development facilities.

The main focus of the terrestrial sampling was for the content of tritium, carbon-14, strontium-90, iodine-129, and isotopes of uranium, thorium, plutonium and americium in milk, fruit and vegetables. Grass and soil samples were collected and analysed for isotopes of uranium. The concentrations of radionuclides found in 2010 are shown in Table 2.3(a). As in previous years, elevated concentrations of uranium isotopes, compared with those at a greater distance, were found in soils around the site, but the isotopic ratio showed they are most likely to be from natural abundance. Low concentrations of thorium were found in fruit and vegetables. Most other concentrations of radionuclides were at limits of detection. Results were broadly similar to those of previous years.

Liquid waste discharges and aquatic monitoring

Regulated discharges of liquid waste (including gross alpha and beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and other transuranic radionuclides) are made from the Springfields site to the Ribble Estuary by two pipelines. Discharges in 2010 were generally similar to those in 2008, including the short half-life beta-emitting radionuclides (mostly thorium-234) that have decreased following the end of the Uranium Ore Concentrate purification process in 2006. Discharges of uranium increased in 2010. The Ribble Estuary monitoring programme consisted of dose rate measurements, and the analysis of sediments for uranium and thorium isotopes, and gamma emitting radionuclides. Locally obtained fish, shellfish and samphire were analysed by gamma-ray spectrometry and for uranium, thorium and plutonium isotopes.

Results for 2010 are shown in Tables 2.3(a) and (b). As in previous years, radionuclides due to discharges from both Springfields and Sellafield were found in the Ribble Estuary sediment and biota. Radionuclides found in the Ribble Estuary originating from Sellafield were technetium-99, caesium-137 and americium-241. Isotopes of uranium and the short half-life radionuclides thorium-234 and protactinium-234, from Springfields, were also found. Concentrations of the latter are closely linked to recent discharges from the Springfields site. In 2010, thorium-234 concentrations in sediments over the range of sampling sites were generally similar compared to 2009, although small increases in concentrations were observed at a few sites around Penwortham in comparison to 2009 data. Over a much longer timescale (1998 – 2010), these concentrations have declined due to reductions in discharges as shown by the trend of sediment concentrations at Lower Penwortham (Figure 2.3).

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

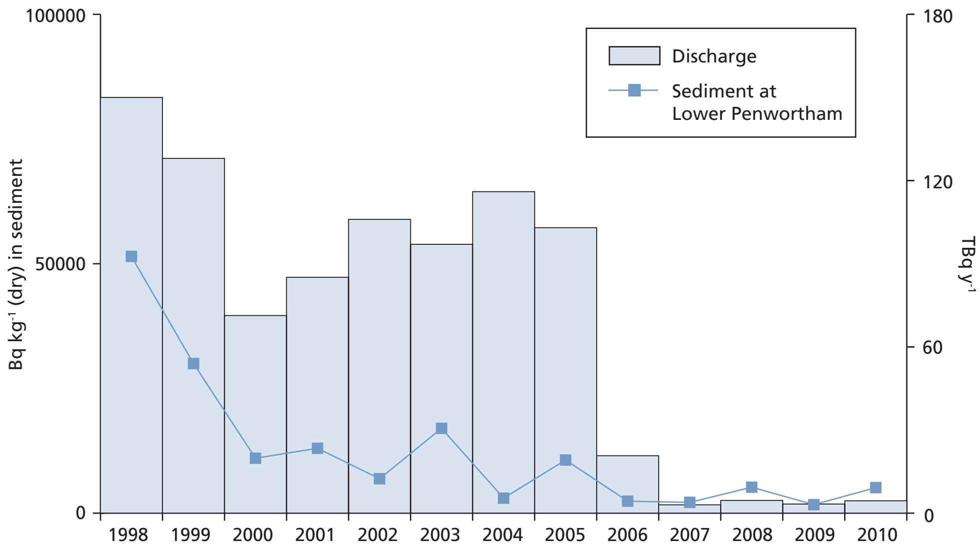


Figure 2.3. Total beta in liquid discharges from Springfields and concentrations in sediment at Lower Penwortham, 1998-2010

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 2010, gamma dose rates in the estuary, excluding rates taken for houseboat assessments, were generally similar to those in 2009, but with some variations at some sites. Gamma dose rates measured at Becconsall (vicinity of the houseboats) were increased, and those at Warton Salt Marsh and Banks Marsh were reduced overall, in 2010. Beta dose rates on fishing nets were also enhanced above those expected due to natural background and were due to concentrations of beta-emitting radionuclides from Springfields. Where comparisons can be made from similar ground types and locations, beta dose rates from sediments in 2010 were generally similar to those in 2009.

Solid waste disposals and related monitoring

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

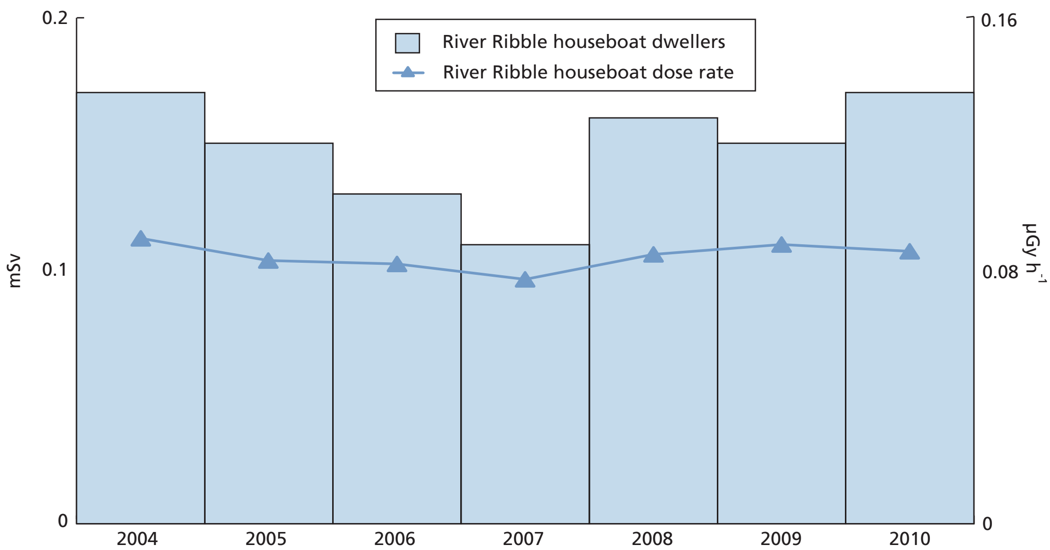


Figure 2.4. *Total dose* from all sources and dose rates at Springfields, 2004-2010

2.3 Sellafield, Cumbria

This site is operated by Sellafield Limited (formally called British Nuclear Group Sellafield Limited), but is owned by the NDA. The main operations on the Sellafield site are: fuel reprocessing at the Magnox Reprocessing Plant and the Thermal Oxide Reprocessing Plant (THORP); decommissioning and clean-up of redundant nuclear facilities; the manufacture of mixed oxide fuel and waste treatment and storage. The site also contains the Calder Hall Magnox nuclear power station, which ceased generating in 2003 and is undergoing decommissioning. The Windscale site is located on the Sellafield site, and is discussed in Section 2.4.

Sellafield Limited has begun to decommission the Calder Hall site. The first stage involves preparations for care and maintenance. These preparations have included, but have not been limited to, the cooling towers demolition and the progressive asbestos strip of 16 reactor heat exchangers. The project to strip asbestos cladding from the heat exchangers, turbine halls and associated plants was completed on 23 March 2010. In all, 2,300 tonnes of asbestos cladding was removed in a five year project. The top ducts are now being removed from the heat exchangers as part of ongoing hazard reduction, and to minimise impact on the environment they will be recycled where practicable. Preparations are ongoing for removal of spent fuel from the site's four reactors, which is scheduled to begin next year. Earlier work concerned with the asbestos removal from Calder Hall is described elsewhere (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a).

In January 2007, the HSE announced that it had granted consent for the re-start of the THORP facility (Health and Safety Executive, 2007a), and published a report on its investigation into the leak in 2005 (Health and Safety Executive, 2007b). In 2010, 302 tonnes of spent oxide fuel was reprocessed from THORP, compared with 196 tonnes in 2009. During 2010, the reprocessing of spent Magnox fuel was adversely affected by a number of unplanned outages and by issues with transport flask availability. A total of 317 tonnes of fuel was reprocessed in 2010, compared with 547 tonnes in 2009.

Every five years, a habit survey is conducted in the vicinity of the Sellafield site which investigates the exposure pathways relating to liquid and gaseous discharges, and direct radiation. Between these, annual habits surveys (which investigate the pathways relating to liquid discharges) review high-rate fish and shellfish consumption by local people (known as the Sellafield Fishing Community) and their intertidal occupancy rates. The most recent five-year habits survey was conducted in 2008 (Clyne *et al*., 2009). In the 2010 annual survey, changes were found in the amounts and mixes of species consumed. The consumption rate for mollusc decreased, together with reduced percentage of winkles relative to other molluscs. Crustacean consumption increased, whilst occupancy rates over sediments decreased in 2010. The revised habits data are given in detail in Appendix 1.

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

Monitoring of the environment and food around Sellafield reflects the historic and present day site activities. In view of the importance of this monitoring and the assessment of public radiation exposures, the components of the programme are considered in depth. The discussion is provided in four sub-sections, relating to the assessment of dose, the effects of gaseous discharges, the effects of liquid discharges and unusual pathways of exposure identified around the site.

2.3.1 Doses to the public

Total dose from all pathways and sources

The *total dose* from all pathways and sources has been assessed using consumption and occupancy data from the full habits survey of 2008 and the yearly review in 2010. Calculations were performed for four age groups (adult, 10y, 1y and prenatal).

In 2010, the highest *total dose* was assessed to be 0.18 mSv or 18 per cent of the dose limit to members of the public (Table 2.18). As in 2009, the most exposed age group were adults who consume molluscs at high-rates. This represents a considerable decrease from the *total dose* in 2009 (0.28 mSv). This was mostly attributable to small decreases in concentrations of polonium-210 in molluscs, and, to a lesser effect, from lower consumption rates of winkles in 2010.

The most significant contributors to the *total dose* in 2010 were from the consumption of molluscs, crustaceans and fish (71, 12 and 12 per cent, respectively), the most important radionuclides being americium-241, polonium-210, and plutonium-239+240 (31, 19 and 18 per cent, respectively).

Artificial radionuclides discharged by Sellafield (including external radiation) and historic discharges of naturally-occurring radionuclides from Whitehaven that contributed 0.14 mSv and 0.047 mSv, respectively (values are rounded to two significant figures). The contribution from the external radiation was less than 0.01 mSv. Data for naturally-occurring radionuclides in fish and shellfish, and their variation in recent years, are discussed in Section 7. However, the effects on Sellafield's high-rate consumers of fish and shellfish from historic discharges

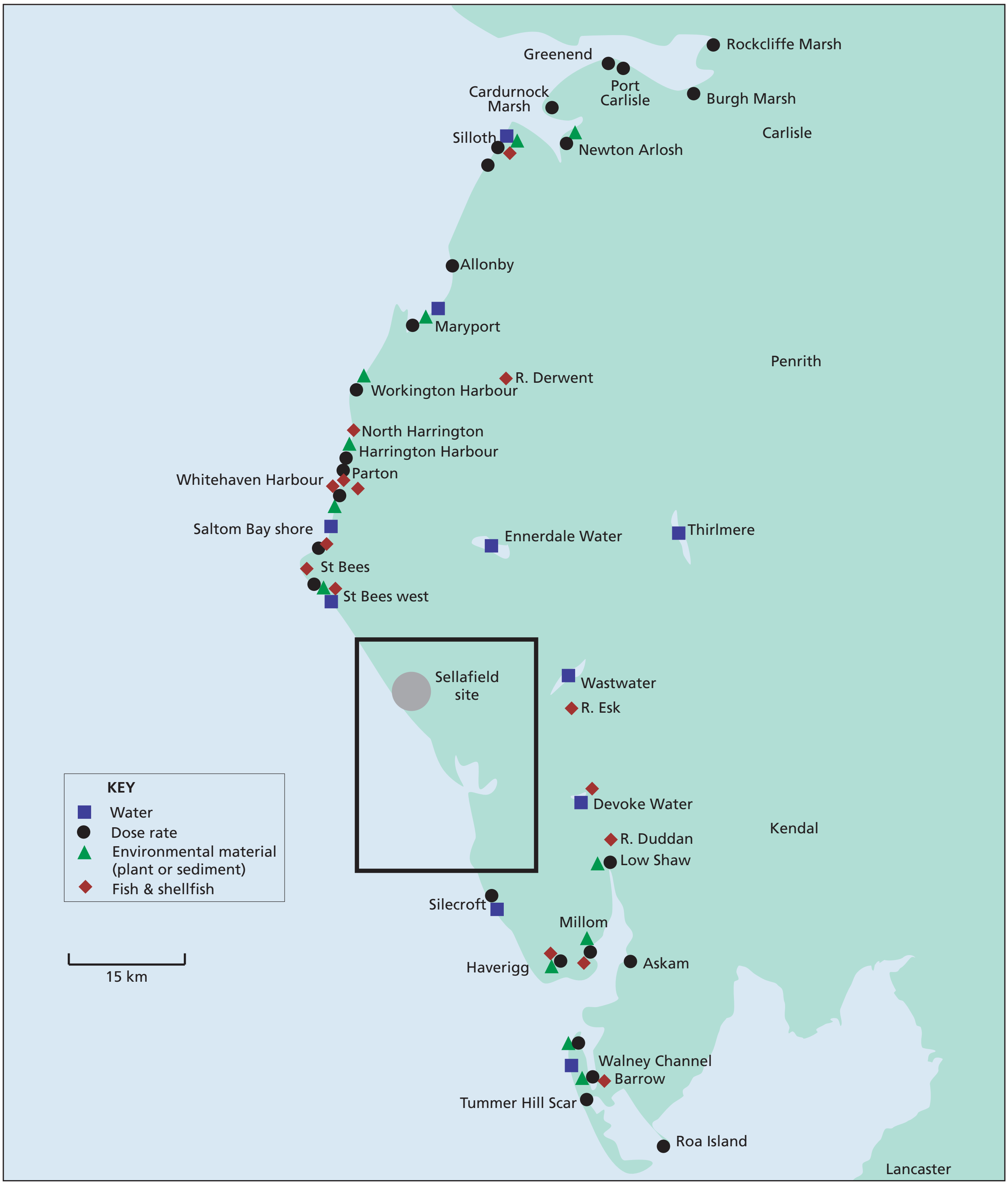


Figure 2.5. Monitoring locations in Cumbria, 2010 (not including farms)

of naturally-occurring radionuclides from non-nuclear industrial activity from the former phosphate works at Whitehaven (Cumbria) are included to determine their contribution to the *total dose*. These works were demolished in 2004 and the permit to discharge radioactive wastes revoked. The increase in concentrations of naturally-occurring radionuclides due to the historic discharges is difficult to determine above a variable background (see Appendix 1).

The contribution to the *total dose* of 0.14 mSv in 2010 from artificial radionuclides was lower than in 2009 (0.15 mSv). In 2010, the contributing radionuclides were mostly americium-241 (73 per cent), and to a lesser extent, plutonium-239+240 (21 per cent). Although concentrations of americium-241 and plutonium radionuclides in molluscs were lower (mussels only) in 2010, the decrease in the contribution to the *total dose* from 2009 was mostly due to the reduction in the winkle consumption rate.

The contribution to the *total dose* of 0.047 mSv in 2010 from naturally-occurring radionuclides was lower than in 2009 (0.14 mSv). In 2010, the contributing radionuclides

Figure 2.6. Monitoring locations at Sellafield, 2010 (not including farms)

were mostly polonium-210 (73 per cent), and to a lesser extent, lead-210 (16 per cent). Decreases in polonium-210 concentrations in molluscs (winkles), and to a much lesser extent a decrease in the winkle consumption rate and polonium-210 in crustaceans (lobster), contributed to a lower *total dose* in 2010.

Contributions to the highest *total dose* each year, by specific radionuclides, are given in Figure 2.21 over the period 2003 – 2010. This trend broadly reflected a combination of changes in the amount of shellfish eaten and of naturally-occurring radionuclides from the non-nuclear industry in these shellfish. The larger step changes (from 2004 to 2005 and from 2008 to 2009) were due to variations in naturally-occurring radionuclides (mainly polonium-210 and lead-210). The changes in *total dose* in the intervening years (from 2005 to 2007) were mainly a result of changes in seafood consumption rates. The most recent decrease in 2010 was due to both reductions in naturally-occurring radionuclides concentrations (polonium-210) and consumption rates. The largest proportion of the *total dose*, up till 2008, was due to enhanced naturally-occurring radionuclides from the historic discharges at Whitehaven; with a smaller contribution from the historic discharges from Sellafield. Since 2008, 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. The artificial radionuclides giving the largest contribution to the *total dose* were americium-241and plutonium-239+240. Recent and current discharges of technetium-99 contributed approximately 1 per cent of the dose (from artificial radionuclides) to the Sellafield seafood consumers in recent years.

Other age groups received less exposure than the adult *total dose* of 0.18 mSv in 2010 (1y: 0.034; 10y: 0.069; prenatal: 0.052, rounded to two significant figures). *Total doses* estimated for each age group may be compared with an average dose of approximately 2.2 mSv to members of the UK public from all natural sources of radiation (Watson *et al*., 2005) and to the annual dose limit to members of the public of 1 mSv.

Doses from gaseous discharges and direct radiation

In 2010, the dose to people receiving the highest *total dose* from the pathways predominantly relating to gaseous discharges and direct radiation was 0.011 mSv (Table 2.18). The most exposed age group were children (1y) who consumed milk at high-rates. This represents a decrease from the *total dose* from 0.046 mSv, and a change in the most exposed age group (from adults) in 2009. The most significant contributors in 2010 to the *total dose* for children were from the consumption of milk and potatoes (82 and 12 per cent, respectively), the most important radionuclides being strontium-90, cobalt-60, caesium-137 and ruthenium-106 (37, 14, 14 and 13 per cent, respectively).

Other age groups received less exposure than the 1-year-old children *total dose* of 0.011 mSv in 2010 (adult: 0.007; 10y: 0.008; prenatal: 0.005). In 2009, the most exposed age group were adults who consumed game meat at high-rates, and the most significant contributions to adult's *total dose* were from caesium-137 (as total caesium) in game and polonium-210 in seafood. The change in the critical age group from adults to children was mostly due to a decrease in the total caesium activity (86 Bq kg^{-1} in 2009; 1.6 Bq kg^{-1} in 2010) in game.

Contributions to the highest *total dose* each year, by specific radionuclides, are given in Figure 2.22 over the period 2003 – 2010. Up till 2007, the *total dose* was reducing each year because of the permanent shut down of Calder Hall power station on the Sellafield site which ended gaseous discharges of argon-41 and sulphur-35. In 2008, the assessment method included cobalt-60 results (below LoD) because detectable activity was observed in other samples from the terrestrial environment. This increased the *total dose* over previous years. The relative increase and the change in the radionuclide contributors in 2009 (and not observed in 2010) resulted from the increase of total caesium in game and the change of the critical age group.

Doses from liquid discharges

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

Source specific doses

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

Doses from terrestrial food consumption

In 2010, 1-year old children who consumed milk at high-rates, and are exposed to external and inhalation pathways from gaseous discharges, received the highest dose of all for age groups, at 0.022 mSv (adult: 0.018; 10y: 0.017; prenatal: 0.011) or approximately 2 per cent of the dose limit to members of the public (Table 2.18). The reason for the decrease in dose from 0.028 mSv in 2009, and for the change in the critical age group from adults to infants, are the same as those contributing to the maximum *total dose* from gaseous discharges and direct radiation.

Doses from seafood consumption

Two sets of habit data were used in these dose assessments. One was based on the habits seen in the area each year (2010 habits survey). The second was based on a five-year

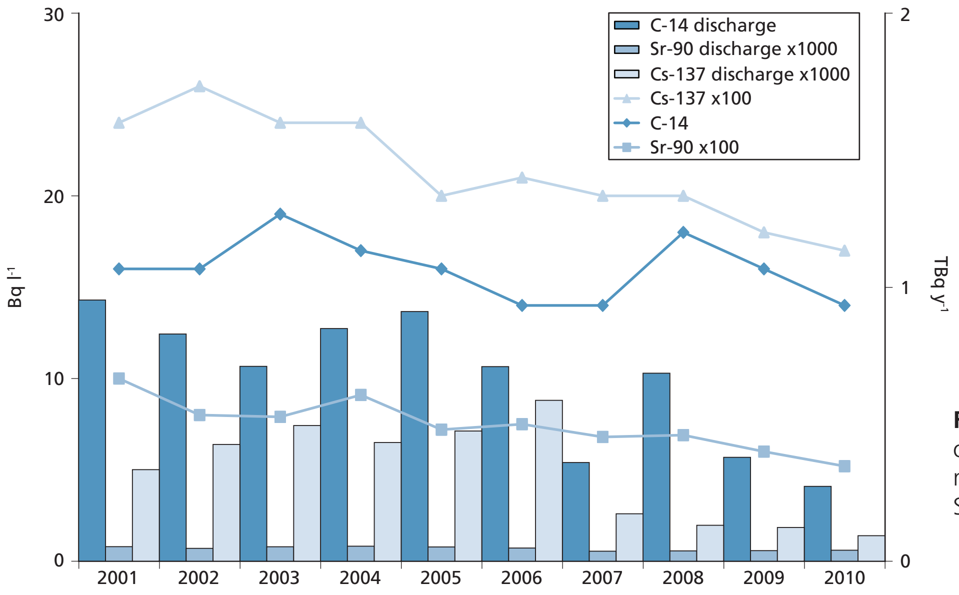


Figure 2.7. Discharges of gaseous wastes and monitoring of milk near Sellafield, 2001-2010

rolling average using habits data gathered from 2006 to 2010. Small changes were found in the amounts and mixes of species consumed. For mollusc, the consumption rate decreased for the 2010 data set, but slightly increased for the 2006 – 2010 data set. Crustacean consumption increased for 2010, with small changes in rates for 2006 – 2010. Occupancy rates over sediments decreased for 2010 and slightly increased for 2006 – 2010. The revised habits data are given in detail in Appendix 1. Aquatic pathway habits are normally the most important in terms of dose at Sellafield and are surveyed every year. This allows generation of a unique yearly set of data and also rolling five-year averages. The rolling averages are intended to smooth the effects of sudden changes in habits and provide an assessment of dose that follows more closely changes in radioactivity concentrations in food and the environment. These are used for the main assessment of doses from liquid discharges, and follow the recommendations of the report of the Consultative Exercise on Dose Assessments (Food Standards Agency, 2001a).

Table 2.18 summarises source specific doses to seafood consumers in 2010. The doses to people from artificial radionuclides, who consume a large amount of seafood, were 0.16 mSv and 0.18 mSv, using annual and five-year rolling average habits data, respectively. These doses each include a contribution due to external radiation exposure over sediments. Both the annual and the rolling average derived doses were lower than the corresponding dose in 2009 (0.19 mSv and 0.20 mSv, respectively). The reason for the decrease in doses in 2010 is the same as those contributing to maximum *total dose* from liquid discharges.

In 2010, using maximising assumptions for the dose coefficients, and the five-year rolling average habits data, the dose to local people (who consume seafood at high-rates) due to the enhancement of concentrations of naturally-occurring radionuclides from former non-nuclear industrial activity in the Sellafield area was estimated to be 0.082 mSv in 2010. Most of this was due to polonium-210 (75 per cent), and lead-210 to a lesser extent (13 per cent).

The reason for the decrease in doses in 2010 (from 0.18 mSv in 2009) is the same as those contributing to maximum *total dose* from liquid discharges. For comparison with the assessment using the five-year average habits data, the dose from the single-year assessment for the Sellafield seafood consumers (based on consumption rates and habits survey data in 2010) was 0.079 mSv (Table 2.18).

Taking artificial and enhanced radionuclides together, the source specific doses were 0.24 and 0.26 mSv respectively. These estimates are larger than the estimate of *total dose* from all sources of 0.18 mSv. The main reason for this is differences in the approach to selecting consumption rates for seafood to represent the most exposed person. The source specific method pessimistically assumes that consumption of high rates of fish, crustaceans and molluscs is additive whereas the *total dose* method takes more realistic consumption rate information from the local habits survey. The differences in dose are not unexpected and well within the uncertainties in the assessments.

Exposures representative of the wider communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Fleetwood, Northern Ireland, North Wales and the Isle of Man have been kept under review (Table 2.18). Where appropriate, the dose from consumption of seafood has been summed with a contribution from external exposure over intertidal areas. The doses received by people in the wider communities are significantly less than for the local Sellafield people because of the lower concentrations and dose rates further afield. There were generally small changes in the doses in each area when compared with those in 2009 (Table 2.17). All doses were well within the dose limit for members of the public of 1 mSv.

The dose to people, who typically consume 15 kg of fish per year from landings at Whitehaven and Fleetwood, is also given in Table 2.18. This consumption rate represents an average for a typical seafood consumer in Cumbria. The dose to such a person was very low, less than 0.005 mSv in 2010.

Doses from sediments

The main radiation exposure pathway associated with sediments is due to external dose from gamma-emitting radionuclides adsorbed on intertidal sediments in areas frequented by the public. This dose can make a significant contribution to the total exposure of members of the public in coastal communities throughout the Irish Sea but particularly in Cumbria and Lancashire. Gamma dose rates currently observed in intertidal areas are mainly due to radiocaesium and naturally-occurring radionuclides. For some people, the following pathways may also contribute to doses from sediments: exposure due to beta-emitters during handling of sediments or fishing gear; inhalation of resuspended beach sediments; and inadvertent ingestion of beach sediments. These pathways are considered later: in the main, they give rise to only minor doses compared with those due to external gamma emitters.

Gamma radiation dose rates over areas of the Cumbrian coast and further afield in 2010 are given in Table 2.9. The results of the assessment of external exposure pathways are included in Table 2.18. The highest whole body exposures due to external radiation resulting from Sellafield discharges, past and present, are received by people who live in houseboats in the Ribble Estuary in Lancashire. In 2010, their dose was 0.16 mSv or 16 per cent of the dose limit for members of the public (see Section 2.2). Other people received lower external doses in 2010. The most important of these was found in the Ravenglass estuary, where exposures are represented by the occupancy of a nature warden, and the dose was 0.044 mSv. In 2009, this dose was 0.048 mSv. Overall, gamma dose rate measurements in 2010 were lower than in 2009 in the Ravenglass estuary. However the decrease in dose in 2010 was mostly due to lower sediment concentrations in the area, resulting in lower contributions from inhalation and ingestion of sediment.

As in 2009, the estimated dose to wildfowlers along the Dumfries and Galloway coast, including their external dose from occupancy over salt marshes, was less than 0.005 mSv in 2010, or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 2.18).

The doses to people from a number of other activities were also estimated in 2010. Assessments were undertaken for typical residents using local intertidal areas for recreational purposes, and for the typical tourist visiting the coast of Cumbria. The use by residents for two different environments, at a number of locations at a distance from the Sellafield influence, have been assessed; residents that visit and use beaches and residents that visit local muddy areas or salt marsh. Typical occupancy rates have been assumed and appropriate gamma dose rates used from Table 2.9. The activities for the typical tourist included consumption of local seafood and occupancy on beaches. Typical occupancy rates have been assumed, concentrations of radioactivity in fish and shellfish used from Table 2.5, and appropriate gamma dose rates used from Table 2.9. The consumption and occupancy rates for activities of typical residents and tourists are provided in Appendix 1.

The dose to people from recreational use of beaches varied from 0.007 to 0.013 mSv with the higher doses being closer to the Sellafield source. The equivalent doses for use of salt marsh and muddy areas had a greater variation from <0.005 to 0.016 mSv but were of a similar order of magnitude. The values for these activities were similar to those for 2009. The dose to the typical tourist visiting the coast of Cumbria, including a contribution from external exposure, was estimated to be less than 0.005 mSv (and similar to that of 0.005 mSv in 2009).

Doses from handling fishing gear and sediment

Exposures can also arise from contact with beta-emitters during handling of sediments, or fishing gear on which fine particulates have become entrained. Habits surveys keep under review the amounts of time spent by fishermen handling their fishing gear, and by bait diggers and shellfish collectors handling sediment. For those most exposed, rates for handling nets, pots and sediments are provided in Appendix 1. In 2010, the skin doses to fishermen from handling their gear (including a component due to naturally-occurring radiation), and bait diggers and shellfish collectors from handling sediment, were 0.10 mSv and 0.037 mSv, respectively and both were less than 0.5 per cent of the appropriate annual dose limit of 50 mSv specifically for skin. Therefore, both handling of fishing gear and sediments continued to be minor pathways of radiation exposure.

Doses from atmospheric sea to land transfer

At Ravenglass, the infant age group received the highest dose from consuming terrestrial foods that were potentially affected by radionuclides transported to land by sea spray. In 2010, their dose (including contributions from Chernobyl and weapon test fallout) was estimated to be 0.038 mSv, which was less than 4 per cent of the dose limit for members of the public. The largest contribution of the dose was from ruthenium-106 and cerium-144 in milk. Both these activity concentrations were below the LoD in all samples taken. This represents an increase in the dose, in comparison to the value obtained in 2009 (0.012 mSv). The increase in dose in 2010 was attributed to the inclusion of both LoD values for the assessment, which were larger than those values used in the 2009 assessment. Therefore, as in 2009, sea-to-land transfer is not of radiological importance in the Ravenglass area.

Doses from seaweed and seawashed pasture

Although small quantities of samphire, *Porphyra* and *Rhodymenia* (a red seaweed) may be eaten, the dose to people in South Wales who consume laverbread at high-rates was less than 0.005 mSv, confirming the low radiological significance of this exposure pathway.

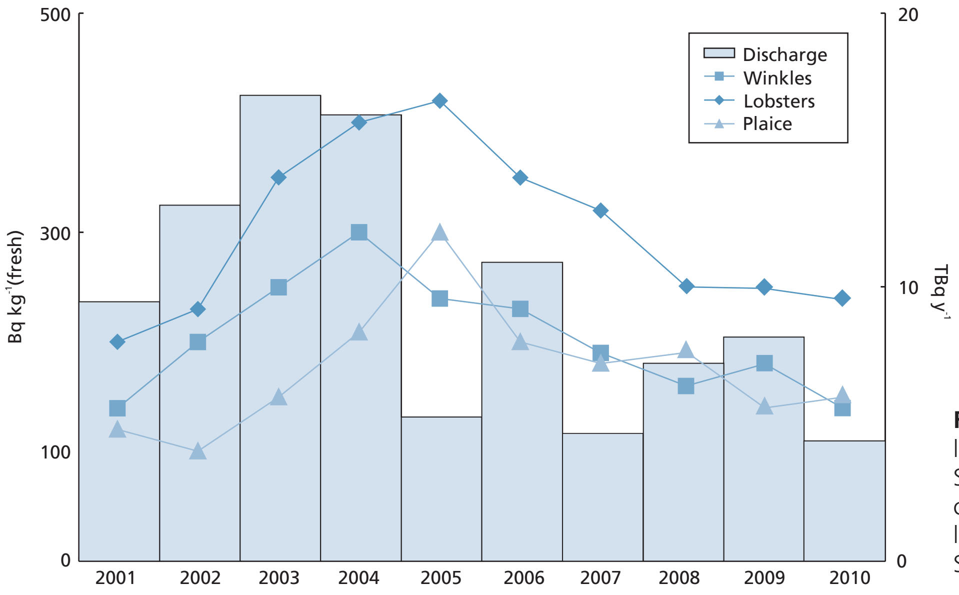


Figure 2.8. Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

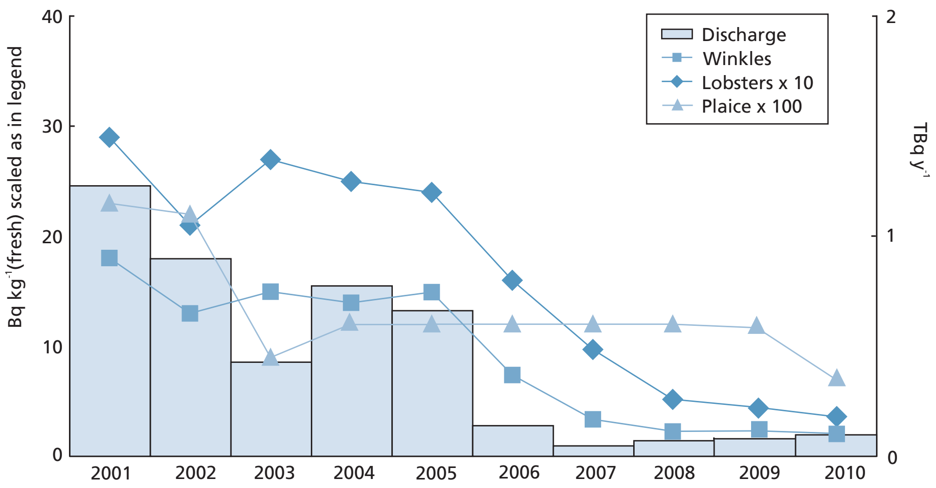


Figure 2.9. Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

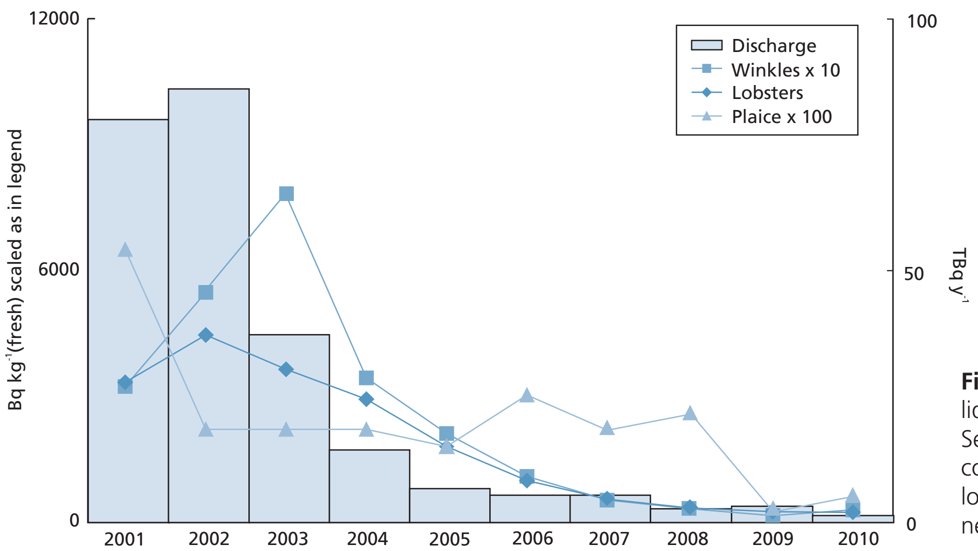


Figure 2.10. Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

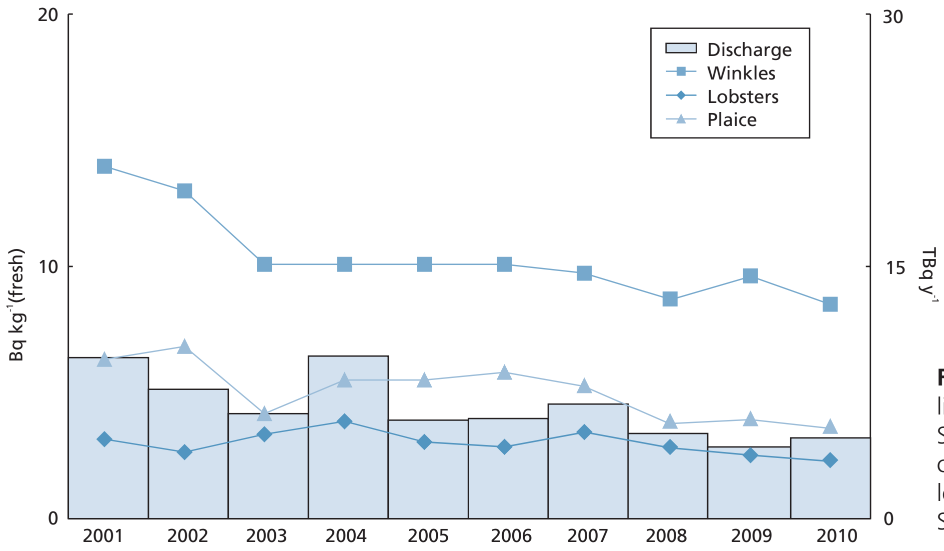


Figure 2.11. Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

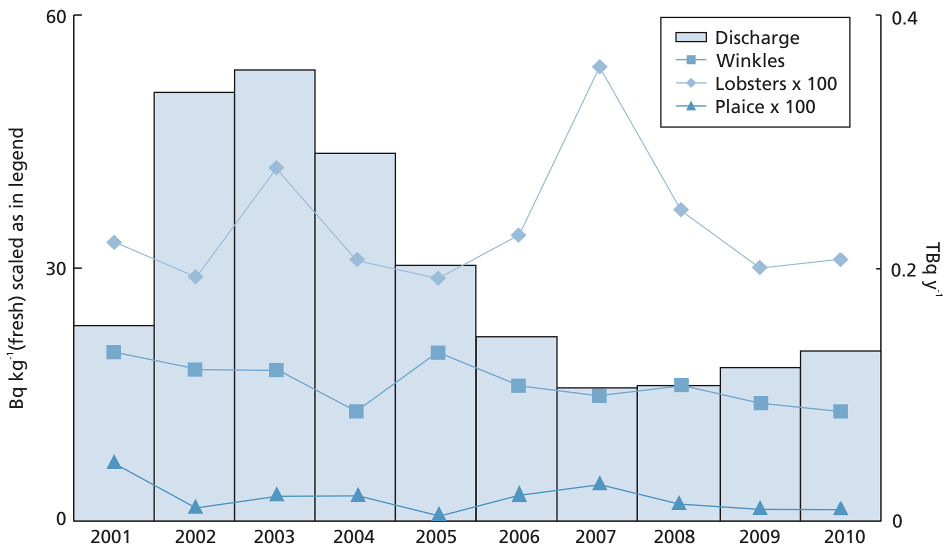


Figure 2.12.
Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

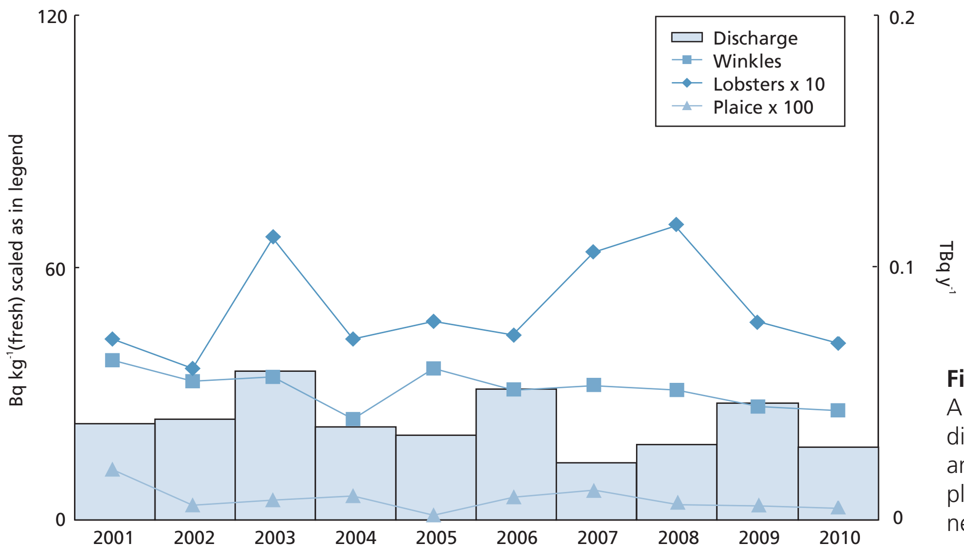


Figure 2.13.
Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2001-2010

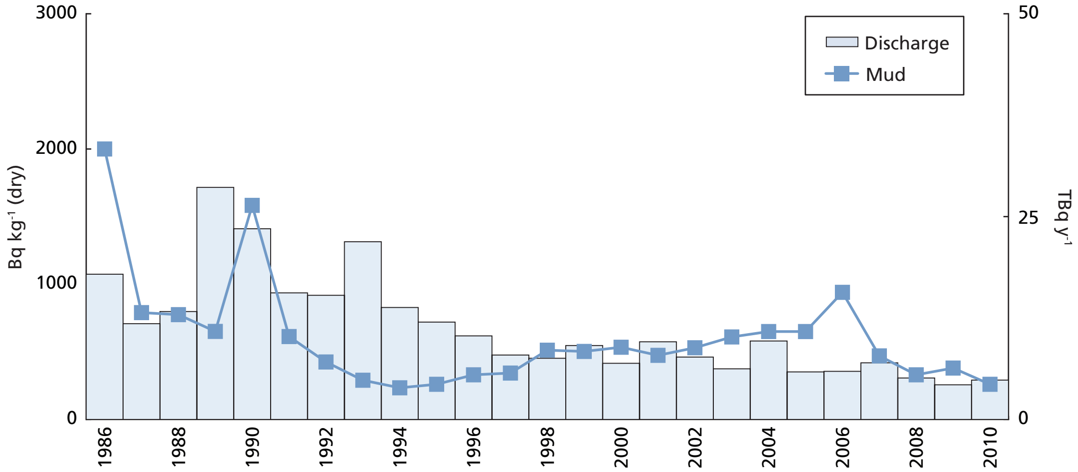


Figure 2.14. Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1986-2010 (data prior to 1988 are from BNFL surveys)

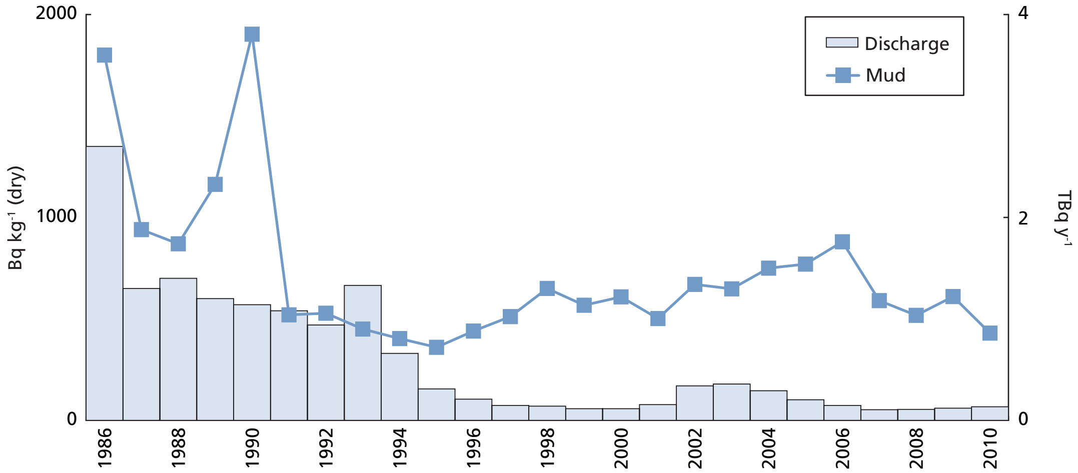


Figure 2.15. Plutonium-alpha liquid discharge from Sellafield and plutonium-239/240 concentration in mud at Ravenglass, 1986-2010 (data prior to 1988 are from BNFL surveys)

Seaweeds are sometimes used as fertilisers and soil conditioners. Assuming that high-rate vegetable consumers obtain all of their supplies from the monitored plots near Sellafield, the dose in 2010 was estimated to be 0.012 mSv. The increase in dose from 0.009 mSv in 2009 was due to the inclusion of the technetium-99 concentration in rhubarb (not sampled in 2009). 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. In 2010, the infant age group received the highest dose, the change in the critical age group (from adults), was due to excluding the LoD for americium-241 in potatoes (not sampled in 2010). 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. Exposure of vegetable consumers at Hinkley Point is given in Section 4.6.

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

In the Scottish islands and coastal communities, seaweed is also eaten directly by sheep and cattle grazing on the foreshore. A research study, conducted by the HPA on behalf of the Food Standards Agency and SEPA, investigated the potential transfer of radionuclides from seaweed to meat products and also from crops grown on land where seaweed had been applied as a soil conditioner (Brown *et al.*, 2009). The study concluded that the highest levels of dose to people using seaweed, as a soil conditioner or an animal feed, were in the range of a few

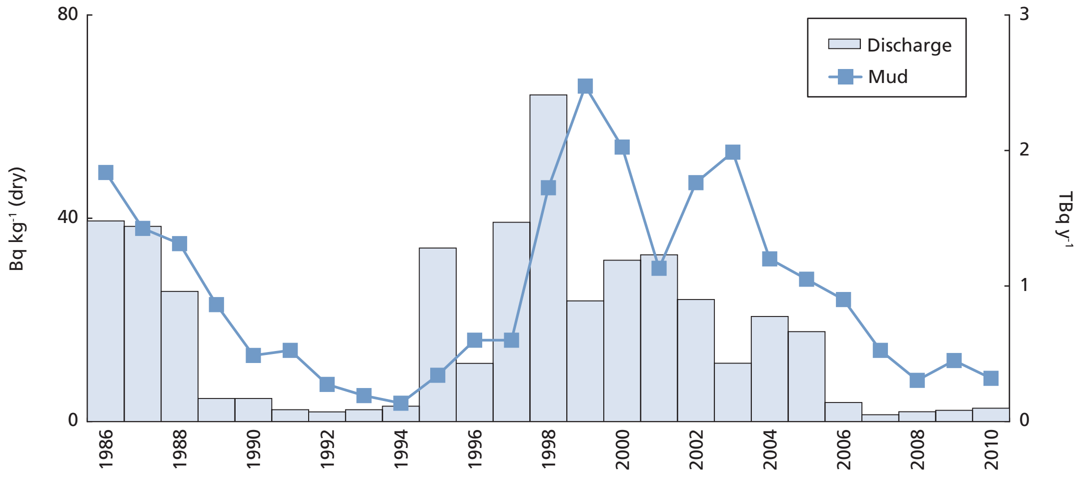


Figure 2.16. Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1986-2010 (data prior to 1988 are from BNFL surveys)

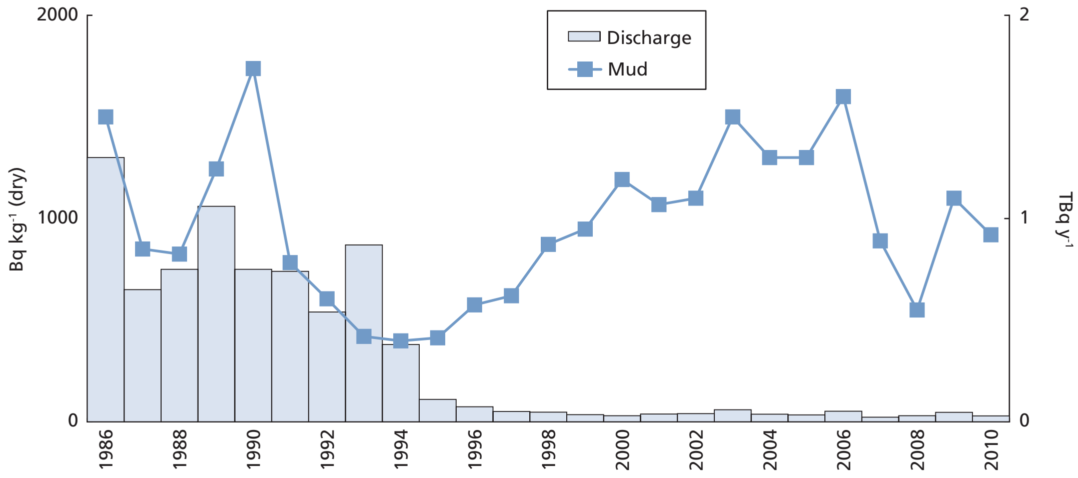


Figure 2.17. Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1986-2010 (data prior to 1988 are from BNFL surveys)

microsieverts and the majority of the doses are at least a factor of 100 lower. The report is available on SEPA website,

http://www.sepa.org.uk/radioactive_substances/publications/other_reports.aspx

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

2.3.2 Gaseous discharges

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

A new permit, with a higher limit for antimony-125, was effective from 1 April 2010 to reflect the trend of increasing releases of this radionuclide from the Sellafield Fuel Handling Plant in 2009. This was associated with increasingly high burn-up spent Magnox fuels being received at Sellafield from the remaining operational power stations at Wylfa and Oldbury. The increase in the limit was accepted and permitted by the Environment Agency after a favourable Euratom Article 37 opinion was received from the European Commission.

Discharges of gaseous wastes from Sellafield in 2010 were much less than the permit limits, and were generally similar to those in 2009, although discharges of tritium and antimony-125 (and to a lesser extent, plutonium radionuclides) decreased in 2010.

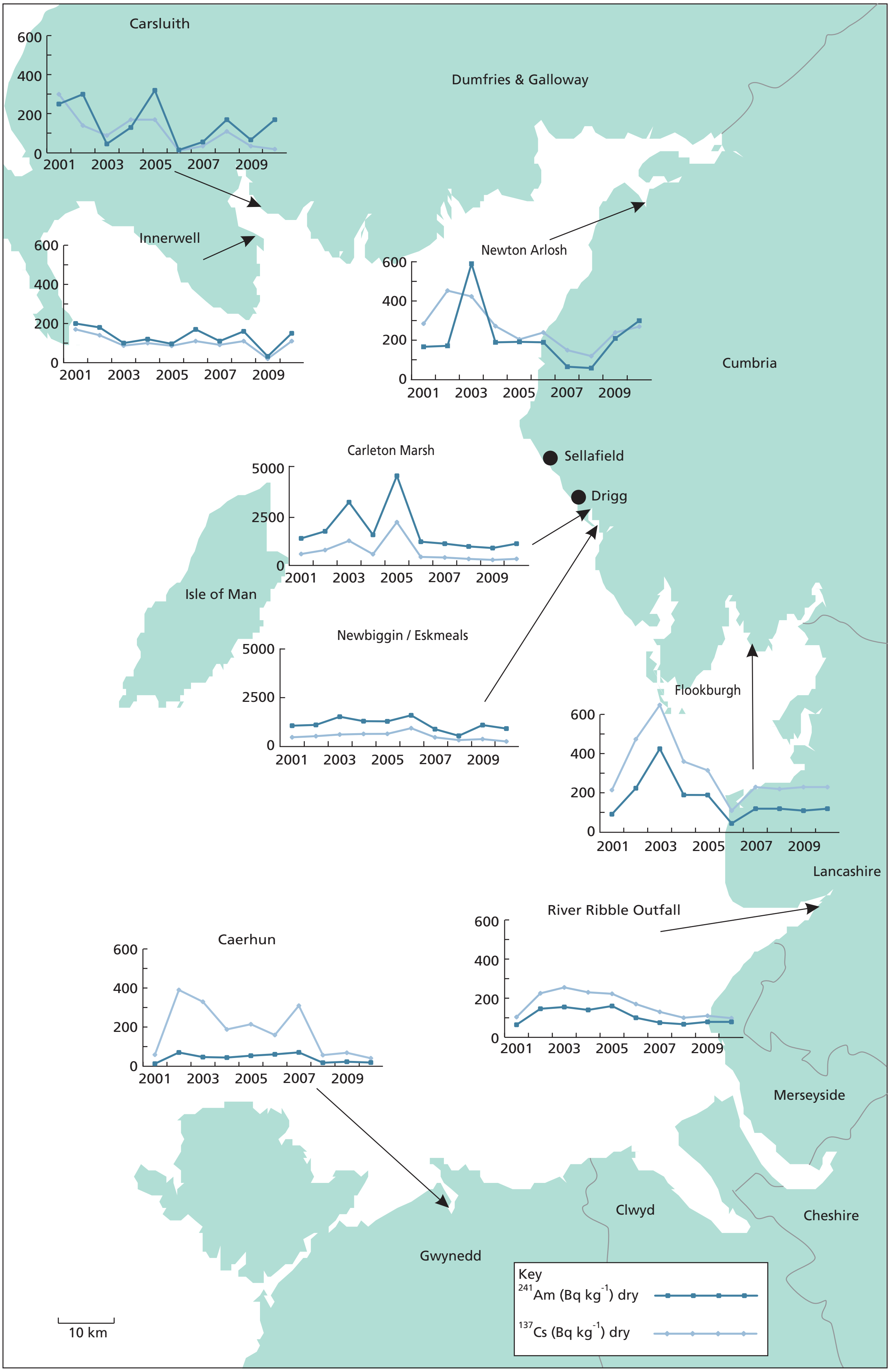


Figure 2.18. Concentrations of americium-241 and caesium-137 in coastal sediments in North West England and South West Scotland between 2001-2010 (Note different scales used for Newbiggin and Carleton Marsh)

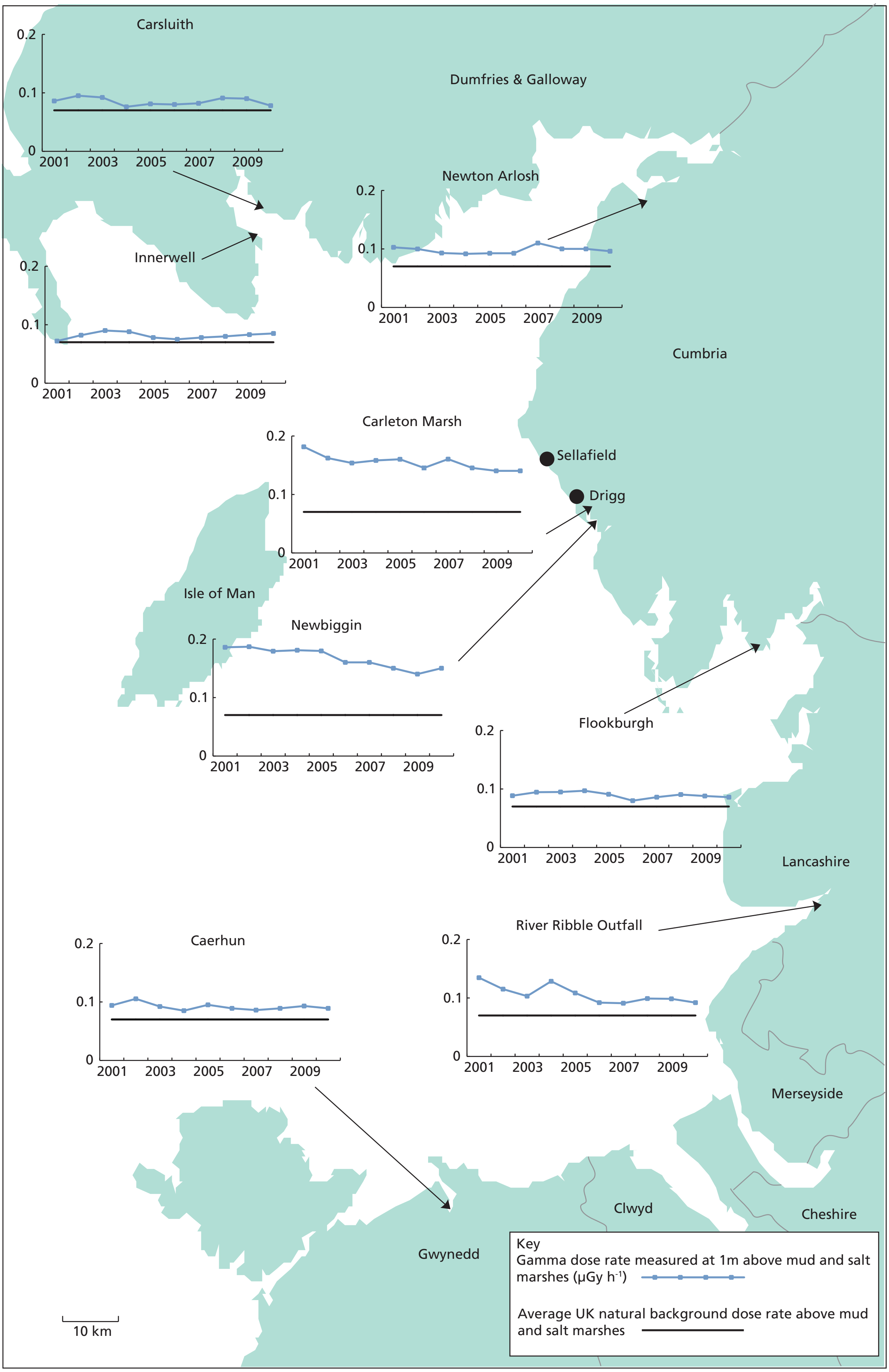


Figure 2.19. Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England and South West Scotland between 2001-2010

Monitoring around the site related to gaseous discharges

There is a substantial programme of monitoring of terrestrial foods in the vicinity of Sellafield conducted by the Food Standards Agency, which includes samples collected in Scotland by SEPA. This programme is the most extensive of those for the nuclear sites in the UK, reflecting the scale of the discharges from the site. A wide range of foodstuffs was sampled in 2010 including milk, fruit, vegetables, meat and offal, game, cereals and environmental materials such as grass and soil. Samples were obtained from different locations around the site to allow for variations due to the influence of meteorological conditions on the dispersal of gaseous discharges. The analyses conducted included gamma-ray spectrometry and specific measurements for tritium, carbon-14, strontium-90, technetium-99, iodine-129, uranium and transuranic radionuclides.

The results of monitoring in 2010 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 2009. Concentrations of radionuclides in meat and offal from cattle and sheep were low (many at, or below, the LoD), with only limited evidence of the effects of Sellafield's atmospheric discharges detected in data for tritium, carbon-14 and strontium-90 (values for iodine radionuclides were below the limit of detection). As in 2008, the total caesium activity concentration in game (deer muscle) was low again (0.25 Bq kg^{-1} in 2010 from 86 Bq kg^{-1} in 2009), but enhanced again in wood pigeon (16 Bq kg^{-1} in 2010 from 2.2 Bq kg^{-1} in 2009). In recent years these concentrations have fluctuated widely. The cause of the fluctuations is not known, but is not linked to variations in discharges. Plutonium concentrations in game when detectable were low and much lower than those found in seafood. A wide range of fruit and vegetables was sampled in 2010 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. Small decreases in concentrations of carbon-14 were found in some food samples (including meat and offal), in comparison to 2009. Concentrations of transuranic radionuclides, when detectable in these foods, were very low. In 2010, antimony-125 concentrations were below limits of detection in foods and soil, and just above the detection limit in grass, despite relatively enhanced discharges over the last two years. Trends in maximum concentrations of radionuclides, and corresponding discharge levels, in milk near Sellafield over the last decade are shown in Figure 2.7. Over the whole period, concentrations of carbon-14 are relatively constant, and caesium-137 concentrations (and strontium-90 to a lesser extent) are declining overall.

2.3.3 Liquid discharges

Regulated liquid discharges are made from a variety of sources at the site including the fuel storage ponds, the reprocessing plants, from the retrieval and treatment of legacy wastes, the laundry and from general site drainage. Wastes from these sources are treated and then discharged to the Irish Sea via the sea pipelines that terminate 2.1 km beyond low water mark. Liquid wastes are also discharged from the factory sewer to the Ehen Estuary. Discharges from the Sellafield pipelines during 2010 are summarised in Appendix 2. The current permit sets limits on gross alpha and beta, and 16 individual nuclides. In addition to overall site limits, individual limits have been set on discharges from the main contributing plants on site (Segregated Effluent Treatment Plant, Site Ion Exchange Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP). All of the discharges in 2010 were well below the limits in the permit. Discharges were generally similar to those in 2009, although carbon-14, technetium-99, americium-241 and uranium releases were decreased in 2010. Overall, this reflects the varying amounts of fuel reprocessed in the THORP and Magnox reprocessing plant shutdowns from year to year.

Discharges of technetium-99 were lower in 2010 than in 2009, and their long-term downward trend, from their peak of 192 TBq in 1995, has continued (Figure 2.20). Technetium-99 discharges from Sellafield are now substantially reduced and met the target set for 2006 in the UK National Discharges Strategy (Department for Environment, Food and Rural Affairs, 2002). The reduction of technetium-99 discharges was due to the diversion, since 2003, of the Medium Active Concentrate (MAC) waste stream from Magnox reprocessing to vitrification and, since 2004, use of a new chemical precipitant (Tetraphenylphosphonium Bromide) in the Enhanced Actinide Removal Plant to remove technetium-99 from the historic stock of MAC.

Monitoring of the marine environment

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

Monitoring of fish and shellfish

Concentrations of beta/gamma activity in fish from the Irish Sea and from further afield are given in Table 2.5. Data are listed by location of sampling or landing point, north to south in Cumbria, then in approximate order of increasing distance from Sellafield. Concentrations of specific naturally-occurring radionuclides in fish and shellfish in the Sellafield area are given in Section 7. The 'Sellafield Coastal Area' extends 15 km to the north and to the south of Sellafield, from St Bees Head to Selker, and 11 km offshore; most of the fish and shellfish eaten by local people, and who are high-rate consumers, are taken from this area. Specific surveys are conducted in the smaller 'Sellafield Offshore Area' where experience has shown that good catch rates may be obtained. This area consists of a rectangle, one nautical mile (1.8 km) wide by two nautical miles (3.6 km) long, situated south of the pipelines with the long side parallel to the shoreline; it averages about 5 km from the pipeline outlet.

The concentrations of most radionuclides have decreased over the previous decades in response to decreases in discharges. Concentrations generally continue to reflect changes in discharges, over time periods, characteristic of radionuclide mobility and organism uptake. Trends in concentrations of radionuclides, and corresponding discharge levels, in seafood near Sellafield (over the last decade) are shown in Figures 2.8 – 2.13. There is variability from year to year, particularly for the more mobile radionuclides. Liquid discharges of technetium-99 decreased in 2010, these concentrations in fish and shellfish have continued to show a reduction from their most recent peak in 2003, but with a small increase in 2010 compared with 2009 (Figure 2.10). For the transuranic elements (Figures 2.12 – 2.13), the long-term trends in reductions of concentrations from earlier decades appear to be slowing. In recent years, elevated concentrations of americium-241 in winkles in 2008, and plutonium-239+240 in lobsters in 2007, were observed. Overall, concentrations of plutonium radionuclides and americium-241 were mostly lower in 2010 compared to 2009.

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 were lower in 2010 than those in 2009. In addition, the caesium-137 concentration in brown trout from the River Calder was 33 Bq kg^{-1} in 2010 and significantly lower than the value to 2009 (which has not been collected since 2002 due to difficulties in obtaining a sample), which flows through the Sellafield site. Activity concentrations in fish (and shellfish) generally reflect progressive dilution with increasing distance from Sellafield. However, the rate of decline of caesium-137 concentrations with distance is not as marked as was the case when significant reductions in discharges were achieved some years ago. There is therefore a greater contribution from historical sources.

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

Other artificial beta/gamma-emitting radionuclides detected in fish included carbon-14 and tritium. With an expected carbon-14 concentration from natural sources ~ 25 Bq kg^{-1}, the data suggest a local enhancement of carbon-14 due to discharges from Sellafield. Tritium (total) gives the highest concentrations of radioactivity in marine fish of approximately 100 Bq kg^{-1}, with similar concentrations of organically bound tritium (OBT). These limited results suggest that virtually all of the total tritium in marine samples was associated with organic matter, although due to the low toxicity of this element and the low concentrations observed, the dose implication was very small. The concentrations of organically bound tritium (OBT) in environmental samples are much lower than observed in the Severn Estuary near Cardiff (see Section 6).

For shellfish, a wide range of radionuclides are detectable, owing to generally greater uptake of radioactivity by these organisms from sediments. Generally, molluscs tend to contain higher concentrations than crustaceans and both contain higher concentrations than fish. Concentrations of beta/gamma-emitting radionuclides are shown in Table 2.6 (Table 2.7 for plutonium-241). Consumers who collect seafood in the Sellafield coastal area provided some of the winkles, mussels and limpets sampled. There can be substantial variations between species; for example, lobsters tend to concentrate more technetium-99 than crabs (see also Knowles *et al*. 1998, Swift and Nicholson, 2001). The highest concentrations from Sellafield discharges are of tritium, carbon-14, and technetium-99. Comparing 2010 and 2009 data across a wide range of sampling locations and shellfish species, technetium-99 concentrations were generally similar, but reduced in comparison to those in earlier years due to progressive reductions in discharges of this radionuclide over a longer time. Concentrations of other radionuclides in 2010 were broadly similar to 2009, however comparing equivalent locations in the north-eastern Irish Sea indicates that caesium-137 concentrations were generally reduced in 2010.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2010 are given in Table 2.7. Transuranics are less mobile than other radionuclides in seawater and have a high affinity for sediments; this is reflected in higher concentrations of transuranics in shellfish compared with fish. Comparing 2010 and 2009 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish in 2010 were generally similar to those in 2009. Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In comparison to 2009 data, the concentrations in shellfish were overall lower for plutonium radionuclides and americium-241 at most of the north-eastern Irish Sea locations in 2010 (including Silloth, Parton, Whitehaven, Nethertown, Ravenglass and at the Sellafield coastal area). These observations are likely to have resulted from a combination of mechanisms including natural environmental variability and redistribution of sediments due to natural processes.

Monitoring of sediments

Radionuclides in Sellafield liquid discharges are taken up into sediments along the Cumbrian Coast in particular in more muddy (fine grained) areas such as estuaries. Some of these areas are used by the public. Levels of radionuclides are regularly monitored, both because of their relevance to exposure and in order to keep distributions of radioactivity under review. The results for 2010 are shown in Table 2.8. Radionuclides detected include cobalt-60, strontium-90, ruthenium-106, caesium-137 and transuranics. The highest concentrations found are close to the site and in fine particulate materials in estuaries and harbours, rather than the coarser-grained sands on open beaches. The concentrations of

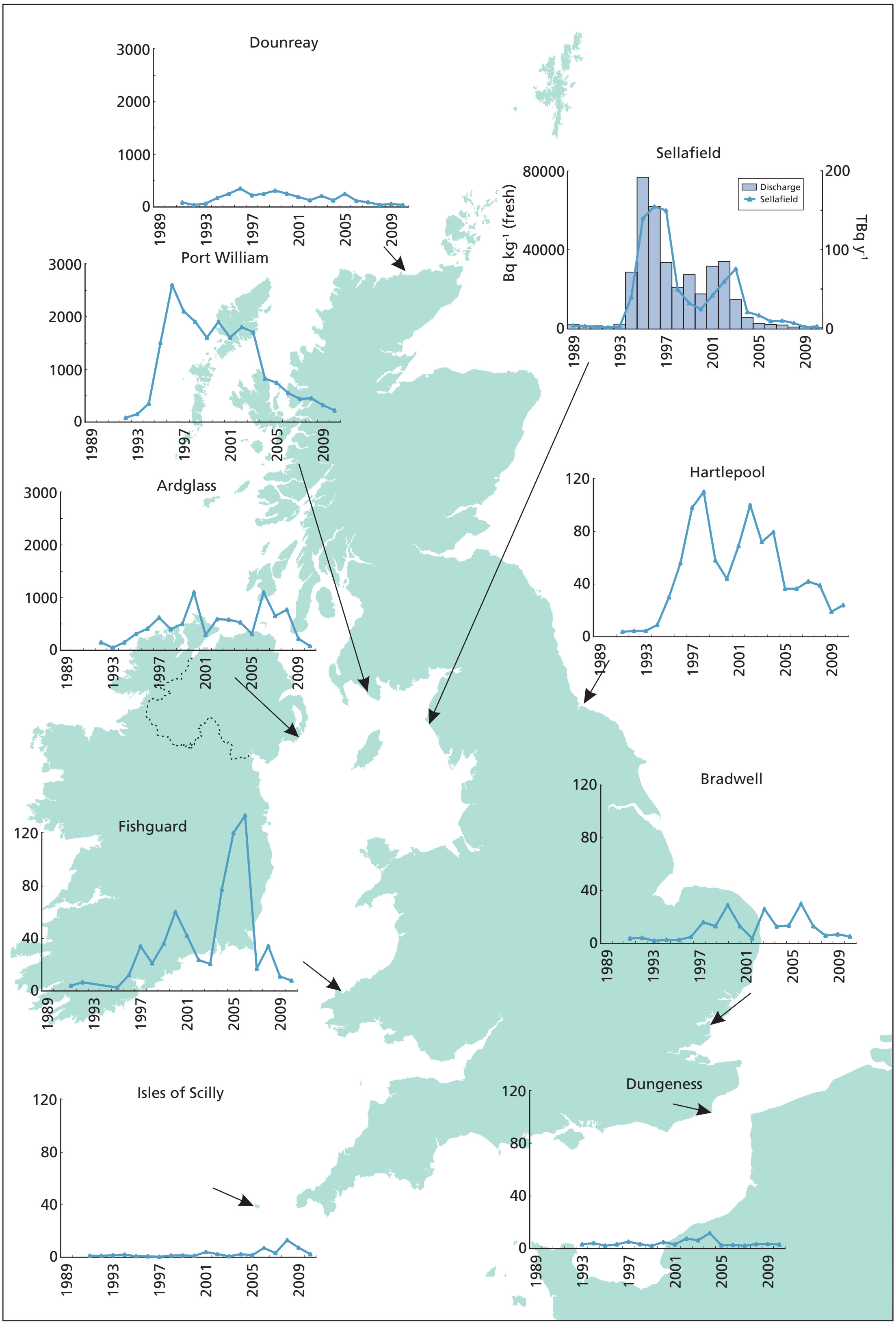


Figure 2.20. Technetium-99 in UK seaweed (*Fucus vesiculosus*) from Sellafield liquid discharges between 1989-2010

long-lived radionuclides, particularly caesium-137 and the transuranics, reflect past discharges from Sellafield, which were considerably higher than in recent years. Over the last 30 years discharges have fallen significantly as the site provided enhanced treatment to remove radionuclides prior to discharge. Overall, concentrations in sediments in 2010 were generally similar to those in recent years.

The trends over time (1986 – 2010) for concentrations in mud from Ravenglass with discharges from Sellafield are shown in Figures 2.14 – 2.17. The concentrations of most radionuclides have decreased over the past 25 years in response to decreases in discharges, with sustained reductions in discharges of caesium-137 and transuranic elements. Discharges of cobalt-60 have been variable over the last decade but reducing in recent years, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 2.16). Over the last decade, caesium-137 and transuranic concentrations in sediments have remained relatively constant (Figures 2.14 – 2.15, 2.17). Since the mid 1990s, discharges of caesium-137, plutonium isotopes and americium-241 have remained at low levels, but there has been some variability, and even a suggestion of small progressive increases in the concentrations in sediments (peaking over the period, ~2003 – 2006). This upward trend has not been continued, with the lowest concentrations of caesium-137 and plutonium isotopes reported in the last four years. The likely explanation is that changes in these concentrations are due to remobilisation and subsequent accretion of fine-grained sediments containing higher activity concentrations. For americium-241, there is also an additional contribution due to radioactive in-growth from the parent plutonium-241 already present in the environment. The effect is less apparent in fish and shellfish (Figures 2.11 – 2.13) and will continue to be monitored. Caesium-137 and americium-241 in sediments from coastal locations in the vicinity of Sellafield are also shown in Figure 2.18. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations at a given location are generally similar in most recent years, and any fluctuations are most likely due to normal variability in the environment. In 2010, caesium-137 and americium-241 concentrations in sediments at Newton Arlosh continued to increase in comparison to most recent years, but are still below peak values reported over the whole period of time. There is no suggestion of progressive increases in the concentrations in sediments in recent years for locations at distance from Sellafield.

Monitoring of dose rates

Dose rates are regularly monitored, both in the Sellafield vicinity and further afield, using environmental radiation dosimeters. Table 2.9 lists the locations monitored by the environment agencies and the gamma dose rates in air at 1 m above ground. Where comparisons can be made from similar ground types and locations, dose rates over intertidal areas throughout the Irish Sea in 2010 were generally similar to those data in recent years. Any variations between years are likely to have been due to normal variability in the environment. Gamma dose rates measured on the banks of the River Calder, which flows through the Sellafield site, continued to show significant excess above natural background downstream of the site (of approximately 0.04 μGy h^{-1}). Although the dose rates are locally enhanced, occupancy by the public, mainly anglers, is low in this area (unlikely to be more than a few tens of hours per year). On this basis the resulting doses were much less than those at other intertidal areas as discussed earlier in this section.

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

Over the last 30 years, levels of radioactivity in the environment around Sellafield have declined as a result of reduced discharges. In more recent years the levels in the Esk have shown a less clear trend, with concentrations of some radionuclides fluctuating from year to year (for example, see Figure 2.15). This effect could be due to the dynamic nature of the sediment in the estuary, which is eroded and transported by tide and freshwater, periodically exposing older deeper sediment containing radioactivity from historic discharges. Due to the variations seen in recent years and local concerns, the Environment Agency initiated a more detailed study of dose rates in the Esk Estuary in 2007. The objectives of the study were to assess the current level of external gamma radiation exposure in the estuary, and changes in the measured dose rates, relative to a more detailed survey of the estuary undertaken in 1989 (Kelly and Emptage, 1991). A six week intensive survey of gamma dose rates was undertaken at a total of 576 locations in the Esk Estuary. The University of Liverpool (Institute for Sustainable Water Integrated Management and Ecosystem Research (SWIMMER)) undertook the study.

The mean dose rate across all 576 locations was 0.14 μGy h^{-1}, with a range of 0.07 – 0.28 μGy h^{-1}. This indicates a significant decrease compared to the mean dose rate reported in 1989 (at similar locations) of 0.23 μGy h^{-1} (range 0.07 – 0.61 μGy h^{-1}). The highest gamma dose rates measured in both surveys are from comparable locations within the estuary. The reduced dose rates in the 2007 survey are due to the effects of reductions in radionuclide discharges from the Sellafield site and also radioactive decay of the inventory within the Esk Estuary sediments and soils since 1989. The full report on this study has been recently published by the Environment Agency (Wood *et al*., 2011).

Monitoring of fishing gear

During immersion in seawater, particles of sediment on which radioactivity is adsorbed may become trapped on fishing gear. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Fishing gear is regularly monitored using surface contamination meters. Results for 2010 are given in Table 2.10. Overall, measured dose rates were slightly increased in comparison to rates in 2008 and 2009.

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments (using contamination monitors), to allow estimation of exposure for people who handle sediments regularly, are given in Table 2.11. In 2010, positively detected dose rates at the majority of sites were generally similar in comparison to recent years, with some measurements below the LoD (limit of detection) or not detecting beta activity. Overall, beta dose rates at Ravenglass (Raven Villa) were higher than in 2009, but much lower than reported prior to 2007.

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 2010, no material was found using these probes in excess of the action level equivalent to 0.01 mSv h^{-1}.

In February 2008, the Environment Agency published a formal programme of work for the assessment of contamination by radioactive particles on and around the west Cumbrian coastline. The assessment is focused on public protection from high activity discrete radioactive particles that have been released to the environment from activities at Sellafield site (Environment Agency, 2008c). In June 2009, the Environment Agency reported on the current status of the work, in the context of delivery against the original objectives, and the focus and direction that are needed to take the work forward, ultimately to a point of completion (Environment Agency, 2009b). The work reported here included investigating the distribution and behaviour of Sellafield-related particles, particle analysis and identification, risks from particles, and a review of particle dispersion and transport models focused on the Eastern Irish Sea and Solway Firth. In March 2010 and April 2011, the Environment Agency provided updates on further progress of the enhanced beach monitoring (Environment Agency, 2010b; 2011c). Earlier work up to 2010 is described elsewhere (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a)

Since vehicle-mounted beach survey work began in November 2006, and up to April 2011, a total of around 1200 Ha of beach area has been surveyed by the Sellafield site operator's contractors, stretching from the north Solway coastline (at the request of SEPA), down to Silecroft (south of Drigg). The survey equipment used to date is the Groundhog™ Evolution system (up to August 2009), which was developed for Dounreay, and has specific capability in relation to the detection of medium/high energy gamma emitting radionuclides. Starting in August 2009, large area beach monitoring has been undertaken using the latest development in the Groundhog™ system – the Synergy. This new system provides improved detection capability for low energy gamma emissions. Up to April 2011, the total number of finds that have been identified since 2006 comprise 1233 stones, pebbles and particles, with around 65 per cent being less than 2 mm in diameter. All have been removed from the beaches. The numbers of radioactive finds identified since March 2010 were 386. The vast majority of the finds are concentrated on the 3 km stretch of beach running NW from the Sellafield site.

Monitoring along the Cumbrian coast will continue, with the current proposal being a further 150 Ha to be surveyed between April 2011 and March 2012, as part of the operator's routine environmental monitoring programme, and will include enhanced strandline and large area beach monitoring capability in relation to the detection of americium-241, strontium-90 and plutonium isotopes.

The Health Protection Agency (HPA) has recently reported on a detailed assessment of risks, and restated the advice that it originally offered to the Environment Agency in 2007 (Brown and Etherington, 2011). The report confirms that no special precautionary actions are required at this time to limit access to or use of the beaches. In relation to food safety, and following a previous assessment of the particles frequency and the activity concentrations, the Food Standards Agency's guidance to the Environment Agency supported HPA's advice. The Environment Agency will also continue to work with relevant authorities to keep the situation under review.

Periodic updates on the beach monitoring and Sellafield radioactive particles are available from the Environment Agency (Environment Agency, 2011c). Further detail on the monitoring data compiled so far can be obtained from Sellafield Limited http://www.sellafieldsites.com/about-us/environment-health-safety--quality/environment/particles-in-the-environment.

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

Monitoring of seaweed

In addition to occasional use in foods and as fertilisers, seaweeds are useful environmental indicator materials

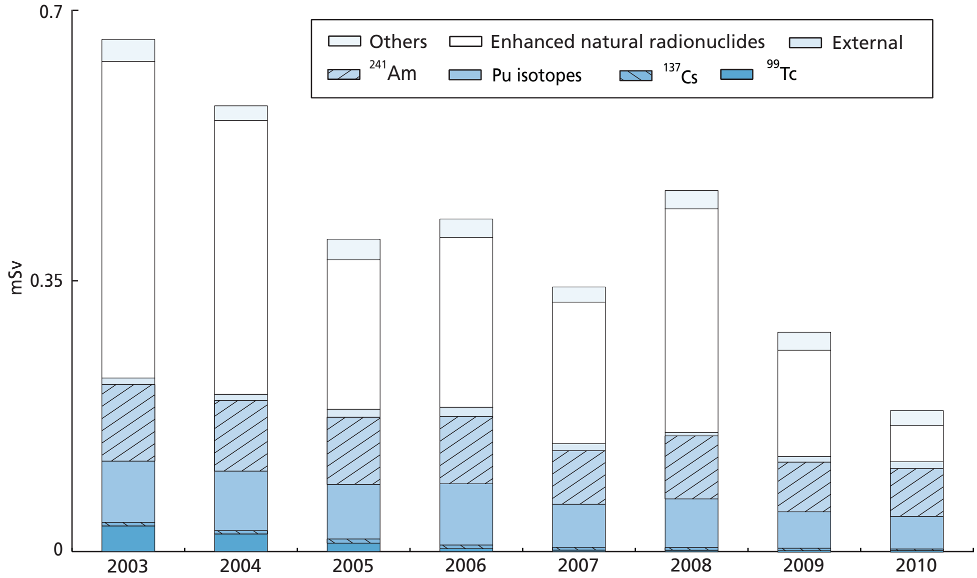


Figure 2.21. Contributions to *total dose* from all sources at Sellafield, 2003-2010

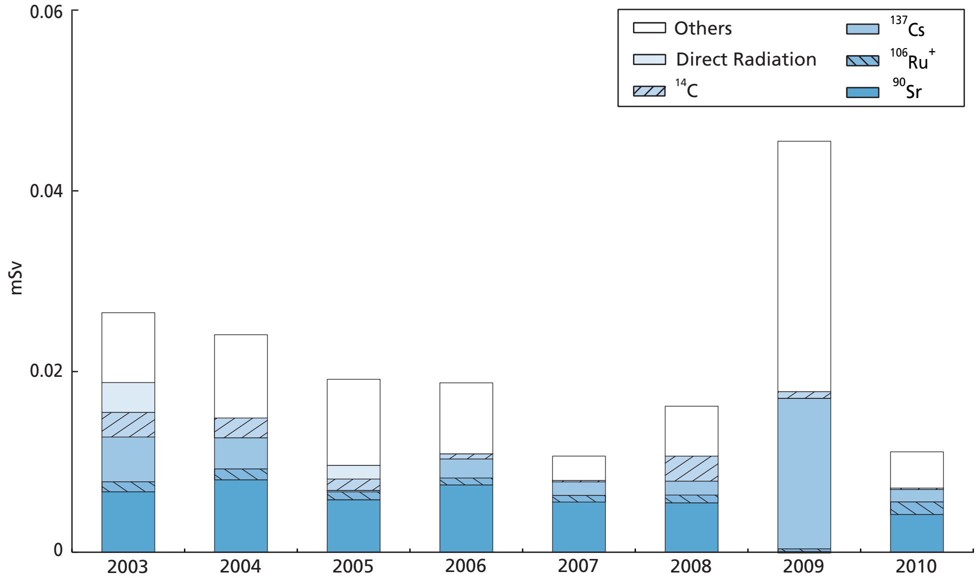


Figure 2.22. Contributions to *total dose* from gaseous discharge and direct radiation sources at Sellafield, 2003-2010 (+ based on limits of detection for concentrations in foods)

(concentrating particular radionuclides), facilitating assessments and assisting the tracing of these radionuclides in the environment. Table 2.12 presents the results of measurements in 2010 of seaweeds from shorelines of the Cumbrian coast and further afield.

Fucus seaweeds are particularly useful indicators of most fission product radionuclides; samples of *Fucus vesiculosus* were collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. The effects of technetium-99 discharges from Sellafield on concentrations in seaweed, between 1989 and 2010, are shown in Figure 2.20. In the north-east Irish Sea there has been a continued decrease in technetium-99 levels, over the last few years, concurrent with a reduction in discharges; the highest concentrations which are found near Sellafield are now much less than those in the mid 1990s. In general, there is still a large reduction in concentrations of technetium-99 in *Fucus vesiculosus* with distance from Sellafield, as the effect of the discharges becomes diluted in moving further afield. Technetium-99 concentrations in *Fucus* were broadly similar in 2010 to those in 2009, including at some specific locations (Cemaes Bay and Carlingford Lough) previously known to have had fluctuating levels over recent years. Activity concentrations at these specific locations have declined consecutively over the last three years. Variations in levels in the past were most likely the result of complex hydrographic transport patterns in the Irish Sea, with technetium-99 being dispersed to a variable degree before arriving at distant locations (Leonard *et al*., 2004). It may also be noted that as the effects of the high technetium discharges of the 1990s continue to disperse, there is the potential for areas distant from Sellafield to exhibit concentrations greater than those in closer proximity, such as Auchencairn, and as observed in seawater in Liverpool Bay for 1998 (McCubbin *et al*., 2002).

Seaweeds are sometimes used as fertilisers and soil conditioners and this potential pathway for the transfer of radionuclides into the food chain continues to be investigated. The results in 2010 are shown in Table 2.13 (together with data for Hinkley Point). The study comprises a survey of the extent of the use of seaweed as a fertiliser in the Sellafield area, collection and analysis of samples and assessments of radiation exposures based on the consumption of crops grown on land to which seaweed, or its compost, had been added (Camplin *et al*., 2000). Although seaweed harvesting in the Sellafield area continues to be rare, several plots of land were identified and investigated further. Samples of soil were analysed by gamma-ray spectrometry and for technetium-99. The Sellafield soil (compost) data show enhanced concentrations of technetium-99 and small amounts of other radionuclides as would be expected from the activity initially present in the seaweed. Where comparisons can be made, technetium-99 concentrations in edible parts of the vegetables grown in these soils were smaller than those found in 2009. The activity concentrations in vegetables provide no evidence for uptake, except for small enhancements of technetium-99 (mostly in rhubarb). Concentrations of gamma-emitting radionuclides were close to or below the LoD in vegetables.

No harvesting of *Porphyra* in west Cumbria, for consumption in the form of laverbread, was reported in 2010; this pathway has, therefore, remained dormant. However, monitoring of Porphyra has continued in view of its potential importance, historical significance and the value of Porphyra as an environmental indicator material. Samples of Porphyra are regularly collected from selected locations along UK shorelines of the Irish Sea. Results of analyses for 2010 are given in Table 2.12. In 2010, ruthenium-106 concentrations in *Porphyra* from the Cumbrian coast were at or below the LoD, and reduced in comparison with earlier years (due to the decreased discharges of this radionuclide in 2005 and 2006). Results for analyses of laverbread, from the major manufacturers that are regularly collected from markets in South Wales, are also given in Table 2.12. In 2009, activity concentrations in laverbread were at or below the LoD.

Monitoring of seawashed pasture

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

Monitoring of sea to land transfer

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

The results of measurements in 2010 are given in Table 2.14. In general, the data are similar to those for 2009 and, where detectable, show lower concentrations than are found in the immediate vicinity of Sellafield. As in 2009, the evidence for sea to land transfer is very limited in 2010. Positively detected technetium-99 concentrations were few, and measured just above the LoD. Small concentrations of artificial nuclides were detected in some samples but the concentrations were very low. Where detectable, observed isotopic ratios of ^{238}Pu:$^{239+240}$Pu concentrations were somewhat higher than 0.025, a value which might be expected if the source was only (or entirely) due to fallout. This may suggest a Sellafield influence.

Monitoring of fishmeal

Low concentrations of man-made radioactivity were found in fishmeal, which is fed to farmed fish, poultry, pigs, cows and sheep. A theoretical study has established that any indirect onward transmission of radioactivity into human diet as a result of this pathway is unlikely to be of radiological significance (Smith and Jeffs, 1999). A detailed survey was undertaken in 2003 to confirm these findings. Samples were obtained from 14 fish farms in Scotland and three in Northern Ireland. They demonstrated that concentrations of radionuclides are indeed very low, most being less than the limits of detection, and the few that were positively determined were all less than 1 Bq kg^{-1} (Food Standards Agency, 2003). Results in farmed salmon from the west of Scotland in 2010 in Tables 2.5 and 2.7 confirm that this remains the case.

Monitoring of waters

Evidence of the effects of liquid discharges from Sellafield on concentrations of radionuclides in seawater is determined by sampling from research vessels and the shore. The results of the seawater programme are given in Section 8.

Sampling of fresh water from rivers and lakes in west Cumbria is conducted as part of the regular environmental monitoring programme around Sellafield; however, other environmental materials would be likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2010 are included in Table 2.15. The gross alpha and beta activities for drinking waters were below the World Health Organisation (WHO) recommended values of 0.5 Bq l^{-1} and 1.0 Bq l^{-1} respectively.

Small amounts of activity are discharged from Sellafield under permit via the factory sewer outfall to the Ehen Estuary, at the confluence with the River Calder. Unlike in previous years, there was no evidence of tritium at the outfall in 2010 (Table 2.15). However, the waters are not potable and any low concentrations observed previously are of no radiological significance. Table 2.15 also includes the results of monitoring from the Ehen Spit (Figure 2.6) near Sellafield where water issues from the ground at low tide. This release is not due to regulated discharges of liquid wastes but to ground water migration from the Sellafield site. The water is brackish so it will not be used as a drinking water source and therefore the only consumption would be inadvertent. Enhanced gross beta and tritium concentrations were observed in 2010 with concentrations similar to those in recent years. The dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant (Environment Agency, 2002a).

2.3.4 Monitoring of unusual pathways

In 1998, high concentrations of caesium-137 (of up to 110,000 Bq kg^{-1}) were found in feral pigeons sampled in Seascale by the Ministry of Agriculture, Fisheries and Food (MAFF). Consumption of the breast meat of only 20 birds contaminated at the highest concentration would have given a dose of 1 mSv to high-rate consumers. Advice issued by MAFF in 1998 was that people should not handle, slaughter or consume pigeons within a 10 mile radius of the site. A full review of the incident was published in 1999 (Copeland Borough Council *et al*., 1999). It was found that pigeons had access to the roof spaces in buildings on the Sellafield site and had become contaminated with radionuclides including caesium-137. The pigeons were also congregating in large numbers at a bird sanctuary in Seascale village and the environment around had become contaminated. Since then, the site operator has undertaken remedial measures, including a substantial cull of feral pigeons in the area and preventing access to the loft spaces in buildings on the Sellafield site. Results of the analysis of wood pigeon samples collected in 2010 are included in Table 2.4. The maximum activity concentration for total caesium in muscle of wood pigeon increased in 2010 (16 Bq kg^{-1}), in comparison to the value reported in 2009 (2.2 Bq kg^{-1}), but was similar to the value in 2008 (22 Bq kg^{-1}). Concentrations of artificial radionuclides were low and would add little to the exposure of local consumers. The Food Standards Agency will continue to monitor this pathway. In view of the limited numbers of feral pigeons now on the site, the Food Standards Agency will be reviewing the need for the precautionary advice to continue.

Following the review of the pigeon incident, the Environment Agency began to sample and analyse sediments from road drains (gully pots) in Seascale and Whitehaven in 1999. Gully pots in road drains collect sediments washed off road surfaces and provide good indicators of contamination of urban environments. The results of analyses in 2010 are shown in Table 2.16 and were generally similar to those in 2009, although elevated concentrations (of stronium-90, caesium-137, americium-241 and plutonium radionuclides) were noted at one site (Seascale SS 233) in comparison to those in recent years. Investigations, including further monitoring, are underway to investigate the elevated concentrations at this site. Generally, activity concentrations in road drains have fallen significantly since remedial measures to reduce contamination were taken.

2.4 Windscale, Cumbria

Windscale is a separate licensed site located on the Sellafield site. The NDA has ownership of the site. In 2008, the Windscale permit was transferred from UKAEA to Sellafield Limited, and combined with the Sellafield permit. Windscale comprises of three reactors, two of which were shut down in 1957 and the third in 1981. Most of the radioactive wastes derive from decontamination and decommissioning operations, some of which are of the early Windscale reactor buildings. Decommissioning activities began in the mid 1980s but have recently been subject to deferrals in order to release resource for high hazard work. Facilities which were undergoing decommissioning will be placed in a safe state until decommissioning work resumes. Gaseous wastes are regulated from specific stacks on the Windscale site; liquid radioactive wastes are disposed of, after appropriate treatment, to the Irish Sea via the Sellafield site pipelines. Both gaseous and liquid discharges are included as part of the regulated Sellafield discharges (Appendix 2). Discharges of both gaseous and liquid radioactive wastes are minor compared to those from the rest of the Sellafield site.

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

Table 2.1. Individual radiation exposures - Capenhurst and Springfields, 2010

Site	Exposed population[a]	Exposure, mSv per year						
		Total	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
Capenhurst								
***Total dose* - all sources**	**Local adult inhabitants (0-0.25km)**	**0.26**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.26**
Source specific doses	Consumers of locally grown food[b,e]	<0.005	-	<0.005	-	-	<0.005	-
	Children playing at Rivacre Brook[d,e]	0.012	-	-	0.012	<0.005	-	-
								-
Springfields								
***Total dose* - all sources**	**Adult occupants on houseboats**	**0.17**	**-**	**-**	**0.17**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.017	0.006	-	0.012	-	-	-
	Houseboat occupants	0.16	-	-	0.16	-	-	-
	Fishermen handling nets or pots[c]	0.050	-	-	0.050	-	-	-
	Children playing at Lower Penwortham[d,e]	<0.005	-	-	<0.005	<0.005	-	-
	Farmers and wildfowlers	0.032	-	-	0.032	-	-	-
	Consumers of locally grown food[e]	<0.005	-	<0.005	-	-	<0.005	-

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

[b] *Children aged 1y*

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

[d] *Children aged 10y*

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

Table 2.2(a). Concentrations of radionuclides in food and the environment near Capenhurst, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{99}Tc	^{125}Sb	^{137}Cs	^{234}Th	^{234}U	^{235}U
Marine samples										
Sole	Liverpool Bay	2	<25							
Sole	Mersey Estuary	1	30							
Flounder	Mersey Estuary	1	<25							
Shrimps	Wirral	2	<25	<0.04	0.82	<0.08	1.3	*		
Mussels	Liverpool Bay	2	<25							
Mussels	Mersey Estuary	2	<25							
Cockles	River Dee	4		<0.08	2.1	<0.15	1.6	<3.9		
Sediment	Rivacre Brook	2[E]			190		3.7	98	120	5.0
Sediment	Rivacre Brook (1.5 km downstream)	2[E]			36		<1.3	<18	22	<1.6
Sediment	Rossmore (3.1 km downstream)	2[E]			14		<0.86	<20	19	<1.5
Sediment	Rivacre Brook (4.3 km downstream)	2[E]			15		1.9	<9.9	15	<1.4
Freshwater	Rivacre Brook	2[E]	<5.6		<0.25				0.086	<0.0065
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<4.2		<0.090				0.029	<0.0060
Freshwater	Rossmore (3.1 km downstream)	2[E]	<3.0		<0.10				0.030	<0.0055
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	<3.0		<0.095				0.027	<0.0050

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{238}U	^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples											
Shrimps	Wirral	2					<0.04				
Cockles	River Dee	4			0.12	0.72	2.0	*	*		
Sediment	Rivacre Brook	2[E]	67	<1.5						540	1300
Sediment	Rivacre Brook (1.5 km downstream)	2[E]	14	<2.5						200	780
Sediment	Rossmore (3.1 km downstream)	2[E]	17	<1.5						340	1100
Sediment	Rivacre Brook (4.3 km downstream)	2[E]	11	<1.5						120	580
Freshwater	Rivacre Brook	2[E]	0.038	<0.10						<0.15	0.3
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	0.016	<0.10						<0.060	0.29
Freshwater	Rossmore (3.1 km downstream)	2[E]	0.017	<0.10						<0.050	0.28
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	0.012	<0.10						<0.18	0.36

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		6	<3.0	<0.0030	<0.0010	<0.00067	<0.00092
Milk	max				0.0019	<0.00090	<0.0010
Cabbage		1			0.0015	<0.00070	0.0016
Gooseberries		1		<0.024	<0.00090	<0.00050	<0.00080
Potatoes		1		<0.026	0.0016	<0.00040	0.0016
Grass		4		<0.012	0.014	<0.0010	0.014
Grass	max				0.023	0.0021	0.022
Grass/herbage	North of Ledsham	1[E]		<2.0	<0.60	<0.40	<0.60
Grass/herbage	South of Capenhurst	1[E]		<0.090	0.28	<0.060	0.22
Grass/herbage	Off lane from Capenhurst to Dunkirk	1[E]		<1.5	<0.50	<0.20	<0.40
Grass/herbage	East of station	1[E]		<2.0	0.43	<0.20	<0.30
Silage		2		<0.012	0.013	<0.00080	0.014
Silage	max				0.014	0.00080	0.016
Soil		1#			9.0	0.36	8.7
Soil	North of Ledsham	1[E]		<5.0	20	<2.0	20
Soil	South of Capenhurst	1[E]		<0.90	20	1.0	18
Soil	Off lane from Capenhurst to Dunkirk	1[E]		5.3	18	<1.4	18
Soil	East of station	1[E]		<6.0	20	1.1	21

* *Not detected by the method used*

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

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

[c] *In distillate fraction of sample*

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

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

Fresh concentrations

Table 2.2(b). Monitoring of radiation dose rates near Capenhurst, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Rivacre Brook Plant outlet	Grass	1	0.099
Rivacre Brook Plant outlet	Concrete and grass	1	0.098
Rivacre Brook 1.5 km downstream	Grass and mud	1	0.089
Rivacre Brook 1.5 km downstream	Grass	1	0.086
Rossmore Road West 3.1 km downstream	Grass and mud	1	0.087
Rossmore Road West 3.1 km downstream	Grass	1	0.084
Rivacre Brook 4.3 km downstream	Mud	1	0.084
Rivacre Brook 4.3 km downstream	Mud and herbage	1	0.087

Table 2.3(a). Concentrations of radionuclides in food and the environment near Springfields, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{129}I	^{137}Cs
Marine samples										
Flounder	Ribble Estuary	1			<0.08			<0.22		4.7
Bass	Ribble Estuary	1			<0.12			<0.28		6.1
Grey mullet	Ribble Estuary	2			<0.08			<0.20		3.8
Salmon	Ribble Estuary	1			<0.10			<0.18		0.17
Shrimps	Ribble Estuary	2		58	<0.07		0.20	<0.17		2.4
Mussels	Ribble Estuary	2			<0.06			<0.15		1.0
Wild fowl	Ribble Estuary	1	<25	51	<0.07	<0.11		<0.13	<1.8	0.91
Samphire	Marshside Sands	1			<0.03			<0.05		0.72
Sediment	River Ribble outfall	4[E]			<0.57					98
Sediment	Savick Brook	2[E]			<1.1					210
Sediment	Lea Gate	2[E]			<0.53					170
Sediment	Lower Penwortham Park	4[E]			<1.0					210
Sediment	Penwortham rail bridge	4[E]			<0.88					210
Sediment	Penwortham rail bridge - West bank	2[E]			<0.45					110
Sediment	Penwortham position 1	4[E]			<0.59					62
Sediment	Penwortham position 2	1[E]			<0.49					41
Sediment	Lytham Yacht Club	1[E]			0.93					280
Sediment	Becconsall	4[E]			<0.63					160
Sediment	Freckleton	1[E]			<2.0					260
Sediment	Hutton Marsh	1[E]			<0.65					410
Sediment	Longton Marsh	1[E]			<0.60					530
Grass	Hutton Marsh	1[E]					4.6			
Soil	Hutton Marsh	1[E]					17			

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{228}Th	^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np
Marine samples										
Flounder	Ribble Estuary	1				*				
Bass	Ribble Estuary	1				*				
Grey mullet	Ribble Estuary	2				*				
Salmon	Ribble Estuary	1				*				
Shrimps	Ribble Estuary	2	0.0084	0.0058	0.0021	*				0.000076
Mussels	Ribble Estuary	2	0.34	0.43	0.19	3.8				
Wild fowl	Ribble Estuary	1	0.0048	0.0033	0.0014	*				
Samphire	Marshside Sands	1				*				
Sediment	River Ribble outfall	4[E]	21	37	19	290	21	<1.3	20	
Sediment	Savick Brook	2[E]	25	89	27	2700	41	<2.0	38	
Sediment	Lea Gate	2[E]	24	75	23	2900	47	<2.1	37	
Sediment	Lower Penwortham Park	4[E]	31	100	31	3500	30	<1.7	30	
Sediment	Penwortham rail bridge	4[E]	31	92	30	2700	30	<1.8	29	
Sediment	Penwortham rail bridge - West bank	2[E]	24	55	22	1600	17	<1.4	18	
Sediment	Penwortham position 1	4[E]	23	40	20	170	22	<1.9	21	
Sediment	Penwortham position 2	1[E]	19	37	18	66	18	<1.1	17	
Sediment	Lytham Yacht Club	1[E]	32	99	33	160	33	<2.5	26	
Sediment	Becconsall	4[E]	29	58	25	340	20	<1.2	20	
Sediment	Freckleton	1[E]	33	100	36	1300	31	<2.3	32	
Sediment	Hutton Marsh	1[E]	39	130	39	180	27	1.3	29	
Sediment	Longton Marsh	1[E]	65	330	54	56	34	<1.6	30	

Table 2.3(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Flounder	Ribble Estuary	1			<0.09				
Bass	Ribble Estuary	1			<0.11				
Grey mullet	Ribble Estuary	2			<0.09				
Salmon	Ribble Estuary	1			<0.08				
Shrimps	Ribble Estuary	2	0.0022	0.012	0.021	*	0.000057		
Mussels	Ribble Estuary	2			0.91				
Wild fowl	Ribble Estuary	1	0.00034	0.0023	0.0048	*	*		
Samphire	Marshside Sands	1			0.25				
Sediment	River Ribble outfall	4[E]			79			420	1400
Sediment	Savick Brook	2[E]			160			710	4100
Sediment	Lea Gate	2[E]			130			540	4100
Sediment	Lower Penwortham Park	4[E]			160			640	5100
Sediment	Penwortham rail bridge	4[E]			150			640	4600
Sediment	Penwortham rail bridge - West bank	2[E]			86			550	3500
Sediment	Penwortham position 1	4[E]			59			450	1500
Sediment	Penwortham position 2	1[E]			28			470	740
Sediment	Lytham Yacht Club	1[E]			210			860	1800
Sediment	Becconsall	4[E]			120			550	1700
Sediment	Freckleton	1[E]			200			460	2700
Sediment	Hutton Marsh	1[E]			260			580	1700
Sediment	Longton Marsh	1[E]			270			800	2100

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{90}Sr	^{129}I	^{137}Cs	Total Cs
Terrestrial samples								
Apples		1	<4.0	11	0.028	<0.024		<0.012
Beetroot		1	<5.0	<3.0	0.058	0.041		0.049
Blackberries		1	<5.0	12	0.070	<0.030		0.045
Cabbage		1	<4.0	<3.0	0.10	<0.024		0.034
Potatoes		1	<5.0	10	0.027	<0.027		0.055
Rabbit		1	<5.0	20	0.0090	<0.059		0.26
Runner beans		1	<5.0	<3.0	0.074	<0.028		0.045
Sediment	Deepdale Brook	2[E]					1.4	
Grass		1					1.7	

Table 2.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{230}Th	^{232}Th	^{234}Th	^{234}U	^{235}U	^{238}U
Terrestrial samples								
Milk		5				<0.0011	<0.00068	<0.0010
Milk	Max					0.0017	<0.00080	<0.0012
Apples		1	0.0030	0.0012		<0.00090	<0.00040	0.00080
Beetroot		1	0.0036	0.0026		0.0060	<0.0013	0.0036
Blackberries		1	0.0065	0.00090		0.0018	<0.00070	0.0019
Cabbage		1	0.0087	0.0019		0.0085	0.0016	0.0072
Potatoes		1	0.0063	0.0074		0.0049	<0.00060	0.0038
Rabbit		1	0.00090	0.00090		<0.0012	<0.0010	0.0018
Runner beans		1	0.0016	0.0011		0.0019	0.00040	0.0018
Sediment	Deepdale Brook	2[E]			63	79	3.3	78
Grass		1				0.094	0.0042	0.086
Grass	Site fence	1[E]				1.6	<0.20	1.3
Grass	Opposite site entrance	1[E]				2.1	<0.20	1.9
Grass	Opposite windmill	1[E]				2.7	<0.26	2.5
Grass	Deepdale Brook	1[E]				1.7	<0.10	1.4
Grass	Lea Town	1[E]				0.72	<0.36	0.77
Grass	N of Lea Town	1[E]				5.7	0.240	5.70
Silage		1				0.72	0.032	0.71
Soil		1[#]				20	0.81	19
Soil	Site fence	1[E]				60	2.5	61
Soil	Opposite site entrance	1[E]				150	7.1	140
Soil	Opposite windmill	1[E]				110	3.8	110
Soil	Deepdale Brook	1[E]				82	<2.4	85
Soil	Lea Town	1[E]				36	1.2	32
Soil	N of Lea Town	1[E]				46	2.2	47
Freshwater	Deepdale Brook	4[E]				0.38	<0.016	0.38

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples								
Apples		1	0.00030	<0.00020	<0.053	0.00020		
Beetroot		1	<0.00020	<0.00020	<0.057	0.00020		
Blackberries		1	<0.00010	0.00020	<0.056	0.00030		
Cabbage		1	<0.00010	<0.00020	<0.042	0.00030		
Potatoes		1	<0.00010	<0.00020	<0.049	0.00010		
Rabbit		1	<0.00020	<0.00060	0.12	<0.00020		
Runner beans		1	0.00020	<0.00010	<0.050	0.00020		
Sediment	Deepdale Brook	2[E]					380	1100
Grass		1				1.0		
Freshwater	Deepdale Brook	4[E]					<0.45	0.54

* *Not detected by the method used*

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

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

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

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

[#] *Fresh concentrations*

Table 2.3(b). Monitoring of radiation dose rates near Springfields, 2010

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	0.10
Warton Mud Marsh	Grass	2	0.13
Warton Mud Marsh	Grass[a]	2	0.13
Warton Salt Marsh	Grass and salt marsh	1	0.10
Warton Salt Marsh	Grass	1	0.099
Freckleton	Grass	1	0.090
Naze Point	Grass	2	0.11
Banks Marsh	Grass	2	0.11
Banks Marsh	Grass[a]	2	0.11
Hesketh Bank	Grass	2	0.11
Becconsall Boatyard	Grass and mud	2	0.086
Becconsall Boatyard	Grass	2	0.085
Becconsall (vicinity of houseboats)	Asphalt	2	0.081
Longton Marsh	Grass	1	0.14
Hutton Marsh	Grass and mud	1	0.15
River Ribble outfall	Mud	2	0.092
River Ribble outfall	Grass and mud	2	0.092
Savick Brook, confluence with Ribble	Grass and mud	1	0.098
Savick Brook, confluence with Ribble	Grass	1	0.093
Savick Brook, tidal limit	Grass and mud	1	0.11
Savick Brook, tidal limit	Grass	1	0.097
Savick Brook, Lea Gate	Grass and mud	1	0.10
Savick Brook, Lea Gate	Grass	1	0.098
South bank opposite outfall	Grass and mud	1	0.11
Penwortham Bridge cadet hut	Mud	1	0.088
Penwortham Bridge cadet hut	Mud and stones	1	0.085
Lower Penwortham Park	Mud	1	0.084
Lower Penwortham Park	Grass	3	0.087
Lower Penwortham Railway Bridge	Mud	1	0.085
Lower Penwortham Railway Bridge	Grass and mud	1	0.088
Lower Penwortham Railway Bridge	Mud and stones	2	0.087
River Darwen	Grass	4	0.083
Riverbank Angler location 1	Grass and mud	1	0.082
Riverbank Angler location 1	Grass and sand	1	0.082
Riverbank Angler location 1	Grass	1	0.084
Riverbank Angler location 1	Stones	1	0.075
Riverbank Angler location 2	Mud and sand	1	0.088
Ulnes Walton, BNFL area survey	Grass	3	0.084
Mean beta dose rates			µSv h^{-1}
Lytham - Granny's Bay	Mud and salt marsh	1	0.040
Ribble Estuary	Gill net	2	0.087
Ribble Estuary	Shrimp net	2	0.057
Banks Marsh	Grass	2	0.020
Warton Mud Marsh	Grass	2	0.030
Warton Salt Marsh	Grass and salt marsh	1	*
Warton Salt Marsh	Grass	1	0.060

[a] *15cm above substrate*

* *Not detected by the method used*

Table 2.4. Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2010

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		18	<4.7	<4.6	14	<0.18	0.052	0.0060	<1.1	<0.36	<0.0079	<0.0039
Milk	max		<7.5	6.0	17	<0.19	0.15		<1.3	<0.47	<0.011	<0.0055
Apples		2	<5.5	7.0	4.0	<0.10	0.17	<0.029	<1.1	<0.40	<0.024	
Apples	max		<9.0	9.0	5.0		0.24		<1.6	<0.50	<0.026	
Barley		1		<8.0	38	<0.10	0.62		<0.80	<0.40	<0.039	
Beef kidney		1	<9.0	<9.0	19	<0.30	0.41	<0.063	<1.8	<0.60	<0.045	
Beef liver		1	<8.0	<8.0	25	<0.20	0.27	<0.026	<1.3	<0.30	<0.035	
Beef muscle		1	<8.0	8.0	29	<0.20	0.011	<0.021	<1.2	<0.30	<0.040	
Blackberries		2	<9.0	14	12	<0.15	0.96		<1.1	<0.35	<0.034	
Blackberries	max		<16	15		<0.20	1.2		<1.3	<0.40	<0.043	
Broccoli		1	<5.0	<5.0	<3.0	<0.30	0.038		<1.6	<0.40	<0.031	
Cabbage		2	<4.5	<4.5	<3.0	<0.15	0.22		<1.4	<0.30	<0.024	
Cabbage	max		<5.0	<5.0		<0.20	0.33		<1.5	<0.40		
Carrots		1	<3.0	<3.0	5.0	<0.20	0.19	<0.024	<1.5	<0.60	<0.027	
Deer muscle		1	<14	14	16	<0.20	0.014	<0.028	<0.60	<0.40	<0.041	
Eggs		1	<7.0	7.0	31	<0.20	0.035		<0.90	<0.50	<0.029	
Elderberries		1	<4.0	<4.0	16	<0.20	0.35		<0.90	<0.40	<0.028	
Honey		1		<7.0	48	<0.10	0.045		<0.70	<0.40	<0.013	
Mushrooms		1	<6.0	<6.0	<6.0	<0.20	0.64		<1.4	<0.30	<0.023	
Onions		1	<4.0	<4.0	<3.0	<0.20	0.038		<0.60	<0.30	<0.021	
Pheasants		1	<9.0	9.0	25	<0.20	0.045	<0.027	<0.70	<0.30	<0.034	
Potatoes		2	<5.0	<5.0	9.5	<0.20	0.043		<1.5	<0.50	<0.028	
Potatoes	max				11		0.056		<1.7		<0.033	
Rabbit		1	<7.0	<7.0	12	<0.20	0.048	<0.027	<1.3	<0.40	<0.041	
Runner beans		1	<5.0	<4.0	<3.0	<0.20	0.17		<1.2	<0.50	<0.024	
Sheep muscle		2	5.0	11	22	<0.20	0.025	<0.028	<0.85	<0.35	<0.030	
Sheep muscle	max		6.0	12	23		0.026	0.034	<1.1	<0.40	<0.037	
Sheep offal		2	<8.0	<8.0	<13	<0.20	0.14	<0.029	<1.1	<0.25	<0.029	
Sheep offal	max				16		0.17	<0.030	<1.2	<0.30	<0.030	
Sprouts		1	<5.0	<5.0	<3.0	<0.20	0.17		<0.90	<0.30	<0.024	
Strawberries		1	<4.0	4.0	6.0	<0.10	0.076		<1.1	<0.20	<0.031	
Swede		1	<5.0	<5.0	<4.0	<0.20	0.21		<1.8	<0.50	<0.045	
Wheat		1		<8.0	80	<0.20	0.38		<0.80	<0.30	<0.040	
Wood pigeon muscle		2	<6.0	<6.0	26	<0.20	0.038		<1.4	<0.50	<0.040	
Wood pigeon muscle	max		<7.0	<7.0	38		0.049		<1.7	<0.70	<0.052	
Grass		5				<0.10		<0.022	<0.52	0.69		
Grass	max								<0.60	0.91		
Soil		3				<0.21			<0.63	<0.27		
Soil	max					0.33			<0.80	<0.30		

Table 2.4. continued

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		18	<0.21	0.17				<0.00010	<0.00015	<0.028	<0.00011
Milk	max		<0.38	0.42					<0.00020	<0.030	<0.00013
Apples		2		0.70				<0.00010	0.00090	<0.055	0.00070
Apples	max			1.2				0.00010	0.0015	0.065	0.00090
Barley		1		0.82				0.00080	0.0063	<0.043	0.0064
Beef kidney		1		0.53	0.0036	<0.0013	<0.0021				
Beef liver		1		0.39				<0.00020	<0.00040	<0.053	0.00060
Beef muscle		1		0.69				<0.00020	<0.00040	<0.053	0.00030
Blackberries		2		0.37				0.00025	0.00070	<0.057	0.00095
Blackberries	max			0.40				0.00030	0.00080	0.062	0.0011
Broccoli		1		0.16				<0.00010	<0.00020	<0.040	0.00040
Cabbage		2		0.11				<0.00015	<0.00020	<0.050	0.00035
Cabbage	max			0.16	0.0020	0.00070	0.0018	0.00020	0.00020	<0.051	0.00040
Carrots		1		0.067							
Deer muscle		1		0.25				<0.00010	<0.00020	<0.071	
Eggs		1		0.13				<0.00010	0.00030	<0.048	0.00040
Elderberries		1		0.64				0.00060	0.0041	<0.044	0.0092
Honey		1		0.086				<0.00020	<0.00030	0.091	0.00030
Mushrooms		1		0.48				0.0012	0.0082	<0.053	0.00050
Onions		1		0.063							
Pheasants		1		0.44				<0.00020	<0.00040	<0.063	<0.00010
Potatoes		2		0.14							
Potatoes	max			0.20	0.0068	0.0014	0.0028				
Rabbit		1		1.6				<0.00020	<0.00020	<0.057	0.039
Runner beans		1		0.17				<0.00010	<0.00010	<0.046	0.00040
Sheep muscle		2		0.78				0.00030	<0.00030	<0.075	<0.00025
Sheep muscle	max			0.93					<0.00040	<0.085	0.00030
Sheep offal		2		0.33	0.011	0.0032	0.0046	<0.00020	0.00070	<0.076	0.00090
Sheep offal	max			0.38	0.016	0.0040	0.0047			<0.077	0.0010
Sprouts		1		0.36				<0.00010	0.00020	<0.046	0.00030
Strawberries		1		0.070				<0.00020	0.00040	<0.050	0.00030
Swede		1		0.11							
Wheat		1		0.18				0.00020	0.00060	<0.069	0.0023
Wood pigeon muscle		2		8.0				<0.00015	<0.00035	<0.076	<0.00020
Wood pigeon muscle	max			16				<0.00020	<0.00040	0.093	0.00020
Grass		5	0.98								<0.14
Grass	max		2.0								<0.20
Soil		3	50								5.0
Soil	max		58		14	0.69	13				6.4

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

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

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

Table 2.5. Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Cumbria										
Maryport	Plaice	4				<0.06		<0.15	<0.14	
River Derwent	Sea trout	1				<0.23		<0.62	<0.64	
Parton	Cod	4				<0.08		<0.16	<0.13	
Whitehaven	Cod	4			93	<0.09	<0.028	<0.18	<0.14	
Whitehaven	Plaice	4				<0.09	0.047	<0.19	<0.17	
Whitehaven	Skates / rays	4				<0.08		<0.17	<0.13	
Whitehaven	Sole	4				<0.16		<0.43	<0.47	
River Ehen	Salmon	1				<0.08		<0.20	<0.20	
River Ehen	Sea trout	1				<0.19		<0.54	<0.61	
Sellafield coastal area	Cod	8				<0.10		<0.29	<0.31	
Sellafield coastal area	Plaice	4	81	94		<0.06		<0.41	<0.61	
Sellafield coastal area	Bass	1				<0.12		<0.43	<0.56	
Sellafield coastal area	Grey mullet	1				<0.10		<0.31	<0.34	
Sellafield offshore area	Plaice[a]	2			150	<0.07	<0.046	<0.15	<0.14	6.2
Sellafield offshore area	Skates / rays	3			120	<0.17	<0.054	<0.48	<0.52	<0.28
Sellafield offshore area	Smooth hound	1				<0.09		<0.20	<0.16	
Sellafield offshore area	Spurdog	1				<0.06		<0.14	<0.12	
Sellafield offshore area	Dab	2				<0.11		<0.24	<0.20	
Sellafield offshore area	Gurnard	1				<0.15		<0.30	<0.22	
River Esk	Sea trout	1				<0.08		<0.58	<1.1	
River Calder	Brown trout	1				<0.28		<2.8	*	
Ravenglass	Cod	6				<0.10		<0.27	<0.29	
Ravenglass	Plaice	4	78	90		<0.08		<0.17	<0.15	
Morecambe Bay (Flookburgh)	Flounder	4			92	<0.10		<0.35	<0.61	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Whiting	4				<0.08		<0.20	<0.19	
Morecambe Bay (Morecambe)	Bass	2				<0.11		<0.48	<0.78	
Morecambe Bay (Morecambe)	Flounder	4	<25	32		<0.08	<0.029	<0.20	<0.19	0.86
Morecambe Bay (Sunderland Point)	Whitebait	1				<0.07	0.066	<0.27	<0.33	
River Duddon	Sea trout	1				<0.18		<0.60	<0.85	
Fleetwood	Plaice	4				<0.05		<0.15	<0.18	
Fleetwood	Red gurnard	4			78	<0.07	<0.036	<0.23	<0.32	<0.27
Ribble Estuary	Grey mullet	2				<0.08		<0.22	<0.20	
Ribble Estuary	Flounder	1				<0.08		<0.16	<0.10	
Ribble Estuary	Bass	1				<0.12		<0.23	<0.18	
Ribble Estuary	Salmon	1				<0.10		<0.17	<0.13	
Liverpool Bay	Sole	2		<25						
Mersey Estuary	Flounder	1		<25						
Mersey Estuary	Sole	1		30						
Scotland										
Shetland	Fish meal	2				<0.17	0.31	<0.42	<0.39	
Shetland	Fish oil	2				<0.11		<0.31	<0.30	
Minch	Herring	1				<0.07		<1.1	*	
Minch	Mackerel	1			69	<0.12	<0.084	<0.30	<0.28	
West of Scotland	Mackerel	1				<0.14		<0.41	<0.51	
West of Scotland	Farmed salmon	1				<0.10		<0.28	<0.29	
Kirkcudbright	Lemon sole	3[S]			27	<0.10		<0.17	<0.14	0.33
Inner Solway	Flounder	1[S]			30	<0.12	<0.11	<0.40		<0.28
Inner Solway	Salmon	1[S]		12		<0.10		<0.25	<0.36	
Inner Solway	Sea trout	1[S]		<5.0		<0.10		<0.28	<0.29	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	Gross beta
Cumbria									
Maryport	Plaice	4	<0.56	<0.15	<0.06	2.7	<0.28	<0.13	
River Derwent	Sea trout	1	<2.4	<0.53	<0.22	1.8	<1.1	<0.50	
Parton	Cod	4	<0.67	<0.19	<0.07	5.5	<0.36	<0.19	
Whitehaven	Cod	4	<0.77	<0.22	<0.09	5.8	<0.36	<0.18	
Whitehaven	Plaice	4	<0.75	<0.21	<0.08	3.3	<0.38	<0.19	
Whitehaven	Skates / rays	4	<0.73	<0.20	<0.08	3.7	<0.35	<0.18	
Whitehaven	Sole	4	<1.5	<0.34	<0.17	2.5	<0.54	<0.25	
River Ehen	Salmon	1	<0.70	<0.16	<0.07	0.24	<0.30	<0.13	
River Ehen	Sea trout	1	<2.0	<0.40	<0.19	2.4	<0.67	<0.25	
Sellafield coastal area	Cod	8	<0.86	<0.24	<0.10	6.5	<0.44	<0.21	210
Sellafield coastal area	Plaice	4	<0.52	<0.14	<0.06	2.7	<0.42	<0.17	160
Sellafield coastal area	Bass	1	<1.2	<0.30	<0.13	11	<0.51	<0.21	
Sellafield coastal area	Grey mullet	1	<0.76	<0.19	<0.09	6.1	<0.29	<0.12	
Sellafield offshore area	Plaice[a]	2	<0.54	<0.15	<0.07	3.6	<0.21	<0.10	
Sellafield offshore area	Skates / rays	3	<1.6	<0.37	<0.17	5.1	<0.56	<0.24	
Sellafield offshore area	Smooth hound	1	<0.87	<0.21	<0.10	3.3	<0.35	<0.17	
Sellafield offshore area	Spurdog	1	<0.53	<0.16	<0.06	7.1	<0.26	<0.12	
Sellafield offshore area	Dab	2	<0.88	<0.26	<0.10	4.0	<0.46	<0.24	
Sellafield offshore area	Gurnard	1	<1.5	<0.37	<0.15	3.5	<0.69	<0.32	
River Esk	Sea trout	1	<1.0	<0.23	<0.10	1.5	<0.59	<0.23	
River Calder	Brown trout	1	<3.7	<0.79	<0.30	33	<1.9	<0.64	
Ravenglass	Cod	6	<0.82	<0.22	<0.09	5.2	<0.40	<0.19	
Ravenglass	Plaice	4	<0.64	<0.18	<0.07	3.4	<0.35	<0.17	
Morecambe Bay (Flookburgh)	Flounder	4	<0.93	<0.26	<0.10	10	<0.43	<0.19	
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4	<0.68	<0.19	<0.08	6.4	<0.31	<0.15	
Morecambe Bay (Morecambe)	Bass	2	<1.0	<0.28	<0.10	11	<0.57	<0.26	
Morecambe Bay (Morecambe)	Flounder	4	<0.72	<0.20	<0.08	6.9	<0.36	<0.18	
Morecambe Bay (Sunderland Point)	Whitebait	1	<0.73	<0.21	<0.08	4.6	<0.45	<0.20	
River Duddon	Sea trout	1	<1.8	<0.36	<0.16	7.1	<0.69	<0.25	
Fleetwood	Plaice	4	<0.46	<0.12	<0.05	2.6	<0.25	<0.11	
Fleetwood	Red gurnard	4	<0.68	<0.18	<0.07	3.5	<0.31	<0.15	
Ribble Estuary	Grey mullet	2	<0.79	<0.20	<0.08	3.8	<0.35	<0.16	
Ribble Estuary	Flounder	1	<0.74	<0.22	<0.09	4.7	<0.33	<0.16	
Ribble Estuary	Bass	1	<1.2	<0.28	<0.13	6.1	<0.45	<0.20	
Ribble Estuary	Salmon	1	<0.77	<0.18	<0.10	0.17	<0.25	<0.13	
Scotland									
Shetland	Fish meal	2	<1.6	<0.43	<0.17	0.63	<0.84	<0.38	
Shetland	Fish oil	2	<1.1	<0.31	<0.12	<0.11	<0.60	<0.24	
Minch	Herring	1	<1.0	<0.22	<0.08	0.16	<0.64	<0.21	
Minch	Mackerel	1	<1.1	<0.31	<0.13	<0.12	<0.62	<0.31	
West of Scotland	Mackerel	1	<1.3	<0.29	<0.14	<0.12	<0.50	<0.22	
West of Scotland	Farmed salmon	1	<0.89	<0.24	<0.10	0.23	<0.48	<0.24	
Kirkcudbright	Lemon sole	3[S]	<0.65	<0.20	<0.10	<0.10	<0.42	<0.20	
Inner Solway	Flounder	1[S]	<1.1	<0.29	<0.11	7.2	<0.61	<0.26	
Inner Solway	Salmon	1[S]	<0.53	<0.14	<0.10	0.18	<0.35	<0.16	
Inner Solway	Sea trout	1[S]	<0.81	<0.23	<0.10	0.31	<0.46	<0.21	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg-1							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc
Isle of Man										
Isle of Man	Cod	4				<0.06		<0.13	<0.10	
Isle of Man	Herring	2				<0.10		<0.30	<0.32	
Isle of Man	Mackerel	2				<0.08		<0.16	<0.12	
Wales										
North Anglesey	Thornback ray	1				<0.07		<0.15	<0.10	
North Anglesey	Lesser spotted dogfish	2				<0.20		<0.74	<1.1	
North Anglesey	Spurdog	1				<0.21		<1.4	<2.7	
North Anglesey	Plaice	2	<25	<28	45	<0.05		<0.10	<0.08	
North Anglesey	Bass	1				<0.05		<0.08	<0.06	
Northern Ireland										
North coast	Spurdog	1[N]				<0.12		<0.75	<1.6	
North coast	Skates / rays	3[N]				<0.16		<0.59	<0.80	
Ardglass	Herring	2[N]				<0.10		<0.26	<0.26	
Kilkeel	Cod	4[N]			49	<0.06		<0.29	<0.48	
Kilkeel	Plaice	4[N]				<0.13		<0.57	<0.92	
Kilkeel	Skates / rays	4[N]				<0.19		<1.1	<2.5	
Kilkeel	Haddock	4[N]				<0.09		<0.69	<0.15	
Glenarm	Brown trout	1				<0.10		<0.24	<0.21	<0.28
Further afield										
Baltic Sea	Cod	2				<0.08		<0.28	<0.34	
Baltic Sea	Herring	2				<0.08		<0.25	<0.28	
Barents Sea	Cod	2				<0.05		<0.13	<0.12	
Norwegian Sea	Cod	1				<0.07		<0.55	<1.5	
Norwegian Sea	Herring	2				<0.07		<0.81	<0.15	
Norwegian Sea	Saithe	1				<0.07		<0.47	<0.99	
Norwegian processed	Cod	1			22	<0.06		<0.23	<0.25	
Iceland area	Cod	1				<0.06		<0.34	<0.61	
Skagerrak	Cod	1				<0.09		<0.17	<0.13	
Skagerrak	Herring	2				<0.10		<0.30	<0.33	
Skagerrak	Saithe	1				<0.04		<0.11	<0.11	
Northern North Sea	Cod	2				<0.06	<0.027	<0.15	<0.12	
Northern North Sea	Plaice	2				<0.04		<0.09	<0.08	
Northern North Sea	Haddock	1			25	<0.05		<0.10	<0.08	
Northern North Sea	Herring	1				<0.12		<1.2	*	
Northern North Sea	Whiting	1				<0.05		<0.10	<0.08	
Mid North Sea	Cod	2			9.5	<0.04	<0.025	<0.11	<0.12	
Mid North Sea	Plaice	2			16	<0.05	0.034	<0.15	<0.17	
Gt Yarmouth (retail shop)	Cod	2				<0.06		<0.12	<0.10	
Gt Yarmouth (retail shop)	Plaice	2				<0.03		<0.06	<0.04	
Southern North Sea	Cod	2				<0.05	<0.026	<0.10	<0.09	
Southern North Sea	Plaice	1				<0.03	<0.025	<0.06	<0.04	
Southern North Sea	Sole	1				<0.06		<0.11	<0.07	
Southern North Sea	Herring	1				<0.06		<0.21	<0.28	
English Channel-East	Plaice	2				<0.05		<0.14	<0.14	
English Channel-East	Whiting	2				<0.06		<0.15	<0.13	
English Channel-West	Plaice	2			35	<0.04		<0.09	<0.08	
English Channel-West	Mackerel	2				<0.06		<0.14	<0.14	
English Channel-West	Whiting	2				<0.05		<0.11	<0.09	
Celtic Sea	Haddock	2			33	<0.10	0.017	<0.27	<0.24	
Celtic Sea	Plaice	1				<0.09		<0.21	<0.18	
Celtic Sea	Whiting	1				<0.07		<0.17	<0.18	
Northern Irish Sea	Dab	1				<0.20		<0.50	<0.50	
Northern Irish Sea	Lesser spotted dogfish	1				<0.16		<0.56	<0.67	
Northern Irish Sea	Skates / rays	1				<0.08		<0.24	<0.27	

Table 2.5. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu
Isle of Man								
Isle of Man	Cod	4	<0.52	<0.13	<0.06	1.4	<0.23	<0.11
Isle of Man	Herring	2	<0.86	<0.20	<0.09	0.53	<0.40	<0.18
Isle of Man	Mackerel	2	<0.72	<0.20	<0.08	0.67	<0.39	<0.20
Wales								
North Anglesey	Thornback ray	1	<0.64	<0.17	<0.07	0.89	<0.32	<0.18
North Anglesey	Lesser spotted dogfish	2	<2.1	<0.41	<0.20	1.5	<0.66	<0.27
North Anglesey	Spurdog	1	<2.4	<0.43	<0.21	1.0	<0.75	<0.28
North Anglesey	Plaice	2	<0.44	<0.12	<0.05	1.4	<0.23	<0.12
North Anglesey	Bass	1	<0.36	<0.09	<0.04	3.4	<0.13	<0.06
Northern Ireland								
North coast	Spurdog	1[N]	<1.2	<0.26	<0.13	2.3	<0.50	<0.20
North coast	Skates / rays	3[N]	<1.6	<0.33	<0.15	1.3	<0.65	<0.26
Ardglass	Herring	2[N]	<0.89	<0.20	<0.10	0.59	<0.36	<0.17
Kilkeel	Cod	4[N]	<0.58	<0.14	<0.06	2.1	<0.29	<0.13
Kilkeel	Plaice	4[N]	<1.3	<0.29	<0.13	1.0	<0.56	<0.22
Kilkeel	Skates / rays	4[N]	<2.0	<0.39	<0.19	0.99	<0.78	<0.28
Kilkeel	Haddock	4[N]	<0.95	<0.21	<0.10	0.83	<0.42	<0.17
Glenarm	Brown trout	1	<0.94	<0.24	<0.10	0.55	<0.47	<0.24
Further afield								
Baltic Sea	Cod	2	<0.76	<0.21	<0.08	7.6	<0.37	<0.17
Baltic Sea	Herring	2	<0.74	<0.18	<0.08	4.4	<0.33	<0.14
Barents Sea	Cod	2	<0.43	<0.11	<0.05	0.15	<0.22	<0.11
Norwegian Sea	Cod	1	<0.64	<0.13	<0.07	0.22	<0.27	<0.10
Norwegian Sea	Herring	2	<0.78	<0.16	<0.08	0.16	<0.34	<0.12
Norwegian Sea	Saithe	1	<0.74	<0.17	<0.08	0.17	<0.41	<0.18
Norwegian processed	Cod	1	<0.59	<0.14	<0.06	0.19	<0.31	<0.15
Iceland area	Cod	1	<0.57	<0.12	<0.06	0.13	<0.25	<0.10
Skagerrak	Cod	1	<0.57	<0.13	<0.07	0.22	<0.20	<0.10
Skagerrak	Herring	2	<0.97	<0.24	<0.11	0.34	<0.44	<0.20
Skagerrak	Saithe	1	<0.34	<0.09	<0.04	0.31	<0.17	<0.08
Northern North Sea	Cod	2	<0.53	<0.14	<0.06	0.21	<0.27	<0.14
Northern North Sea	Plaice	2	<0.37	<0.09	<0.04	0.11	<0.17	<0.08
Northern North Sea	Haddock	1	<0.34	<0.08	<0.04	0.14	<0.12	<0.05
Northern North Sea	Herring	1	<1.3	<0.26	<0.13	<0.12	<0.57	<0.19
Northern North Sea	Whiting	1	<0.36	<0.08	<0.04	0.11	<0.13	<0.06
Mid North Sea	Cod	2	<0.34	<0.08	<0.04	0.28	<0.14	<0.06
Mid North Sea	Plaice	2	<0.44	<0.10	<0.05	0.13	<0.19	<0.08
Gt Yarmouth (retail shop)	Cod	2	<0.52	<0.14	<0.06	0.15	<0.27	<0.15
Gt Yarmouth (retail shop)	Plaice	2	<0.30	<0.08	<0.03	0.07	<0.16	<0.07
Southern North Sea	Cod	2	<0.38	<0.09	<0.05	0.29	<0.14	<0.07
Southern North Sea	Plaice	1	<0.31	<0.09	<0.04	0.09	<0.19	<0.10
Southern North Sea	Sole	1	<0.47	<0.11	<0.06	0.09	<0.19	<0.09
Southern North Sea	Herring	1	<0.57	<0.14	<0.06	0.25	<0.27	<0.11
English Channel-East	Plaice	2	<0.47	<0.11	<0.05	0.08	<0.25	<0.12
English Channel-East	Whiting	2	<0.54	<0.13	<0.06	0.22	<0.27	<0.14
English Channel-West	Plaice	2	<0.37	<0.09	<0.04	0.10	<0.16	<0.07
English Channel-West	Mackerel	2	<0.51	<0.13	<0.06	0.17	<0.23	<0.12
English Channel-West	Whiting	2	<0.45	<0.12	<0.05	0.29	<0.24	<0.12
Celtic Sea	Haddock	2	<1.0	<0.24	<0.11	0.83	<0.50	<0.23
Celtic Sea	Plaice	1	<0.78	<0.18	<0.09	0.13	<0.32	<0.15
Celtic Sea	Whiting	1	<0.57	<0.13	<0.06	0.12	<0.24	<0.11
Northern Irish Sea	Dab	1	<1.9	<0.40	<0.20	0.70	<0.61	<0.27
Northern Irish Sea	Lesser spotted dogfish	1	<1.7	<0.39	<0.17	1.2	<0.84	<0.35
Northern Irish Sea	Skates / rays	1	<0.79	<0.20	<0.08	2.0	<0.41	<0.20

* *Not detected by the method used*
[a] *The concentrations of ^{129}I and ^{147}Pm were <2.7 and <0.089 Bq kg^{-1} respectively*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 2.6. Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria											
Silloth	Shrimps	4				<0.07		<0.14	<0.10		<0.60
Silloth	Mussels	4		<25		<0.20		<0.17	<0.11		<0.91
Parton	Crabs	4				0.24		<0.13	<0.11		<0.57
Parton	Lobsters	4				<0.09		<0.09	<0.08		<0.42
Parton	Winkles	4				0.95		<0.15	<0.10		3.3
Whitehaven	*Nephrops*	4			80	<0.10	0.044	<0.26	<0.27	39	<0.92
Whitehaven	Cockles	2				<0.10		<0.34	<0.40		<0.99
Whitehaven	Mussels	2				<0.05	0.024	<0.15	<0.16		<0.48
Whitehaven outer harbour	Mussels	2				0.47		<0.18	<0.15		<1.6
Saltom Bay	Winkles	4				0.79		<0.24	<0.21		<2.3
St Bees	Winkles[a]	4			150	1.3	1.4	<0.22	<0.19	45	4.9
St Bees	Mussels	4				0.71		<0.16	<0.15		3.6
St Bees	Limpets	4				0.67		<0.20	<0.15		3.3
Nethertown	Winkles	12	<25	<25	140	2.1	3.6	<0.20	<0.16	30	7.7
Nethertown	Mussels	4	58	68	150	1.1		<0.14	<0.11	53	7.8
Sellafield coastal area	Crabs[b]	8			180	0.68	0.053	<0.40	<0.19	7.0	<1.2
Sellafield coastal area	Lobsters	8			240	<0.36	0.093	<0.29	<0.45	240	<0.76
Sellafield coastal area	*Nephrops*	1				<0.07		<0.13	<0.12	32	<0.46
Sellafield coastal area[c]	Winkles	8			140	1.8	0.97	<0.20	<0.14	29	6.8
Sellafield coastal area[c]	Mussels	4				1.1	0.62	<0.14	<0.10		6.4
Sellafield coastal area[c]	Limpets	4			91	0.64	3.8	<0.21	<0.15	81	3.8
Whitriggs	Shrimps	1				<0.08		<0.19	<0.18		<0.60
Drigg	Winkles	4			180	3.6		<0.34	<0.25	70	15
Ravenglass	Crabs	4				0.35	0.065	<0.20	<0.21	3.9	<0.69
Ravenglass	Lobsters	6				<0.14	0.050	<0.25	<0.36	160	<0.68
Ravenglass	Winkles	2				0.97		<0.11	<0.08		4.8
Ravenglass	Cockles	4			160	2.3	0.82	<0.13	<0.10	4.3	4.0
Ravenglass	Mussels	4		42		1.0		<0.14	<0.12	110	5.2
Tarn Bay	Winkles	4				1.6		<0.18	<0.15		6.9
Haverigg	Winkles	1				0.41		<0.16	<0.12		1.2
Haverigg	Cockles	1				0.94		<0.23	<0.17		<1.3
Millom	Mussels	4				0.27		<0.10	<0.06		1.1
Barrow	Crabs	4				<0.09		<0.15	<0.14		<0.55
Barrow	Lobsters	4				<0.07		<0.14	<0.13	90	<0.51
Roosebeck	Pacific oysters	2				<0.09		<0.16	<0.14		<0.69
Morecambe Bay (Flookburgh)	Shrimps	4			88	<0.09		<0.26	<0.34	0.61	<0.73
Morecambe Bay (Flookburgh)	Cockles	2			74	0.29	0.20	<0.21	<0.26	1.6	<0.55
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Shrimps	2				<0.06		<0.12	<0.10		<0.54
Morecambe Bay (Morecambe)	Mussels	4	60	66	76	<0.07		<0.14	<0.12	15	<0.58
Red Nab Point	Winkles	4				<0.14		<0.19	<0.15		<0.77
Morecambe Bay (Middleton Sands)	Cockles	2				<0.22		<0.23	<0.22		<0.92
Knott End	Mussels	2				<0.13		<0.11	<0.09		<0.54
Fleetwood	Whelks	1				<0.09		<0.22	<0.24		<0.72
Ribble Estuary	Shrimps	2			58	<0.07		<0.13	<0.10	0.20	<0.62
Ribble Estuary	Mussels	2				<0.06		<0.10	<0.08		<0.51
Liverpool Bay	Mussels	2		<25							
Mersey Estuary	Mussels	2		<25							
Dee Estuary	Cockles	4				<0.08		<0.13	<0.10	2.1	<0.60
Wirral	Shrimps	2		<25		<0.04		<0.09	<0.07	0.82	<0.33

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}							
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	^{155}Eu	Gross beta
Cumbria										
Silloth	Shrimps	4	<0.12	<0.17	<0.07	3.4	<0.27		<0.13	
Silloth	Mussels	4	<0.14	<0.31	<0.09	2.7	<0.31		<0.15	
Parton	Crabs	4	<0.11	<0.15	<0.06	1.1	<0.25		<0.11	
Parton	Lobsters	4	<0.08	<0.11	<0.05	1.3	<0.23		<0.11	
Parton	Winkles	4	<0.14	0.91	<0.09	9.0	<0.33		<0.16	
Whitehaven	*Nephrops*	4	<0.17	<0.22	<0.09	2.8	<0.41		<0.18	180
Whitehaven	Cockles	2	<0.18	<0.22	<0.11	<0.09	<0.38		<0.18	
Whitehaven	Mussels	2	<0.09	<0.11	<0.05	<0.05	<0.21		<0.10	
Whitehaven outer harbour	Mussels	2	<0.12	0.83	<0.08	1.5	<0.30		<0.14	
Saltom Bay	Winkles	4	<0.20	<0.63	<0.11	3.3	<0.46		<0.23	
St Bees	Winkles[a]	4	<0.22	0.76	<0.11	4.4	<0.41	0.32	<0.20	
St Bees	Mussels	4	<0.12	1.0	<0.07	2.1	<0.29		<0.13	
St Bees	Limpets	4	<0.17	1.8	<0.10	5.6	<0.40		<0.20	
Nethertown	Winkles	12	<0.28	1.2	<0.10	8.5	<0.48	1.2	<0.24	260
Nethertown	Mussels	4	<0.12	1.7	<0.07	2.0	<0.34		<0.16	190
Sellafield coastal area	Crabs[b]	8	<0.16	<0.25	<0.08	1.5	<0.34	0.080	<0.13	170
Sellafield coastal area	Lobsters	8	<0.24	<0.24	<0.08	2.3	<0.35	0.067	<0.15	360
Sellafield coastal area	*Nephrops*	1	<0.10	<0.13	<0.06	3.4	<0.17		<0.08	
Sellafield coastal area[c]	Winkles	8	<0.24	1.3	<0.10	5.2	<0.47	0.23	<0.22	
Sellafield coastal area[c]	Mussels	4	<0.12	1.1	<0.07	2.8	<0.30		<0.14	
Sellafield coastal area[c]	Limpets	4	<0.19	1.5	<0.10	5.2	<0.53		<0.27	
Whitriggs	Shrimps	1	<0.13	<0.16	<0.07	2.2	<0.24		<0.11	
Drigg	Winkles	4	<0.43	1.7	<0.18	8.6	<0.81	1.3	<0.41	340
Ravenglass	Crabs	4	<0.14	<0.20	<0.07	1.1	<0.35		<0.16	130
Ravenglass	Lobsters	6	<0.17	<0.17	<0.07	1.5	<0.32		<0.15	400
Ravenglass	Winkles	2	<0.11	0.59	<0.06	5.2	<0.32		<0.16	
Ravenglass	Cockles	4	<0.11	0.56	<0.06	3.3	<0.39		<0.16	140
Ravenglass	Mussels	4	<0.12	1.0	<0.07	1.2	<0.32		<0.15	
Tarn Bay	Winkles	4	<0.19	1.2	<0.09	5.2	<0.41		<0.21	
Haverigg	Winkles	1	<0.13	1.1	<0.07	3.6	<0.22		<0.10	
Haverigg	Cockles	1	<0.20	<0.27	<0.12	3.0	<0.43		<0.19	
Millom	Mussels	4	<0.09	<0.17	<0.05	0.99	<0.23		<0.12	
Barrow	Crabs	4	<0.11	<0.14	<0.06	0.74	<0.24		<0.11	
Barrow	Lobsters	4	<0.11	<0.13	<0.06	1.1	<0.23		<0.11	210
Roosebeck	Pacific oysters	2	<0.12	<0.23	<0.07	1.2	<0.31		<0.14	
Morecambe Bay (Flookburgh)	Shrimps	4	<0.15	<0.20	<0.08	4.9	<0.33		<0.15	
Morecambe Bay (Flookburgh)	Cockles	2	<0.10	<0.14	<0.06	2.8	<0.25		<0.12	
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Shrimps	2	<0.10	<0.14	<0.06	3.6	<0.24		<0.13	
Morecambe Bay (Morecambe)	Mussels	4	<0.10	<0.18	<0.06	2.0	<0.25		<0.12	
Red Nab Point	Winkles	4	<0.14	<0.26	<0.08	2.6	<0.39		<0.20	
Morecambe Bay (Middleton Sands)	Cockles	2	<0.15	<0.20	<0.09	2.0	<0.31		<0.14	
Knott End	Mussels	2	<0.09	0.32	<0.05	1.8	<0.25		<0.13	
Fleetwood	Whelks	1	<0.14	<0.19	<0.08	0.43	<0.37		<0.18	
Ribble Estuary	Shrimps	2	<0.11	<0.17	<0.07	2.4	<0.28		<0.15	
Ribble Estuary	Mussels	2	<0.09	<0.15	<0.06	1.0	<0.26		<0.14	
Dee Estuary	Cockles	4	<0.11	<0.15	<0.07	1.6	<0.28		<0.14	
Wirral	Shrimps	2	<0.07	<0.08	<0.04	1.3	<0.14		<0.06	

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Scotland											
Lewis	Mussels	1[S]				<0.10		<0.10	<0.10		<0.28
Skye	Lobsters	1[S]				<0.10		<0.38		8.8	<0.71
Skye	Mussels	1[S]				<0.10		<0.46			<0.84
Islay	Crabs	1[S]				<0.10			<0.22		<0.75
Islay	Scallops	1[S]				<0.10		<0.10	<0.10		<0.35
Kirkcudbright	Scallops	4[S]				<0.11		<0.19	<0.23	0.32	<0.44
Kirkcudbright	Queens	4[S]				<0.10		<0.12	<0.14	0.43	<0.34
Kirkcudbright	Limpets	1[S]				0.16		<0.30	<0.43		<0.61
Southerness	Winkles	4[S]		<5.0		<0.16	0.12	<0.14	<0.13	37	<0.49
North Solway coast	Crabs	4[S]			75	<0.16	<0.10	<0.18	<0.16	3.9	<0.60
North Solway coast	Lobsters	4[S]			83	<0.10	<0.10	<0.23	<0.22	72	<0.68
North Solway coast	Winkles	4[S]				<0.17	<0.11	<0.17	<0.15	35	<0.59
North Solway coast	Cockles	1[S]				0.41		<0.10	<0.10		<0.18
North Solway coast	Mussels	4[S]		<5.5	79	0.19	0.50	<0.13	<0.12	77	<0.37
Inner Solway	Shrimps	2[S]		<7.2		<0.10	<0.11	<0.31	<0.46	1.4	<0.72
Isle of Man											
Isle of Man	Lobsters	4				<0.05		<0.09	<0.07	19	<0.41
Isle of Man	Scallops	4				<0.05		<0.10	<0.08		<0.40
Wales											
Conwy	Mussels	2			38	<0.04		<0.07	<0.04		<0.36
North Anglesey	Crabs	2				<0.05		<0.10	<0.08	0.88	<0.46
North Anglesey	Lobsters	2				<0.04		<0.08	<0.06	21	<0.40
Lavernock Point	Limpets	2	<29	<25	15	<0.13		<0.28	<0.21		<1.3
Northern Ireland											
Ballycastle	Lobsters	2[N]				<0.09		<0.35	<0.45	19	<0.94
County Down	Scallops	2[N]				<0.07		<0.27	<0.39		<0.56
Kilkeel	Crabs	4[N]				<0.10		<0.35	<0.45		<0.99
Kilkeel	Lobsters	4[N]				<0.10		<0.30	<0.34	25	<0.98
Kilkeel	*Nephrops*	4[N]				<0.14		<0.59	<0.96	7.8	<1.4
Minerstown	Toothed winkles	2[N]				<0.05		<0.09	<0.06		<0.40
Carlingford Lough	Mussels	2[N]				<0.12		<0.51	<0.79	13	<1.4
Further afield											
Northern North Sea	*Nephrops*	2				<0.06		<0.15	<0.16	1.4	<0.53
Cromer	Crabs	1				<0.05		<0.11	<0.07		<0.49
Southern North Sea	Cockles	1				<0.06		<0.17	<0.18		<0.52
Southern North Sea	Mussels	2				<0.11		<0.22	<0.18	1.1	<1.0
Southern North Sea	Cockles[d]	1				<0.05		<0.12	<0.13	<0.31	<0.33
Southern North Sea	Mussels[d]	1				<0.04		<0.11	<0.11		<0.33
English Channel-East	Queens	1				<0.10		<0.23	<0.21		<0.85
English Channel-East	Scallops	1			29	<0.07		<0.16	<0.15		<0.57
English Channel-West	Crabs	2			15	<0.07		<0.16	<0.13		<0.62
English Channel-West	Lobsters	2				<0.06		<0.13	<0.10	0.46	<0.54
English Channel-West	Scallops	2			23	<0.06		<0.12	<0.10		<0.44
Northern Irish Sea	Crabs	1				<0.17		<0.58	<0.76		<1.6
Northern Irish Sea	Squid	1				<0.12		<0.37	<0.44		<1.2

Table 2.6. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	Gross beta
Scotland									
Lewis	Mussels	1[S]	<0.10	<0.10	<0.10	<0.10	<0.19	<0.10	
Skye	Lobsters	1[S]	<0.10	<0.18	<0.10	0.15	<0.44	<0.17	
Skye	Mussels	1[S]	<0.10	<0.22	<0.10	<0.10	<0.46	<0.18	
Islay	Crabs	1[S]	<0.10	<0.21	<0.10	0.19	<0.50	<0.20	
Islay	Scallops	1[S]	<0.10	<0.10	<0.10	<0.10	<0.22	<0.11	
Kirkcudbright	Scallops	4[S]	<0.11	<0.15	<0.11	<0.10	<0.27	<0.15	
Kirkcudbright	Queens	4[S]	<0.10	<0.11	<0.10	<0.20	<0.21	<0.11	
Kirkcudbright	Limpets	1[S]	<0.10	0.44	<0.10	2.2	<0.38	<0.18	
Southerness	Winkles	4[S]	<0.11	<0.18	<0.10	1.2	<0.30	<0.14	
North Solway coast	Crabs	4[S]	<0.10	<0.17	<0.10	0.90	<0.36	<0.16	
North Solway coast	Lobsters	4[S]	<0.12	<0.19	<0.10	1.4	<0.42	<0.18	
North Solway coast	Winkles	4[S]	<0.11	<0.20	<0.10	1.1	<0.34	<0.16	
North Solway coast	Cockles	1[S]	<0.10	0.11	<0.10	2.8	<0.12	<0.10	
North Solway coast	Mussels	4[S]	<0.10	<0.19	<0.10	2.6	<0.21	<0.12	
Inner Solway	Shrimps	2[S]	<0.12	<0.20	<0.10	3.4	<0.44	<0.18	
Isle of Man									
Isle of Man	Lobsters	4	<0.08	<0.10	<0.05	0.27	<0.18	<0.09	130
Isle of Man	Scallops	4	<0.08	<0.10	<0.05	0.25	<0.17	<0.08	
Wales									
Conwy	Mussels	2	<0.07	<0.09	<0.04	0.16	<0.15	<0.07	
North Anglesey	Crabs	2	<0.09	<0.12	<0.05	0.37	<0.24	<0.11	
North Anglesey	Lobsters	2	<0.08	<0.11	<0.04	0.27	<0.22	<0.11	110
Lavernock Point	Limpets	2	<0.21	<0.31	<0.14	0.49	<0.63	<0.30	
Northern Ireland									
Ballycastle	Lobsters	2[N]	<0.17	<0.22	<0.09	0.16	<0.49	<0.21	
County Down	Scallops	2[N]	<0.13	<0.13	<0.06	0.30	<0.26	<0.12	
Kilkeel	Crabs	4[N]	<0.18	<0.22	<0.10	0.24	<0.40	<0.16	
Kilkeel	Lobsters	4[N]	<0.18	<0.23	<0.10	0.27	<0.44	<0.20	
Kilkeel	*Nephrops*	4[N]	<0.26	<0.29	<0.14	0.58	<0.49	<0.20	
Minerstown	Toothed winkles	2[N]	<0.08	<0.11	<0.05	0.36	<0.19	<0.10	
Carlingford Lough	Mussels	2[N]	<0.23	<0.30	<0.13	0.32	<0.67	<0.28	
Further afield									
Northern North Sea	*Nephrops*	2	<0.10	<0.12	<0.06	<0.08	<0.26	<0.13	
Cromer	Crabs	1	<0.09	<0.14	<0.05	0.07	<0.31	<0.15	
Southern North Sea	Cockles	1	<0.10	<0.13	<0.06	<0.06	<0.28	<0.14	
Southern North Sea	Mussels	2	<0.17	<0.23	<0.11	<0.12	<0.39	<0.18	
Southern North Sea	Cockles[d]	1	<0.07	<0.08	<0.04	0.04	<0.12	<0.06	
Southern North Sea	Mussels[d]	1	<0.07	<0.08	<0.04	<0.03	<0.12	<0.05	28
English Channel-East	Queens	1	<0.15	<0.19	<0.09	<0.08	<0.34	<0.14	
English Channel-East	Scallops	1	<0.12	<0.13	<0.06	<0.06	<0.23	<0.11	
English Channel-West	Crabs	2	<0.12	<0.17	<0.07	<0.06	<0.32	<0.17	
English Channel-West	Lobsters	2	<0.10	<0.14	<0.06	<0.06	<0.28	<0.15	
English Channel-West	Scallops	2	<0.09	<0.11	<0.05	<0.05	<0.20	<0.10	
Northern Irish Sea	Crabs	1	<0.28	<0.33	<0.16	0.88	<0.53	<0.22	
Northern Irish Sea	Squid	1	<0.20	<0.27	<0.11	0.22	<0.57	<0.24	

* *Not detected by the method used*
[a] *The concentration of ^{129}I was <2.2 Bq kg^{-1}*
[b] *The concentration of ^{129}I was <1.5 Bq kg^{-1}*
[c] *Samples collected by Consumer 971*
[d] *Landed in Holland or Denmark*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 2.7. Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cumbria									
Silloth	Shrimps	1		0.0031	0.016	0.15	0.033	*	*
Silloth	Mussels	1		0.66	3.8		7.6	*	0.0054
Maryport	Plaice	4					<0.09		
River Derwent	Sea trout	1					<0.44		
Parton	Cod	4					<0.18		
Parton	Crabs	4					0.84		
Parton	Lobsters	4					2.1		
Parton	Winkles	1		1.8	9.7	66	19	*	*
Whitehaven	Cod	1		0.00088	0.0048		0.010	*	*
Whitehaven	Plaice	1		0.0059	0.034		0.066	0.00011	0.000082
Whitehaven	Skates / rays	1		0.00073	0.0035		0.0064	*	*
Whitehaven	Sole	1		0.0048	0.020		0.026	*	*
Whitehaven	*Nephrops*	1		0.028	0.17		1.2	*	0.0012
Whitehaven	Cockles	1		0.0011	0.0053		0.0081	*	0.00031
Whitehaven	Mussels	1		0.00077	0.0052	<0.62	0.0039	*	*
Whitehaven outer harbour	Mussels	2					7.7		
Saltom Bay	Winkles	4					10		
St Bees	Winkles	1	0.011	1.4	7.5	49	14	*	0.0071
St Bees	Mussels	2		0.88	4.6	35	11	*	0.014
St Bees	Limpets	1		1.4	8.0		15	*	0.019
Nethertown	Winkles	4	0.040	2.5	13	92	26	<0.0085	0.023
Nethertown	Mussels	4		1.3	6.2		15	*	0.030
River Ehen	Salmon	1					<0.08		
River Ehen	Sea trout	1					<0.13		
Sellafield coastal area	Cod	2		0.00048	0.0024		0.0075	*	0.000028
Sellafield coastal area	Plaice	1		0.0036	0.019		0.039	*	0.000038
Sellafield coastal area	Bass	1					<0.12		
Sellafield coastal area	Grey mullet	1					<0.07		
Sellafield coastal area	Crabs	2	0.0026	0.085	0.45	3.9	1.7	*	<0.0017
Sellafield coastal area	Lobsters	2	0.010	0.066	0.31	3.0	4.2	*	0.0031
Sellafield coastal area	*Nephrops*	1		0.052	0.31		1.3	*	0.0039
Sellafield coastal area[a]	Winkles	2	0.0082	1.7	8.5	62	17	*	<0.017
Sellafield coastal area[a]	Mussels	1		1.5	7.4	59	15	*	0.040
Sellafield coastal area[a]	Limpets	1		1.5	7.9	56	25	*	0.021
Sellafield offshore area	Plaice	1	0.00035	0.0024	0.014		0.028	0.000082	*
Sellafield offshore area	Skates / rays	1		0.0034	0.018		0.032	*	0.000055
Sellafield offshore area	Dab	2					<0.30		
Sellafield offshore area	Gurnards	1					<0.32		
Sellafield offshore area	Smooth hound	1					<0.10		
Sellafield offshore area	Spurdog	1					0.11		
River Esk	Sea trout	1					<0.21		
River Calder	Brown trout	1					<0.59		
Whitriggs	Shrimps	1					0.09		
Drigg	Winkles	1	0.033	3.4	18	130	33	*	0.032
Ravenglass	Cod	1		0.00028	0.0015		0.0030	*	*
Ravenglass	Plaice	1		0.0020	0.011		0.019	*	*
Ravenglass	Crabs	1		0.036	0.18	1.1	1.2	*	0.0019
Ravenglass	Lobsters	1		0.031	0.18	1.3	2.4	*	*
Ravenglass	Winkles	2					18		
Ravenglass	Cockles	1		1.5	7.1	52	23	*	0.028
Ravenglass	Mussels	1		0.91	4.4	36	9.9	*	0.020
Tarn Bay	Winkles	1		1.6	8.3	60	12	*	*
Haverigg	Winkles	1					8.4		
Haverigg	Cockles	1					17		
Millom	Mussels	1		0.26	1.4		3.3	*	*
Barrow	Crabs	1		0.014	0.066		0.51	*	*
Barrow	Lobsters	4					1.1		
Roosebeck	Pacific oysters	1		0.16	0.91		1.0	*	0.00074
Morecambe Bay (Flookburgh)	Flounder	1		0.00025	0.0017		0.0030	*	*
Morecambe Bay (Flookburgh)	Shrimps	1		0.0036	0.021	<0.58	0.040	*	*
Morecambe Bay (Flookburgh)	Cockles	1		0.21	1.4	8.4	4.8	*	0.0042

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Whiting	4					<0.13		
Morecambe Bay (Morecambe)	Bass	2					<0.28		
Morecambe Bay (Morecambe)	Flounder	4					<0.19		
Morecambe Bay (Morecambe)	Shrimps	2					<0.13		
Morecambe Bay (Morecambe)	Mussels	1		0.21	1.2		2.1	*	*
Red Nab Point	Winkles	1		0.17	1.1		2.0	*	*
Morecambe Bay (Middleton Sands)	Cockles	1		0.13	0.77		2.5	*	*
Morecambe Bay (Sunderland Point)	Whitebait	1		0.028	0.17	0.65	0.31	*	0.00032
River Duddon	Sea trout	1					<0.13		
Knott End	Mussels	1		0.22	1.3		2.6	*	0.0043
Fleetwood	Plaice	1		0.00025	0.0059		0.0027	*	0.000027
Fleetwood	Red gurnard	1		0.00056	0.0031		0.0055	*	*
Fleetwood	Whelks	1					0.73		
Ribble Estuary	Grey mullet	2					<0.09		
Ribble Estuary	Flounder	1					<0.09		
Ribble Estuary	Bass	1					<0.11		
Ribble Estuary	Salmon	1					<0.08		
Ribble Estuary	Shrimps	1	0.000076	0.0022	0.012		0.021	*	0.000057
Ribble Estuary	Mussels	2					0.91		
Dee Estuary	Cockles	1		0.12	0.72		2.0	*	*
Wirral	Shrimps	2					<0.04		
Scotland									
Shetland	Fish meal	1		0.000067	0.00044		0.00059	*	*
Shetland	Fish oil	2					<0.14		
Minch	Herring	1					<0.19		
Minch	Mackerel	1		0.000078	0.00015		0.00039	*	*
West of Scotland	Mackerel	1					<0.13		
West of Scotland	Farmed salmon	1					<0.28		
Lewis	Mussels	1[S]					<0.10		
Skye	Lobsters	1[S]					<0.10		
Skye	Mussels	1[S]					<0.10		
Islay	Crabs	1[S]					<0.12		
Islay	Scallops	1[S]					<0.11		
Kirkcudbright	Lemon sole	1[S]		<0.0040	0.0042		0.0041		
Kirkcudbright	Scallops	1[S]		0.0053	0.040		0.039		
Kirkcudbright	Queens	1[S]		0.0077	0.028		0.017		
Kirkcudbright	Limpets	1[S]					4.6		
Southerness	Winkles	1[S]		0.17	0.97		1.7		
North Solway coast	Crabs	1[S]		0.017	0.12	0.24	0.50		
North Solway coast	Lobsters	1[S]		0.018	0.097	0.36	0.67		
North Solway coast	Winkles	1[S]		0.17	0.95	2.1	1.7		
North Solway coast	Cockles	1[S]		0.61	3.5		9.1		
North Solway coast	Mussels	1[S]		0.81	4.6	2.1	9.7		
Inner Solway	Flounder	1[S]		<0.00050	0.0022		0.00088		
Inner Solway	Salmon	1[S]					<0.14		
Inner Solway	Sea trout	1[S]					<0.12		
Inner Solway	Shrimps	1[S]		0.0024	0.012		0.043		
Isle of Man									
Isle of Man	Cod	1		0.000071	0.00045		0.00083	*	*
Isle of Man	Herring	2					<0.19		
Isle of Man	Mackerel	1		0.00011	0.00093		0.0019	*	*
Isle of Man	Lobsters	4					<0.08		
Isle of Man	Scallops	1		0.029	0.16		0.046	*	*

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$
Wales							
Conwy	Mussels	1	0.016	0.10	0.19	*	*
North Anglesey	Thornback ray	1			<0.20		
North Anglesey	Spurdog	1			<0.14		
North Anglesey	Lesser spotted dogfish	1	0.000065	0.00034	0.00076	*	*
North Anglesey	Plaice	2			<0.14		
North Anglesey	Bass	1			<0.04		
North Anglesey	Crabs	1	0.0031	0.019	0.063	*	0.00015
North Anglesey	Lobsters	2			<0.14		
Lavernock Point	Limpets	2			<0.28		
Northern Ireland							
North coast	Skates / rays	3[N]			<0.18		
North coast	Spurdog	1[N]			<0.10		
Ballycastle	Lobsters	2[N]			<0.21		
County Down	Scallops	2[N]			<0.18		
Ardglass	Herring	2[N]			<0.10		
Kilkeel	Cod	4[N]			<0.14		
Kilkeel	Plaice	4[N]			<0.15		
Kilkeel	Skates / rays	4[N]			<0.17		
Kilkeel	Haddock	4[N]			<0.16		
Kilkeel	Crabs	4[N]			<0.10		
Kilkeel	Lobsters	4[N]			<0.17		
Kilkeel	*Nephrops*	1[N]	0.0022	0.015	0.035	*	*
Minerstown	Toothed winkles	1[N]	0.051	0.31	0.21	*	*
Carlingford Lough	Mussels	2[N]			<0.25		
Glenarm	Brown trout	1[N]			<0.29		
Further afield							
Baltic Sea	Cod	2			<0.18		
Baltic Sea	Herring	2			<0.08		
Barents Sea	Cod	2			<0.11		
Norwegian Sea	Cod	1			<0.06		
Norwegian Sea	Herring	1			<0.06		
Norwegian Sea	Saithe	1			<0.20		
Norwegian processed	Cod	1	0.000042	0.00020	0.00029	*	*
Iceland area	Cod	1			<0.06		
Skagerrak	Cod	1			<0.06		
Skagerrak	Herring	2			<0.15		
Skagerrak	Saithe	1			<0.05		
Northern North Sea	Cod	1	0.000030	0.000072	0.00017	*	*
Northern North Sea	Plaice	2			<0.04		
Northern North Sea	Haddock	1			<0.03		
Northern North Sea	Herring	1			<0.10		
Northern North Sea	Whiting	1	0.000037	0.00038	0.00024	*	*
Northern North Sea	*Nephrops*	1	0.00010	0.0013	0.0012	*	*
Mid North Sea	Cod	2			<0.04		
Mid North Sea	Plaice	2			<0.05		
Cromer	Crabs	1			<0.14		
Gt Yarmouth (retail shop)	Cod	2			<0.18		
Gt Yarmouth (retail shop)	Plaice	2			<0.06		
Southern North Sea	Cod	2			<0.04		
Southern North Sea	Plaice	1			<0.10		
Southern North Sea	Herring	1			<0.06		
Southern North Sea	Sole	1			<0.06		
Southern North Sea	Cockles	1	0.00095	0.0050	0.0080	*	0.00034
Southern North Sea	Mussels	1	0.0027	0.019	0.0078	*	*
Southern North Sea	Cockles[b]	1	0.0014	0.0072	0.0098	*	0.00040
Southern North Sea	Mussels[b]	1	0.00019	0.0019	0.0012	*	0.000035
English Channel-East	Plaice	2			<0.13		
English Channel-East	Whiting	2			<0.16		
English Channel-East	Scallops	1	0.00049	0.0024	0.00090	*	0.000031
English Channel-East	Queens	1			<0.07		
English Channel-West	Plaice	2			<0.04		
English Channel-West	Mackerel	2			<0.12		

Table 2.7. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}				
			^{238}Pu	$^{239}Pu + ^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm + ^{244}Cm$
English Channel-West	Whiting	2			<0.14		
English Channel-West	Crabs	1	0.000044	0.00061	0.00083	*	0.00010
English Channel-West	Lobsters	2			<0.18		
English Channel-West	Scallops	1	0.00019	0.0038	0.00073	*	*
Celtic Sea	Plaice	1			<0.09		
Celtic Sea	Haddock	2			<0.24		
Celtic Sea	Whiting	1			<0.06		
Northern Irish Sea	Dab	1			<0.14		
Northern Irish Sea	Lesser spotted dogfish	1			<0.31		
Northern Irish Sea	Skates / rays	1			0.26		
Northern Irish Sea	Crabs	1			0.27		
Northern Irish Sea	Squid	1			<0.22		

* *Not detected by the method used*
[a] *Samples collected by consumer 971*
[b] *Landed in Holland or Denmark*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 2.8. Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria												
Newton Arlosh	Sediment	4	<1.4		<2.3	<0.84	<8.7		<4.5	<1.0	270	<4.1
Maryport Outer Harbour	Sediment	2	<1.3	<16	<1.5	<0.63	<6.0		<3.2	<0.75	99	<3.1
Workington Harbour	Sediment	2	<0.85		<1.5	<0.75	<5.5		<3.1	<0.80	49	<2.9
Harrington Harbour	Sediment	2	<0.91		<1.4	<0.66	<6.0		<3.4	<0.78	190	<3.1
Whitehaven Outer Harbour	Sediment	4	<1.0	<1.5	<1.9	<0.76	<6.8		<3.8	<0.89	78	<3.4
St Bees beach	Sediment	4	<1.5		<1.5	<0.57	<5.4		<2.9	<0.70	60	<2.5
Sellafield beach, S of former pipeline	Sediment	2	<1.1		<0.88	<0.40	<3.7		<2.1	<0.46	46	<2.1
River Calder - downstream	Sediment	2	<0.54		<1.3	<0.39	<3.7		<2.0	<0.48	28	<2.3
River Calder - upstream	Sediment	2	<0.73		<1.2	<0.56	<4.6		<2.4	<0.63	45	<2.8
Seascale beach	Sediment	4	<0.90		<1.3	<0.48	<4.6		<2.5	<0.57	43	<2.4
Ravenglass - Carleton Marsh	Sediment	4	7.8		<2.1	<0.80	<37		<5.8	<0.97	330	<5.4
River Mite Estuary (erosional)	Sediment	4	5.0	50	<1.3	<0.95	<33		<3.1	<0.64	370	<4.7
Ravenglass - Raven Villa	Sediment	4	3.9		<1.9	<0.71	<25		<3.8	<0.86	170	<4.0
Newbiggin (Eskmeals)	Sediment	4	8.5	77	<2.3	<0.87	28		<4.7	<0.99	260	<4.3
Haverigg	Sediment	2	1.7		<1.1	<0.51	<4.4		<2.5	<0.55	54	<2.4
Millom	Sediment	2	1.5		<1.3	<0.61	<9.5		<3.1	<0.66	130	<2.8
Low Shaw	Sediment	2	<0.76		<1.2	<0.50	<4.8		<2.5	<0.62	79	<2.4
Walney Channel - N of discharge point	Sediment	2	<0.79		<0.61	<0.32	<2.7		<1.4	<0.34	71	<1.6
Walney Channel - S of discharge point	Sediment	2	<1.4		<0.70	<0.39	<5.8		<1.7	<0.37	99	<1.8
Sand Gate Marsh	Sediment	4	<0.86		<1.6	<0.67	<5.8		<3.0	<0.73	60	<2.8
Kents Bank	Sediment	4	<0.87		<1.6	<0.62	<6.6		<3.5	<0.77	230	<3.5
Lancashire												
Morecambe	Sediment	2	<0.94								5.1	
Half Moon Bay	Sediment	2	<0.82								44	
Red Nab Point	Sediment	2	<1.1								21	
Potts Corner	Sediment	2	<0.92								20	
Sunderland Point	Sediment	4	<0.87		<1.8	<0.74	<6.1		<3.4	<0.95	81	<3.4
Conder Green	Sediment	4	<0.87		<1.8	<0.66	<6.0		<3.2	<0.80	79	<3.1
Hambleton	Sediment	4	<1.3		<1.8	<0.74	<7.2		<3.9	<0.82	280	<3.9
Skippool Creek	Sediment	4	<1.4		<2.2	<0.76	<7.1		<3.7	<0.83	280	<3.8
Fleetwood	Sediment	4	<0.63		<1.8	<0.44	<4.4		<2.2	<0.56	9.9	<2.2
Blackpool	Sediment	4	<0.62		<1.8	<0.46	<4.4		<2.3	<0.57	3.4	<2.2
Crossens Marsh	Sediment	4	<1.3		<3.1	<1.0	<10		<5.1	<1.3	250	<4.6
Ainsdale	Sediment	4	<0.61		<1.7	<0.48	<4.6		<2.4	<0.59	4.9	<2.4
Rock Ferry	Sediment	4	<1.1		<2.0	<0.73	<6.6		<3.6	<0.89	62	<3.2
New Brighton	Sediment	4	<0.73		<1.6	<0.55	<5.2		<2.9	<0.67	3.9	<2.6
Scotland												
Campbeltown	Sediment	1[S]	<0.10		<0.24	<0.26	<0.62	<0.10	<0.19	<0.10	6.5	<0.57
Garlieston	Sediment	1[S]	0.35		0.54	0.22	<0.76	<0.12	0.51	<0.10	30	<0.72
Innerwell	Sediment	1[S]	1.0		<0.12	<0.16	1.5	<0.10	1.0	<0.10	110	<0.50
Carsluith	Sediment	1[S]	0.44		<0.16	<0.20	<0.39	<0.10	0.50	<0.10	19	<0.36
Skyreburn	Sediment	1[S]	2.5		<0.39		<1.6	<0.20	1.1	<0.17	250	<1.3
Kirkcudbright	Sediment	1[S]	5.6		<0.57	<0.66	4.2	<0.32	4.8	<0.28	360	<2.6
Rascarrel Bay	Sediment	1[S]	0.52		0.47	0.79	<0.66	<0.11	3.3	<0.10	46	<0.63
Palnackie Harbour	Sediment	1[S]	0.93		<0.48	<0.72	<1.2	<0.16	<0.46	<0.13	150	<1.2
Gardenburn	Sediment	1[S]	1.1		<0.40	<0.43	2.9	<0.17	1.1	<0.14	150	<1.3
Kippford Slipway	Sediment	1[S]	1.1		<0.43	<0.64	1.7	<0.16	1.7	<0.13	130	<1.1
Kippford Merse	Sediment	1[S]	0.44		<0.23	<0.31	<2.1	<0.13	<0.96	<0.11	1500	<2.2
Southerness	Sediment	1[S]	0.16		<0.20	<0.30	<0.65	<0.11	0.39	<0.10	20	<0.71
Kirkconnel Merse	Sediment	1[S]	0.68		<0.57	<0.54	<1.7	<0.18	1.4	<0.14	510	<1.7

Table 2.8. continued

Location	Material	No. of sampling observ- ations	Mean radioactivity concentration (dry), $Bq\ kg^{-1}$							
			^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Cumbria										
Newton Arlosh	Sediment	4	<3.1	<1.9				300	690	1200
Maryport Outer Harbour	Sediment	2	<2.2	<1.5	19	110	730	230	600	1100
Workington Harbour	Sediment	2	<2.3	<1.4				26	510	950
Harrington Harbour	Sediment	2	<2.3	<1.9				76	540	1300
Whitehaven Outer Harbour	Sediment	4	<2.6	<1.6	11	65	410	110	450	880
St Bees beach	Sediment	4	<2.2	<1.2				170	450	570
Sellafield beach, S of former pipeline	Sediment	2	<1.5	<0.99				130	300	570
River Calder - downstream	Sediment	2	<1.4	<1.0				20	200	770
River Calder - upstream	Sediment	2	<2.0	<1.3					300	1300
Seascale beach	Sediment	4	<1.8	<1.1				140	350	580
Ravenglass - Carleton Marsh	Sediment	4	4.5	<4.5				1100	1900	1700
River Mite Estuary (erosional)	Sediment	4	4.3	<2.7	97	550	3700	1200	2200	1700
Ravenglass - Raven Villa	Sediment	4	2.3	<1.7				580	1200	1200
Newbiggin (Eskmeals)	Sediment	4	3.7	<3.3	79	430	3100	920	1500	1200
Haverigg	Sediment	2	<0.98	<1.1				220	490	540
Millom	Sediment	2	1.2	<1.6				320	870	1000
Low Shaw	Sediment	2	<2.0	<1.2				140	340	620
Walney Channel - N of discharge point	Sediment	2	<1.1	<0.80				140	460	840
Walney Channel - S of discharge point	Sediment	2	<1.3	<0.91				190	640	880
Sand Gate Marsh	Sediment	4	<2.2	<1.3				51	190	650
Kents Bank	Sediment	4	<2.3	<1.6				120	400	820
Lancashire										
Morecambe	Sediment	2						<2.1		
Half Moon Bay	Sediment	2			5.1	27		51		
Red Nab Point	Sediment	2						23		
Potts Corner	Sediment	2						12		
Sunderland Point	Sediment	4	<2.3	<1.6				72	380	720
Conder Green	Sediment	4	<2.3	<1.5				82	330	690
Hambleton	Sediment	4	<2.5	<1.8				250	640	1300
Skippool Creek	Sediment	4	<2.4	<1.7				260	530	1200
Fleetwood	Sediment	4	<1.7	<1.0				13	<100	410
Blackpool	Sediment	4	<1.7	<1.0				4.4	<100	270
Crossens Marsh	Sediment	4	<3.4	<2.2				230	510	1400
Ainsdale	Sediment	4	<1.8	<1.1				3.6	<100	<250
Rock Ferry	Sediment	4	<2.7	<1.5				43	420	880
New Brighton	Sediment	4	<2.1	<1.3				3.2	<110	430
Scotland										
Campbeltown	Sediment	1^{S}	<0.13	0.45				0.95		
Garlieston	Sediment	1^{S}	<0.17	0.65	4.8	28		52		
Innerwell	Sediment	1^{S}	0.57	1.1				150		
Carsluith	Sediment	1^{S}	0.53	0.81	10	58		170	240	890
Skyreburn	Sediment	1^{S}	1.4	1.8				340		
Kirkcudbright	Sediment	1^{S}	2.4	9.0				440		
Rascarrel Bay	Sediment	1^{S}	<0.10	<0.22				49		
Palnackie Harbour	Sediment	1^{S}	0.75	0.76	26	150		220		
Gardenburn	Sediment	1^{S}	0.77	1.5	23	140		110		
Kippford Slipway	Sediment	1^{S}	0.80	0.93	19	110		190		
Kippford Merse	Sediment	1^{S}	3.0	<1.0	72	450		910		
Southerness	Sediment	1^{S}	<0.16	<0.44	2.8	17		28		
Kirkconnel Merse	Sediment	1^{S}	1.1	1.6	30	180		320	400	1700

Table 2.8. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}								
			^{60}Co	^{95}Zr	^{95}Nb	^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Isle of Man											
Ramsey	Sediment	1	<1.0	<2.6	<0.71	<6.9		<3.7	<0.92	7.5	<3.7
Wales											
Rhyl	Sediment	2	<1.2	<2.4	<0.87	<8.1		<4.4	<1.1	86	<4.0
Llandudno	Sediment	2	<0.93	<2.0	<0.73	<6.8		<3.6	<0.90	3.1	<3.4
Caerhun	Sediment	2	<0.98	<2.1	<0.78	<6.9		<3.8	<0.89	41	<3.5
Llanfairfechan	Sediment	2	<0.88	<2.0	<0.68	<6.3		<3.4	<0.81	19	<3.1
Northern Ireland											
Carrichue	Mud	1^{N}	<0.48	<1.3	<1.1	<5.1	<0.96	<1.3	<0.64	1.1	<2.3
Carrichue	Mud and sand	1^{N}	<0.78	<5.5	<15	<8.3	<1.7	<1.7	<0.81	1.5	<3.6
Portrush	Sand	2^{N}	<0.42	<1.9	<2.7	<4.4	<0.80	<1.0	<0.47	<0.46	<2.6
Oldmill Bay	Mud	2^{N}	<0.76	<4.8	<11	<8.7	<1.7	<2.1	<1.0	30	<4.5
Ballymacormick	Mud	1^{N}	<0.63	<1.5	<1.1	<5.0	<1.1	<1.6	<0.73	13	<2.8
Ballymacormick	Mud and sand	1^{N}	<0.86	<6.8	<17	<10	<1.9	<2.2	<0.96	11	<5.4
Strangford Lough - Nicky's Point	Mud	2^{N}	<0.79	<4.5	<9.1	<8.0	<1.5	<2.0	<1.0	27	<4.0
Dundrum Bay	Mud	1^{N}	<0.94	<2.2	<1.6	<8.9	<1.5	<2.6	<1.3	31	<5.3
Dundrum Bay	Mud and sand	1^{N}	<0.81	<3.2	<4.2	<8.5	<1.5	<1.7	<0.92	5.5	<3.2
Carlingford Lough	Mud	2^{N}	<0.84	<2.8	<3.4	<8.3	<1.5	<2.2	<1.1	52	<4.5

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	<2.8	<1.8			<1.4			180	500
Wales											
Rhyl	Sediment	2	<3.1	<1.9			56			470	1100
Llandudno	Sediment	2	<2.5	<1.7			<1.4			<140	510
Caerhun	Sediment	2	<2.6	<1.7			19			310	860
Llanfairfechan	Sediment	2	<2.4	<1.5			13			290	820
Northern Ireland											
Carrichue	Mud	1^{N}	<1.6	<1.2	0.055	0.38	0.63	*	0.0035		
Carrichue	Mud and sand	1^{N}	<2.0	<1.1			0.98				
Portrush	Sand	2^{N}	<1.4	<1.1			<1.2				
Oldmill Bay	Mud	2^{N}	<2.3	<1.9			15				
Ballymacormick	Mud	1^{N}	<2.0	<1.4			12				
Ballymacormick	Mud and sand	1^{N}	<2.5	<2.0			15				
Strangford Lough - Nicky's Point	Mud	2^{N}	<2.4	<1.9			11				
Dundrum Bay	Mud	1^{N}	<2.6	<3.0			<4.5				
Dundrum Bay	Mud and sand	1^{N}	<2.6	<1.3			1.3				
Carlingford Lough	Mud	2^{N}	<2.6	<2.1	2.2	13	8.6	*	*		

* *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, 2010

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Grass	2	0.081
Burgh Marsh	Grass	2	0.084
Port Carlisle 1	Mud	2	0.087
Port Carlisle 1	Mud and sand	2	0.090
Port Carlisle 2	Grass	4	0.090
Greenend 1	Mud	1	0.089
Greenend 1	Mud and sand	2	0.094
Greenend 1	Grass	1	0.088
Greenend 2	Grass	4	0.089
Cardurnock Marsh	Grass	4	0.081
Newton Arlosh	Grass	4	0.096
Silloth harbour	Mud and pebbles	2	0.10
Silloth harbour	Pebbles and sand	1	0.10
Silloth harbour	Pebbles	1	0.11
Silloth silt pond	Grass	4	0.082
Allonby	Sand	2	0.083
Allonby	Pebbles and sand	2	0.11
Maryport harbour	Mud	1	0.094
Maryport harbour	Sand	1	0.090
Workington harbour	Pebbles and stones	1	0.11
Workington harbour	Pebbles and rock	1	0.11
Harrington harbour	Pebbles and sand	2	0.11
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Sand	1	0.090
Whitehaven - outer harbour	Pebbles and sand	3	0.10
St Bees	Sand	2	0.083
St Bees	Pebbles and sand	2	0.078
Nethertown beach	Pebbles	2	0.12
Braystones	Pebbles	2	0.12
Sellafield dunes	Grass	2	0.10
North of former pipeline on foreshore	Sand	2	0.084
South of former pipeline on foreshore	Sand	2	0.086
River Calder downstream of factory sewer	Grass	2	0.091
River Calder upstream of factory sewer	Grass	2	0.097
Seascale beach	Sand	3	0.084
Seascale beach	Pebbles and sand	1	0.085
Seascale	Grass	4	0.086

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, µGy h^{-1}
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Grass and mud	1	0.14
Ravenglass - Carleton Marsh	Grass	3	0.15
Ravenglass - River Mite estuary (erosional)	Grass	4	0.16
Ravenglass - Raven Villa	Mud and salt marsh	1	0.15
Ravenglass - Raven Villa	Salt marsh	2	0.15
Ravenglass - Raven Villa	Grass and salt marsh	1	0.14
Ravenglass - boat area	Mud and stones	1	0.11
Ravenglass - boat area	Sand and stones	2	0.11
Ravenglass - boat area	Pebbles and sand	1	0.095
Ravenglass - ford	Mud	1	0.11
Ravenglass - ford	Mud and sand	1	0.12
Ravenglass - ford	Mud and pebbles	1	0.11
Ravenglass - ford	Pebbles and sand	1	0.11
Muncaster Bridge	Grass	4	0.12
Ravenglass - salmon garth	Mud	1	0.11
Ravenglass - salmon garth	Mud and sand	1	0.11
Ravenglass - salmon garth	Mud and pebbles	2	0.11
Ravenglass - Eskmeals Nature Reserve	Mud and salt marsh	2	0.13
Ravenglass - Eskmeals Nature Reserve	Salt marsh	1	0.14
Ravenglass - Eskmeals Nature Reserve	Grass	1	0.16
Newbiggin/Eskmeals viaduct	Mud and salt marsh	1	0.12
Newbiggin/Eskmeals viaduct	Grass and mud	1	0.11
Newbiggin/Eskmeals viaduct	Mud and pebbles	2	0.12
Newbiggin/Eskmeals Bridge	Salt marsh	4	0.15
Tarn Bay	Sand	2	0.074
Silecroft	Pebbles	1	0.11
Silecroft	Pebbles and stones	1	0.12
Haverigg	Mud and pebbles	1	0.099
Haverigg	Sand	1	0.076
Millom	Mud and salt marsh	1	0.11
Millom	Grass and mud	1	0.11
Low Shaw	Grass	2	0.088
Askam	Sand	2	0.074
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud	1	0.091
Walney Channel, N of discharge point	Mud and sand	1	0.085
Walney Channel, S of discharge point	Mud	1	0.095
Walney Channel, S of discharge point	Mud and sand	1	0.093
Tummer Hill Marsh	Salt marsh	1	0.12
Tummer Hill Marsh	Grass	1	0.12
Roa Island	Mud	1	0.098
Roa Island	Mud and sand	1	0.10
Greenodd Salt Marsh	Grass	2	0.085
Sand Gate Marsh	Grass	4	0.086
Kents Bank 2	Grass and salt marsh	1	0.095
Kents Bank 2	Grass	3	0.094
High Foulshaw	Grass and mud	2	0.084
High Foulshaw	Grass	2	0.086
Arnside 1	Mud	3	0.086
Arnside 1	Mud and sand	1	0.087
Arnside 2	Grass	4	0.098
Lancashire and Merseyside			
Morecambe Central Pier	Sand	1	0.072
Morecambe Central Pier	Pebbles and sand	1	0.082
Half Moon Bay	Sand	1	0.079
Half Moon Bay	Sand and stones	1	0.089
Red Nab Point	Sand	2	0.088
Middleton Sands	Sand	2	0.079
Sunderland Point	Mud	4	0.11
Sunderland	Salt marsh	4	0.099
Colloway Marsh	Salt marsh	2	0.12
Colloway Marsh	Grass	2	0.14
Lancaster	Grass	4	0.085

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Lancashire and Merseyside			
Aldcliffe Marsh	Grass and mud	1	0.13
Aldcliffe Marsh	Grass and salt marsh	1	0.10
Aldcliffe Marsh	Grass	2	0.11
Conder Green	Mud	1	0.095
Conder Green	Grass and mud	2	0.088
Conder Green	Grass	1	0.095
Pilling Marsh	Grass	4	0.098
Knott End	Mud	1	0.084
Knott End	Mud and sand	1	0.082
Heads - River Wyre	Grass and mud	2	0.10
Heads - River Wyre	Grass	2	0.11
Height o' th' hill - River Wyre	Grass	4	0.12
Hambleton	Grass and mud	1	0.11
Hambleton	Grass	3	0.11
Skippool Creek 1	Grass	4	0.12
Skippool Creek 2	Grass and mud	2	0.12
Skippool Creek 2	Grass	2	0.11
Skippool Creek 3	Wood	4	0.11
Skippool Creek boat 2	Wood	4	0.098
Skippool Creek boat 2 - in vicinity of boats	Mud	4	0.090
Fleetwood Marsh Nature Park	Salt marsh	4	0.12
Fleetwood shore 1	Sand	3	0.077
Fleetwood shore 1	Pebbles and sand	1	0.072
Blackpool	Sand	4	0.068
Crossens Marsh	Mud and salt marsh	1	0.097
Crossens Marsh	Salt marsh	2	0.097
Crossens Marsh	Grass	1	0.097
Ainsdale	Sand	4	0.068
Rock Ferry	Mud	1	0.097
Rock Ferry	Mud and sand	2	0.092
Rock Ferry	Sand	1	0.092
New Brighton	Sand	4	0.068
West Kirby	Mud	1	0.078
West Kirby	Grass and mud	1	0.073
West Kirby	Sand	2	0.072
Little Neston Marsh 1	Grass and salt marsh	1	0.089
Little Neston Marsh 1	Grass	1	0.092
Little Neston Marsh 2	Grass and salt marsh	1	0.078
Little Neston Marsh 2	Grass	1	0.081
Flint 1	Mud	2	0.094
Flint 2	Salt marsh	2	0.11
Scotland			
Piltanton Burn	Salt marsh	4[S]	<0.056
Garlieston	Mud	4[S]	0.070
Innerwell	Mud	4[S]	0.079
Bladnoch	Mud	4[S]	0.080
Carsluith	Mud	4[S]	0.078
Skyreburn Bay (Water of Fleet)	Salt marsh	4[S]	0.073
Kirkcudbright	Salt marsh	4[S]	0.072
Cutters Pool	Winkle bed	4[S]	0.081
Rascarrel Bay	Winkle bed	4[S]	0.093
Gardenburn	Salt marsh	1[S]	0.046
Palnackie Harbour	Mud	1[S]	0.092
Kippford - Slipway	Mud	4[S]	0.092
Kippford - Merse	Salt marsh	1[S]	0.13
Southerness	Winkle bed	4[S]	0.061
Kirkconnell Marsh	Salt marsh	1[S]	0.078
Isle of Man			
Ramsey	Pebbles and sand	1	0.091

Table 2.9. continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, $\mu Gy\ h^{-1}$
Wales			
Prestatyn	Sand	2	0.068
Rhyl	Mud and salt marsh	1	0.090
Rhyl	Salt marsh	1	0.088
Llandudno	Pebbles and sand	2	0.091
Caerhun	Grass	2	0.089
Llanfairfechan	Mud	1	0.082
Llanfairfechan	Sand	1	0.073
Northern Ireland			
Lishally	Mud	1N	0.061
Eglington	Shingle	1N	0.050
Carrichue	Mud	1N	0.069
Bellerena	Mud	1N	0.061
Benone	Sand	1N	0.057
Castlerock	Sand	1N	0.066
Portstewart	Sand	1N	0.056
Portrush, Blue Pool	Sand	1N	0.056
Portrush, White Rocks	Sand	1N	0.056
Portballintrae	Sand	1N	0.057
Giant's Causeway	Sand	1N	0.055
Ballycastle	Sand	1N	0.054
Cushendun	Sand	1N	0.064
Cushendall	Sand and stones	1N	0.058
Red Bay	Sand	1N	0.066
Carnlough	Sand	1N	0.061
Glenarm	Sand	1N	0.053
Half Way House	Sand	1N	0.053
Ballygally	Sand	1N	0.056
Drains Bay	Sand	1N	0.056
Larne	Sand	1N	0.057
Whitehead	Sand	1N	0.062
Carrickfergus	Sand	1N	0.061
Jordanstown	Sand	1N	0.061
Helen's Bay	Sand	1N	0.059
Groomsport	Sand	1N	0.058
Millisle	Sand	1N	0.068
Ballywalter	Sand	1N	0.066
Ballyhalbert	Sand	1N	0.064
Cloghy	Sand	1N	0.068
Portaferry	Shingle and stones	1N	0.087
Kircubbin	Sand	1N	0.070
Greyabbey	Sand	1N	0.082
Ards Maltings	Mud	1N	0.080
Island Hill	Mud	1N	0.070
Nicky's Point	Mud	1N	0.077
Strangford	Shingle and stones	1N	0.089
Kilclief	Sand	1N	0.069
Ardglass	Mud	1N	0.086
Killough	Mud	1N	0.083
Rocky Beach	Sand	1N	0.072
Tyrella	Sand	1N	0.074
Dundrum	Sand	1N	0.082
Newcastle	Sand	1N	0.11
Annalong	Sand	1N	0.11
Cranfield Bay	Sand	1N	0.078
Mill Bay	Sand	1N	0.10
Greencastle	Sand	1N	0.078
Rostrevor	Sand	1N	0.11
Narrow Water	Mud	1N	0.088

S *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*
N *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

Table 2.10. Beta radiation dose rates on contact with fishing gear on vessels operating off Sellafield, 2010

Vessel	Type of gear	No. of sampling observations	Mean beta dose rate in tissue, μSv h^{-1}
M	Nets	4	0.066
	Rope	4	0.039
S	Nets	4	0.044
	Pots	4	0.093
T	Gill nets	4	0.13
	Pots	4	0.12
W	Gill nets	2	0.20
	Pots	2	0.12
X	Gill nets	4	0.13
	Pots	4	0.10
Z	Nets	4	0.099

Table 2.11. Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2010

Location	Ground type	No. of sampling observ-ations	Mean beta dose rate in tissue, μSv h^{-1}
Whitehaven - outer harbour	Sand	1	*
Whitehaven - outer harbour	Pebbles and sand	3	<0.040
St Bees	Sand	2	0.060
St Bees	Pebbles and sand	2	<0.060
Sellafield pipeline	Sand	2	0.040
Ravenglass - Raven Villa	Mud and salt marsh	1	0.10
Ravenglass - Raven Villa	Salt marsh	2	0.070
Ravenglass - Raven Villa	Grass and salt marsh	1	0.040
Tarn Bay	Sand	2	0.030

* *Not detected by the method used*

Table 2.12. Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru
Cumbria								
Silloth	Seaweed	2	<0.59		<0.79	<0.40	120	<3.7
Harrington Harbour	Seaweed	2	<0.92		<1.3	<0.58	220	<4.8
St Bees	*Porphyra*[a]	4[F]	<0.17	0.088	<0.16	<0.14	1.4	2.9
St Bees	Seaweed	2	<0.82	<1.3	<0.69	<0.37	400	<3.3
Braystones South	*Porphyra*	4[F]	0.20		<0.10	<0.08		3.6
Sellafield	*Rhodymenia* spp.	2[F]	<0.11		<0.31	<0.36		<0.97
Sellafield	Seaweed	2	1.8	<1.7	<0.97	<0.45	1300	<4.1
Seascale	*Porphyra*[b]	52[F]	<0.40		<0.49	<0.29		<5.7
Ravenglass	Samphire	1[F]	<0.08		<0.17	<0.16	0.47	<0.73
Ravenglass	Seaweed	2	2.1		<1.1	<0.59	240	<5.3
Lancashire								
Half Moon Bay	Seaweed	2	<0.58		<0.75	<0.40	290	<3.4
Marshside Sands	Samphire	1[F]	<0.03		<0.04	<0.03		<0.20
Cockerham Marsh	Samphire	1[F]	<0.06		<0.18	<0.20		<0.59
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]	<0.10		<0.21	<0.17	<0.12	<0.73
Lerwick	*Fucus vesiculosus*	1[S]	<0.10		<1.3	<2.4	28	<1.9
Lewis	*Fucus vesiculosus*	1[S]	<0.10		<0.12	<0.19	39	<0.23
Islay	*Fucus vesiculosus*	1[S]	<0.10		<0.21	<0.20	61	<0.63
Campbeltown	*Fucus vesiculosus*	1[S]	<0.11		<0.41	<0.55	120	<0.84
Port William	*Fucus vesiculosus*	4[S]	<0.10		<0.32	<0.42	220	<0.70
Garlieston	*Fucus vesiculosus*	4[S]	0.26		<0.23	<0.28	83	<0.57
Auchencairn	*Fucus vesiculosus*	4[S]	0.27		<0.33	<0.46	190	<0.73
Isle of Man	*Fucus vesiculosus*	4	<0.74		<0.96	<0.52	180	<4.5
Wales								
Cemaes Bay	Seaweed	2	<0.55		<0.78	<0.40	39	<3.5
Porthmadog	Seaweed	2	<0.53		<0.81	<0.39	4.0	<3.6
Lavernock Point	Seaweed	2	<0.89		<1.0	<0.56	3.0	<4.7
Fishguard	Seaweed	2	<0.48		<0.63	<0.34	7.9	<3.0
South Wales, manufacturer A	Laverbread	4[F]	<0.10		<0.19	<0.17		<0.86
South Wales, manufacturer C	Laverbread	4[F]	<0.10		<0.24	<0.25		<0.93
South Wales, manufacturer D	Laverbread	4[F]	<0.09		<0.22	<0.22		<0.81
South Wales, manufacturer E	Laverbread	1[F]	<0.11		<0.19	<0.14		<0.88
Northern Ireland								
Portrush	*Fucus* spp.	4[N]	<0.05		<0.10	<0.10		<0.36
Portaferry	*Rhodymenia* spp.	4[N]	<0.12		<0.55	<0.99	5.3	<1.2
Ardglass	*Ascophyllum nodosum*	1[N]	<0.15		<0.47	<0.48		<1.6
Ardglass	*Fucus vesiculosus*	3[N]	<0.09		<0.29	<0.42	80	<0.73
Carlingford Lough	*Ascophyllum nodosum*	1[N]	<0.11		<0.42	<0.53		<1.0
Carlingford Lough	*Fucus* spp.	3[N]	<0.07		<0.26	<0.32	56	<0.71
Isles of Scilly	Seaweed	1	<0.27		<0.38	<0.21	<2.3	<1.8

Table 2.12. continued								
Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu
Cumbria								
Silloth	Seaweed	2	<2.1	<0.50	4.9	<1.8		
Harrington Harbour	Seaweed	2	<2.9	<0.68	2.9	<2.0		
St Bees	*Porphyra*[a]	4[F]	<0.24	<0.06	1.1	<0.24	<0.11	0.34
St Bees	Seaweed	2	<1.9	<0.40	3.5	<1.6		1.2
Braystones South	*Porphyra*	4[F]	<0.22	<0.05	1.1	<0.21	<0.10	0.56
Sellafield	*Rhodymenia* spp.	2[F]	<0.23	<0.10	4.9	<0.39	<0.16	0.36
Sellafield	Seaweed	2	<2.4	<0.56	4.4	<1.9		1.6
Seascale	*Porphyra*[b]	52[F]	<1.2	<0.31	1.4	<1.4	<0.67	
Ravenglass	Samphire	1[F]	<0.15	<0.07	0.79	<0.22	<0.10	
Ravenglass	Seaweed	2	<3.1	<0.72	6.6	<2.1		
Lancashire								
Half Moon Bay	Seaweed	2	<1.9	<0.44	3.3	<1.6		
Marshside Sands	Samphire	1[F]	<0.05	<0.02	0.72	<0.10	<0.04	
Cockerham Marsh	Samphire	1[F]	<0.14	<0.06	0.80	<0.30	<0.13	
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]	<0.21	<0.10	0.29	<0.50	<0.22	
Lerwick	*Fucus vesiculosus*	1[S]	<0.48	<0.19	<0.17	<1.1	<0.43	
Lewis	*Fucus vesiculosus*	1[S]	<0.10	<0.10	0.33	<0.17	<0.10	
Islay	*Fucus vesiculosus*	1[S]	<0.18	<0.10	0.25	<0.42	<0.19	
Campbeltown	*Fucus vesiculosus*	1[S]	<0.22	<0.10	0.65	<0.54	<0.22	
Port William	*Fucus vesiculosus*	4[S]	<0.17	<0.10	0.76	<0.45	<0.19	
Garlieston	*Fucus vesiculosus*	4[S]	<0.35	<0.10	3.2	<0.32	<0.17	
Auchencairn	*Fucus vesiculosus*	4[S]	0.36	<0.11	2.6	<0.46	<0.19	
Isle of Man	*Fucus vesiculosus*	4	<2.6	<0.61	<0.57	<2.1	<1.0	
Wales								
Cemaes Bay	Seaweed	2	<2.0	<0.46	<0.44	<1.9		
Porthmadog	Seaweed	2	<1.9	<0.49	<0.44	<1.9		
Lavernock Point	Seaweed	2	<2.9	<0.63	<0.63	<2.1	<1.2	
Fishguard	Seaweed	2	<1.7	<0.38	<0.37	<1.3		
South Wales, manufacturer A	Laverbread	4[F]	<0.19	<0.09	<0.12	<0.29	<0.13	
South Wales, manufacturer C	Laverbread	4[F]	<0.20	<0.10	<0.17	<0.33	<0.14	
South Wales, manufacturer D	Laverbread	4[F]	<0.17	<0.08	0.21	<0.28	<0.12	
South Wales, manufacturer E	Laverbread	1[F]	<0.20	<0.10	<0.10	<0.28	<0.14	
Northern Ireland								
Portrush	*Fucus* spp.	4[N]	<0.09	<0.04	<0.07	<0.15	<0.07	
Portaferry	*Rhodymenia* spp.	4[N]	<0.25	<0.12	0.34	<0.45	<0.17	0.042
Ardglass	*Ascophyllum nodosum*	1[N]	<0.37	<0.16	0.55	<0.77	<0.34	
Ardglass	*Fucus vesiculosus*	3[N]	<0.16	<0.09	0.32	<0.28	<0.15	
Carlingford Lough	*Ascophyllum nodosum*	1[N]	<0.25	<0.12	0.41	<0.54	<0.26	
Carlingford Lough	*Fucus* spp.	3[N]	<0.15	<0.08	0.51	<0.29	<0.18	
Isles of Scilly	Seaweed	1	<1.1	<0.23	1.2	<0.84	<0.39	

Table 2.12. continued

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}					
			$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross beta
Cumbria								
Silloth	Seaweed	2			2.0			
Harrington Harbour	Seaweed	2			2.9			
St Bees	*Porphyra*[a]	4[F]	1.9	14	4.8	*	0.0058	210
St Bees	Seaweed	2	6.2		5.3			
Braystones South	*Porphyra*	4[F]	3.3	21	6.4	0.0041	0.0056	
Sellafield	*Rhodymenia* spp.	2[F]	2.1		4.7	0.017	0.0068	
Sellafield	Seaweed	2	7.1		4.7			
Seascale	*Porphyra*[b]	52[F]			5.2			
Ravenglass	Samphire	1[F]			1.7			
Ravenglass	Seaweed	2			24			
Lancashire								
Half Moon Bay	Seaweed	2			<0.59			
Marshside Sands	Samphire	1[F]			0.25			
Cockerham Marsh	Samphire	1[F]			0.42			33
Scotland								
Aberdeen	*Fucus vesiculosus*	1[S]			<0.15			
Lerwick	*Fucus vesiculosus*	1[S]			<0.25			
Lewis	*Fucus vesiculosus*	1[S]			<0.10			
Islay	*Fucus vesiculosus*	1[S]			<0.14			
Campbeltown	*Fucus vesiculosus*	1[S]			<0.15			
Port William	*Fucus vesiculosus*	4[S]			0.66			
Garlieston	*Fucus vesiculosus*	4[S]			6.1			
Auchencairn	*Fucus vesiculosus*	4[S]			2.8			
Wales								
Cemaes Bay	Seaweed	2			<0.65			
Porthmadog	Seaweed	2			<0.64			
Lavernock Point	Seaweed	2			<0.73			
Fishguard	Seaweed	2			<0.47			
South Wales, manufacturer A	Laverbread	4[F]			<0.10			
South Wales, manufacturer C	Laverbread	4[F]			<0.19			
South Wales, manufacturer D	Laverbread	4[F]			0.22			140
South Wales, manufacturer E	Laverbread	1[F]			0.10			
Northern Ireland								
Portrush	*Fucus* spp.	4[N]			<0.10			
Portaferry	*Rhodymenia* spp.	4[N]	0.24		0.43	0.00092	0.00027	
Ardglass	*Ascophyllum nodosum*	1[N]			<0.33			
Ardglass	*Fucus vesiculosus*	3[N]			<0.16			
Carlingford Lough	*Ascophyllum nodosum*	1[N]			<0.31			
Carlingford Lough	*Fucus* spp.	3[N]			<0.08			
Isles of Scilly	Seaweed	1			<0.30			

* *Not detected by the method used*
[a] *The concentration of ^{14}C was 31 Bq kg^{-1}*
[b] *Counted fresh*
[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency*
[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*
[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*
All other measurements are made on behalf of the Environment Agency

Table 2.13. Concentrations of radionuclides in vegetables, grass and soil measured to investigate the transfer of radionuclides from sea to land, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{14}C	^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Sellafield 14[b]	Cabbage	1		<0.04	<0.09	<0.07	21	<0.38	<0.09
Sellafield 14[b]	Onions	1		<0.03	<0.06	<0.05	1.1	<0.27	<0.07
Sellafield 14[b]	Rhubarb	1		<0.05	<0.09	<0.07	37	<0.43	<0.10
Sellafield 14[b]	Soil	1		2.7	<1.7	<1.9	490	<4.8	<1.5
Sellafield 154[b]	Beetroot	1		<0.07	<0.17	<0.16	<0.12	<0.65	<0.15
Sellafield 154[b]	Onions	1		<0.10	<0.35	<0.50	<0.12	<0.93	<0.19
Sellafield 154[b]	Runner beans	1		<0.07	<0.17	<0.16	<0.12	<0.64	<0.13
Sellafield 154[b]	Soil	1		<0.73	<4.7	<10	68	<7.3	<1.9
Sellafield 474[b]	French beans	1		<0.07	<0.15	<0.13	0.079	<0.60	<0.13
Sellafield 474[b]	Parsnips	1		<0.04	<0.07	<0.05	<0.13	<0.25	<0.06
Sellafield 474[b]	Shallots	1		<0.03	<0.05	<0.04	<0.20	<0.26	<0.07
Sellafield 474[b]	Soil	1		<0.15	<0.60	<0.72	<1.4	<1.6	<0.41
Hinkley	Carrots	1	17	<0.09	<0.23	<0.24		<0.79	<0.17
Hinkley	Potatoes	1	17	<0.12	<0.34	<0.35		<1.2	<0.28
Hinkley	Soil	1	6.4	<0.28	<1.2	<1.7		<2.9	<0.78

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{155}Eu	^{241}Am
Sellafield 14[b]	Cabbage	1	<0.04	0.08	<0.18	<0.13	<0.09	<0.08
Sellafield 14[b]	Onions	1	<0.03	<0.03	<0.13	<0.10	<0.07	<0.09
Sellafield 14[b]	Rhubarb	1	<0.05	0.17	<0.20	<0.17	<0.10	<0.10
Sellafield 14[b]	Soil	1	<0.66	51	<2.9	<1.5	<1.3	40
Sellafield 154[b]	Beetroot	1	<0.07	<0.06	<0.30	<0.20	<0.14	<0.13
Sellafield 154[b]	Onions	1	<0.10	<0.08	<0.31	<0.29	<0.13	<0.07
Sellafield 154[b]	Runner beans	1	<0.06	<0.06	<0.21	<0.19	<0.09	<0.04
Sellafield 154[b]	Soil	1	<0.91	68	<3.4	<2.4	<1.4	2.9
Sellafield 474[b]	French beans	1	<0.07	<0.06	<0.19	<0.21	<0.08	<0.05
Sellafield 474[b]	Parsnips	1	<0.03	<0.03	<0.08	<0.13	<0.04	<0.02
Sellafield 474[b]	Shallots	1	<0.03	0.50	<0.13	<0.10	<0.06	<0.04
Sellafield 474[b]	Soil	1	<0.22	3.5	<1.0	<0.48	<0.48	<0.35
Hinkley	Carrots	1	<0.08	<0.07	<0.31	<0.29	<0.13	<0.07
Hinkley	Potatoes	1	<0.12	<0.10	<0.58	<0.34	<0.25	<0.23
Hinkley	Soil	1	<0.38	6.5	<2.2	<0.83	<1.0	<1.0

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

Table 2.14. Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2010

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk[d]		3	<4.5	15	<0.18	0.039	<0.29	<0.23	<0.0030	<1.2	<0.36	<0.0072
Milk	max			16	<0.20	0.058	<0.31	<0.25			<0.37	<0.0075
Apples		1	<5.0	<3.0	<0.20	0.077	<0.30	<0.20	<0.021	<1.3	<0.20	<0.021
Barley		1	<7.0	50	<0.20	0.60	<0.20	<0.20	<0.023	<1.1	<0.40	<0.017
Beef kidney		1	<7.0	14	<0.20	0.36	<0.30	<0.20	<0.026	<1.7	<0.40	<0.085
Beef liver		1	<7.0	28	<0.20	0.13	<0.20	<0.20	<0.022	<0.90	<0.40	<0.035
Beef muscle		1	<5.0	27	<0.20	0.011	<0.30	<0.10	<0.024	<0.80	<0.30	<0.046
Beetroot		1							<0.021			
Blackberries		1	13	13	<0.10	0.12	<0.10	<0.20	0.051	<1.2	<0.30	<0.040
Carrots		1	<5.0	5.0	<0.20	0.12	<0.20	<0.20	<0.024	<1.1	<0.50	<0.026
Goose		1	<5.0	20	<0.20	0.020	<0.20	<0.20	<0.022	<0.70	<0.40	<0.032
Leeks		1	5.0	<3.0	<0.20	0.069	<0.20	<0.20	<0.030	<1.0	<0.20	<0.015
Onions		1							<0.023			
Potatoes		1	<5.0	6.0	<0.10	0.054	<0.10	<0.20	<0.030	<1.0	<0.20	<0.022
Preserves		1	<7.0	55	<0.10	0.070	<0.20	<0.20	0.030	<1.0	<0.40	<0.034
Runner beans		1	<4.0	<3.0	<0.10	0.11	<0.30	<0.20	<0.026	<0.90	<0.30	<0.025
Sheep muscle		2	<7.0	16	<0.15	0.046	<0.25	<0.20	<0.046	<1.1	<0.35	<0.033
Sheep muscle	max		9.0	17	<0.20	0.068	<0.30		0.065		<0.40	<0.036
Sheep offal		2	<7.5	<15	<0.15	0.77	<0.30	<0.20	<0.026	<1.0	<0.35	<0.039
Sheep offal	max		<8.0	20	<0.20	1.3			<0.029	<1.5	<0.50	<0.045
Grass		2							<0.015			

Material and selection[a]		No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			Total Cs	^{144}Ce	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu + {}^{240}Pu$	^{241}Pu	^{241}Am
Milk[d]		3		<0.72				<0.00011	<0.00015	<0.028	<0.00012
Milk	max							<0.00013		<0.029	<0.00013
Apples		1	0.13	<0.60				<0.00020	<0.00020	<0.047	0.00070
Barley		1	1.4	<0.60				0.00050	0.0038	<0.049	0.0074
Beef kidney		1	0.39	<1.1	0.011	0.0010	0.0058	<0.00020	0.0015	<0.069	0.0096
Beef liver		1	0.34	<0.70				0.0016	0.013	<0.077	0.012
Beef muscle		1	0.49	<0.60				<0.00020	<0.00040	<0.067	0.00050
Beetroot		1			0.0032	0.00080	0.0024				
Blackberries		1	0.14	<0.70				0.00020	0.00020	<0.042	0.00080
Carrots		1	0.23	<0.60				<0.00010	0.00010	<0.046	0.00020
Goose		1	0.96	<0.70				0.00030	0.0025	<0.060	0.0028
Leeks		1	0.078	<0.70				<0.00020	<0.00020	<0.040	0.00020
Onions		1			0.0022	<0.00060	0.0022				
Potatoes		1	0.21	<0.60				<0.00010	<0.00020	<0.048	0.00020
Preserves		1	0.10	<0.90				0.00060	0.0049	<0.062	0.0038
Runner beans		1	0.093	<0.70				<0.00010	0.00020	<0.052	0.00030
Sheep muscle		2	5.5	<0.70				<0.00020	<0.00030	<0.060	<0.00025
Sheep muscle	max		10							<0.067	0.00030
Sheep offal		2	2.0	<0.70				<0.00015	0.0019	<0.069	0.0012
Sheep offal	max		3.5	<0.80				<0.00020	0.0027		0.0013
Soil		1			9.5	0.36	9.1				

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

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

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

[d] *The mean concentrations of ^{134}Cs and ^{137}Cs were <0.18 (max <0.19) and <0.20 Bq l^{-1}*

Table 2.15. Concentrations of radionuclides in surface waters from West Cumbria, 2010

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	4	540	<0.27	<0.068	<0.26	<0.43	<0.0068	<0.0075	<2.5	11
River Ehen (100m downstream of sewer outfall)	4	<13	<0.31	<0.050	<1.0	<0.26	<0.0070	<0.0050	<0.043	0.21
River Calder (downstream)	4	<3.2	<0.29	<0.0052	<0.28	<0.25	<0.0073	<0.0055	<0.033	0.21
River Calder (upstream)	4	<3.0	<0.26	<0.045	<0.25	<0.22	<0.0078	<0.0050	<0.030	<0.090
Wast Water	1	<3.0	<0.25			<0.21			<0.020	0.18
Ennerdale Water	1	<3.0	<0.11		<0.10	<0.09			<0.020	<0.10
Devoke Water	1	<3.0	<0.11		<0.11	<0.09			<0.020	<0.10
Thirlmere	1	<3.0	<0.24			<0.21			<0.020	<0.10

Table 2.16. Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2010

Location	No. of sampling observ-ations	Mean radioactivity concentration (dry), Bq kg^{-1}						
		^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Seascale SS 204	1	<1.4	6.0	<1.2	780	5.1	44	52
Seascale SS 233	1	<0.79	58	<1.2	1800	13	140	130
Seascale SS 209	1	<0.78	<1.0	<0.75	26	0.80	5.2	8.5
Seascale SS 232	1	<0.84	<1.0	<0.78	84	2.1	12	19
Seascale SS 231	1	<1.2	3.0	<1.3	31	1.9	11	19
Whitehaven SS 201	1	<2.7	<2.0	<2.5	22	<0.40	0.88	2.3

Table 2.17. Doses from artificial radionuclides in the Irish Sea, 2006-2010

	Exposure, mSv per year				
Group	2006	2007	2008	2009	2010
Isle of Man	0.007	0.006	0.007	0.007	<0.005
Northern Ireland	0.018	0.015	0.017	0.012	0.010
Dumfries and Galloway	0.037	0.060	0.047	0.047	0.040
Whitehaven	0.011	0.009	0.009	0.011	0.010
Sellafield (5 year average consumption)	0.23	0.24	0.23	0.20	0.18
Morecambe Bay	0.038	0.037	0.042	0.041	0.046
Fleetwood	0.018	0.013	0.016	0.013	0.015
North Wales	0.016	0.014	0.018	0.015	0.013

Table 2.18. Individual radiation exposures, Sellafield, 2010

Exposed population[a,g]	Exposure, mSv per year						
	Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
***Total dose* - maximum effect of all sources**							
Adult mollusc consumers	0.18[f]	0.13	0.047	<0.005	0.009	-	-
***Total dose* - maximum effect of gaseous release and direct radiation sources**							
Infant consumers of milk	0.011	<0.005	<0.005	0.011	-	-	<0.005
***Total dose* - maximum effect of liquid release source**							
Adult mollusc consumers	0.18	0.13	0.047	<0.005	0.009	-	-
Source specfic doses							
Seafood consumers							
Local seafood consumers (habits averaged 2006-10)	0.26[d]	0.15	0.082	-	0.031	-	-
Local seafood consumers (habits for 2010)	0.24[e]	0.13	0.079	-	0.033	-	-
Whitehaven seafood consumers	0.010	0.010	-	-	-	-	-
Dumfries and Galloway seafood consumers	0.040	0.025	-	-	0.015	-	-
Morecambe Bay seafood consumers	0.046	0.011	-	-	0.035	-	-
Fleetwood seafood consumers	0.015	0.015	-	-	-	-	-
Isle of Man seafood consumers	<0.005	<0.005	-	-	-	-	-
Northern Ireland seafood consumers	0.010	0.010	-	-	<0.005	-	-
North Wales seafood consumers	0.013	0.007	-	-	0.006	-	-
Other groups							
Ravenglass Estuary, nature warden	0.044	-	-	-	0.039	0.006	-
Fishermen handling nets or pots[c]	0.10	-	-	-	0.10	-	-
Bait diggers and shellfish[c] collectors	0.037	-	-	-	0.037	-	-
Ribble Estuary houseboats	0.16	-	-	-	0.16	-	-
Local consumers at Ravenglass[b]	0.038	-	-	0.038	-	-	-
Local consumers of vegetables grown on land with seaweed added[b]	0.012	-	-	0.012	-	-	-
Local consumers at LLWR near Drigg[b]	0.012	-	-	0.012	-	-	
Local consumers in the Isle of Man[b]	0.009	-	-	0.009	-	-	-
Consumers of laverbread in South Wales	<0.005	-	-	<0.005	-	-	-
Inhabitants and consumers of locally grown food[b]	0.022	-	-	0.022	-	-	<0.005
Dumfries and Galloway wildfowlers	<0.005	<0.005	-	-	<0.005	-	-
Groups with average consumption or exposure							
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-
Average consumer of locally grown food	0.009	-	-	0.009	-	-	-
Typical visitor to Cumbria	<0.005	<0.005	<0.005	-	<0.005	-	-

Table 2.18. continued

Exposed population[a,g]	Exposure, mSv per year						
	Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways
Recreational user of beaches							
North Cumbria	0.013	-	-	-	0.013	-	-
Sellafield	0.010	-	-	-	0.010	-	-
Lancashire	0.007	-	-	-	0.007	-	-
North Wales	0.007	-	-	-	0.007	-	-
Isle of Man	0.010	-	-	-	0.010	-	-
Recreational user of mud/saltmarsh areas							
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-
North Cumbria	0.007	-	-	-	0.007	-	-
Sellafield	0.016	-	-	-	0.016	-	-
Lancashire	0.009	-	-	-	0.009	-	-
North Wales	0.013	-	-	-	0.013	-	-

[a] *The* total dose *is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.*
The total dose *for the representative person with the highest dose is presented.*
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways.
They serve as a check on the validity of the total dose assessment.
Adults are the most exposed group unless otherwise stated
[b] *Children aged 1 yr*
[c] *Exposure to skin for comparison with the 50 mSv dose limit*
[d] *The total dose due to nuclear industry discharges was 0.18 mSv*
[e] *The total dose due to nuclear industry discharges was 0.16 mSv*
[f] *The total dose due to nuclear industry discharges was 0.14 mSv*
[g] *None of the people represented in this table were considered to receive direct radiation from the site*

3. Research establishments

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

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

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

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

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

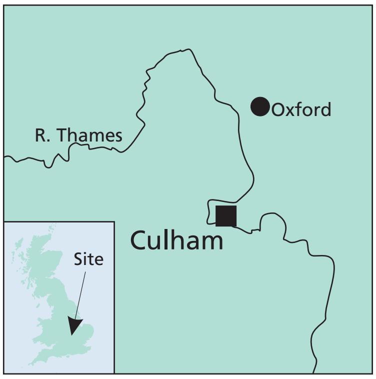
Key points

- Public radiation doses from all sources were less than 5 per cent of the dose limits at all those sites assessed
- Doses, discharges, environmental concentrations and dose rates in 2010 were broadly similar to those in 2009

Dounreay, Highland

- The dose from terrestrial food consumption was still affected by the presence of caesium-137 in game in 2010
- There were small decreases in public radiation doses from liquid discharges due to reduced gamma dose rates in intertidal areas

3.1 Culham, Oxfordshire



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

The source specific dose, from using the River Thames directly as drinking water downstream of the discharge point at Culham in 2010, was estimated to be much less than 0.005 mSv (Table 3.1). *Total dose* has not been determined at this site, in this report, because an integrated habits survey has not been undertaken.

Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2010. Locations and data are shown in Figure 3.1 and Table 3.2 respectively. In recent years, the main effect of the site's operation was the increased tritium concentrations found in

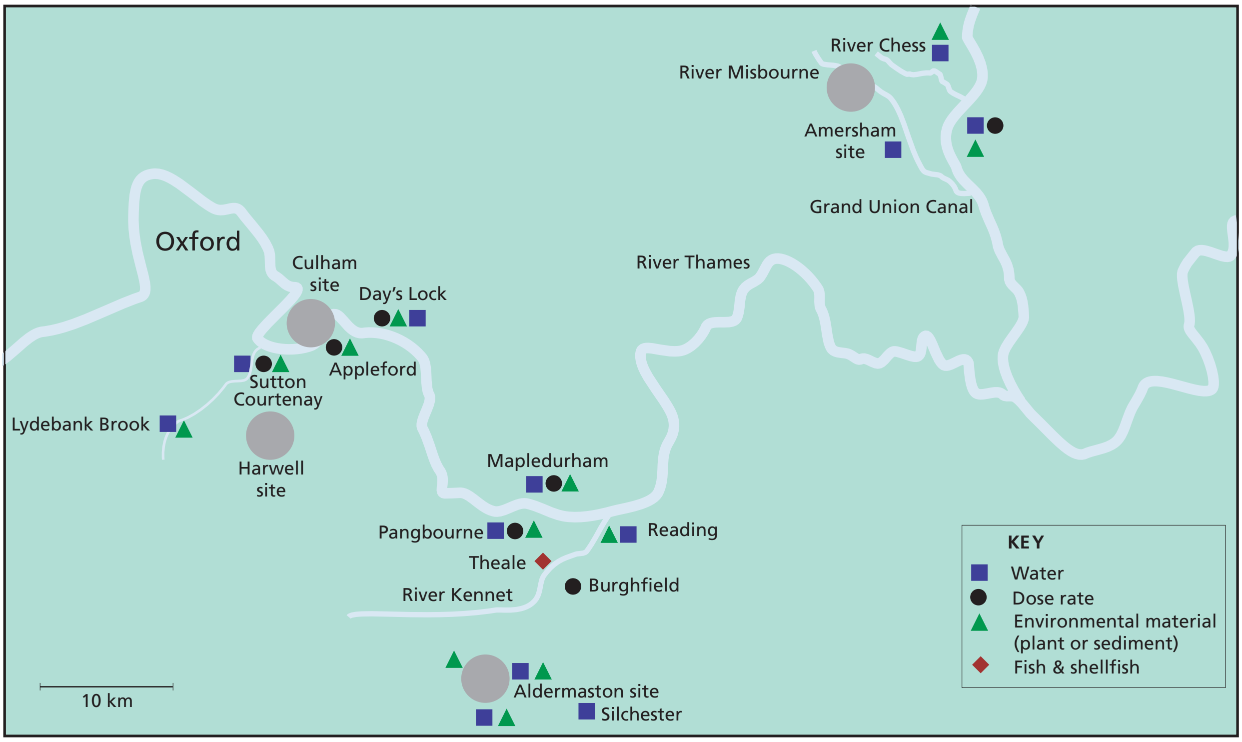
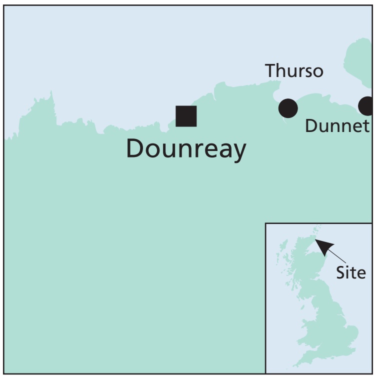


Figure 3.1. Monitoring locations at Thames sites, 2010 (not including farms)

grass collected near the site perimeter. In 2010, measurements of tritium were less than the LoD. Overall, no effects due to site operation were detected. The measured concentrations of caesium-137 in the River Thames sediment are not attributable to Culham but are due to past discharges from Harwell, nuclear weapons testing fallout from the 1950s and 1960s and the Chernobyl reactor accident in 1986.

3.2 Dounreay, Highland



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

From 2005, the NDA became responsible for the UK's civil nuclear liabilities which included those at UKAEA Dounreay, and UKAEA became a contractor to the NDA. In common with other NDA sites, UKAEA prepared a long term decommissioning plan known as the Lifetime Plan. The NDA's Strategy includes a summary of the Parent Body Organisation competition process. Part of this process required the transfer of the three existing radioactive waste disposal authorisations from UKAEA to a new site license company (Dounreay Site Restoration Limited, DSRL), before DSRL took over the site management contract. In 2010, the NDA announced that two consortia will proceed to the next stage of competition for a parent body organisation for DSRL.

In 2010, DSRL applied to SEPA for a new authorisation for the disposal of radioactive waste arising from the decommissioning of the Dounreay site. The content of the application is based upon the predicted requirements of the decommissioning activities which are to be undertaken.

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

Construction of the new ventilation extract facility at the Fuel Cycle Area was completed during 2010. In June 2010, SEPA undertook an inspection of the new ventilation system and the arrangements for the minimisation of particulate ingress into the new extract system.

During 2010, DSRL continued to process batches of Sodium/Potassium (NaK) liquid coolant through the NaK destruction plant in the Dounreay Fast Reactor.

During 2010, SEPA undertook a range of inspections which included the following topics:

- The progress of the improvement conditions, relating to the Environmental Management System
- The facility level documents, which underpin the identification and consignment of solid radioactive waste; solid waste consignment records and waste management procedures

- The arrangements for the disposal of clean and exempt waste from the site
- The work undertaken by DSRL to address the improvement requirement on the inspection of ducting and discharge stacks, and the removal of particulate matter
- Groundwater monitoring arrangements

In 2010, radioactive waste discharges from Dounreay were made by DRSL under authorisations granted by SEPA. The quantities of both gaseous and liquid discharges were generally similar to those in 2009 (Appendix 2). Sampling locations for the terrestrial and marine monitoring programme are shown in Figure 3.2 (north of Scotland) and Figure 3.3 (Dounreay).

The most recent habits survey was conducted in 2008 (Clyne *et al.*, 2011a). Three potentially critical pathways for public radiation exposure in the aquatic environment were confirmed. Figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1. A habit survey to obtain data on activities undertaken on beaches relating to potential public exposure to radioactive particles at Dunnet Bay in Caithness was undertaken in 2009 (Clyne *et al.*, 2011c).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to have been 0.047 mSv (Table 3.1) or less than 5 per cent of the dose limit. The people most exposed were high-rate consumers (adults) of game meat. The dose represents a decrease from that in 2009 and 2008 (0.063 mSv and 0.078 mSv, respectively) due to lower levels of caesium-137 in venison in 2010. Venison is the most consumed of the game meats in the area. Around 90 percent of the dose was from caesium-137 which is present in the environment from a number of sources, such as Chernobyl and weapons testing fallout, historic discharges together with authorised releases from the site. In 2011, SEPA will further investigate the caesium-137 concentrations in the environment. The trend in *total dose* over the period 2004 – 2010 is given in Figure 1.1. The variations in recent years were due to changes in caesium-137 concentrations in game meat, but *total doses* were low.

Source specific assessments of exposures for both high-rate consumers of local terrestrial foodstuffs and seafood, and for external pathways (both for Geo occupants and fishermen), were all less than 0.047 mSv in 2010 (Table 3.1). The dose to consumers of terrestrial foodstuffs was 0.028 mSv or less than 3.0 per cent of the dose limit for members of the public of 1 mSv, and similar to the value in 2009 (0.029 mSv). The dose to consumers of fish and shellfish, and are exposed to external exposure from occupancy over local beaches was 0.006 mSv. This is lower than the dose in 2009 (0.011 mSv), mostly due to lower dose rates over the winkle bed at Sandside Bay in 2010.

Gaseous discharges and terrestrial monitoring

DSRL is authorised by SEPA to discharge gaseous wastes to the local environment via stacks to the atmosphere. Although gaseous discharges were generally similar to those in 2009, releases of iodine-131 from the Dounreay Fuel Cycle Area decreased in 2010 in comparison to discharges in recent years. Monitoring conducted in 2010 included sampling of grass and soil and terrestrial foods including meat, vegetables and cereals. As there are no dairy cattle herds in the Dounreay area, no milk samples were collected from cattle. However, monitoring for radionuclides in goats' milk was included in 2010. The results for terrestrial samples and radioactivity in air are given in Tables 3.3(a) and (c) and generally show low concentrations of radioactivity. In 2010, low concentrations of caesium-137, strontium-90, europium-155, uranium, plutonium and americium-241 were reported in samples. Caesium-137 concentrations in lamb muscle increased, in comparison to levels in 2009 and 2008, but were an order of magnitude less than in 2007. In venison (deer muscle), the caesium-137 concentration was 50 Bq kg–1 and similar to the value for venison (69 Bq kg–1) in 2009, but lower than caesium-137 activity found in rabbit (110 Bq kg–1) in 2008 (rabbit was not sampled in 2009). Additional monitoring for caesium-137 in venison and pheasant samples was carried out to determine typical background concentration in the vicinity of the site. The variation of caesium-137 concentrations in the terrestrial environment in the Dounreay area will have been affected by fallout from weapons testing in the 1960s and from the Chernobyl reactor accident in 1986.

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 (Procurement Executive).

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

Crabs, mussels and winkles from the outfall area were sampled. Additionally, seawater and seaweed were sampled as indicator materials. The results for marine samples and gamma dose

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

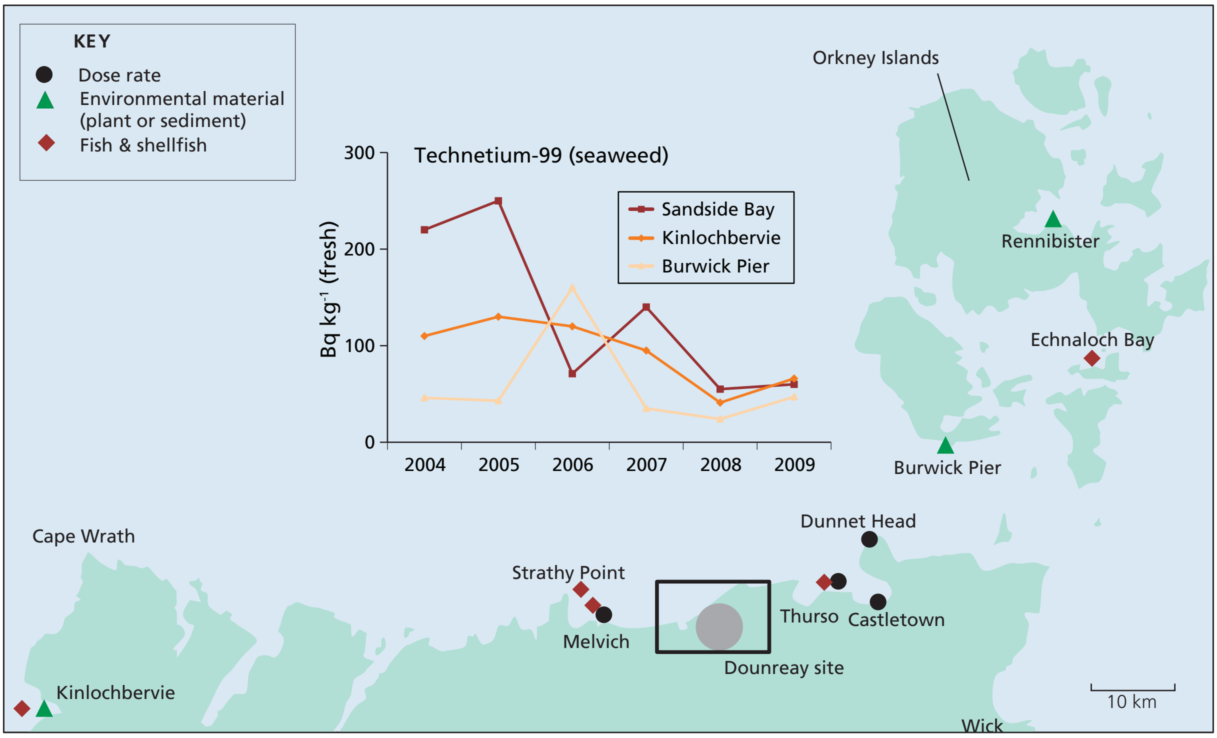


Figure 3.2. Monitoring locations and concentrations of technetium-99 in seaweed in the north of Scotland, 2010 (not including farms)

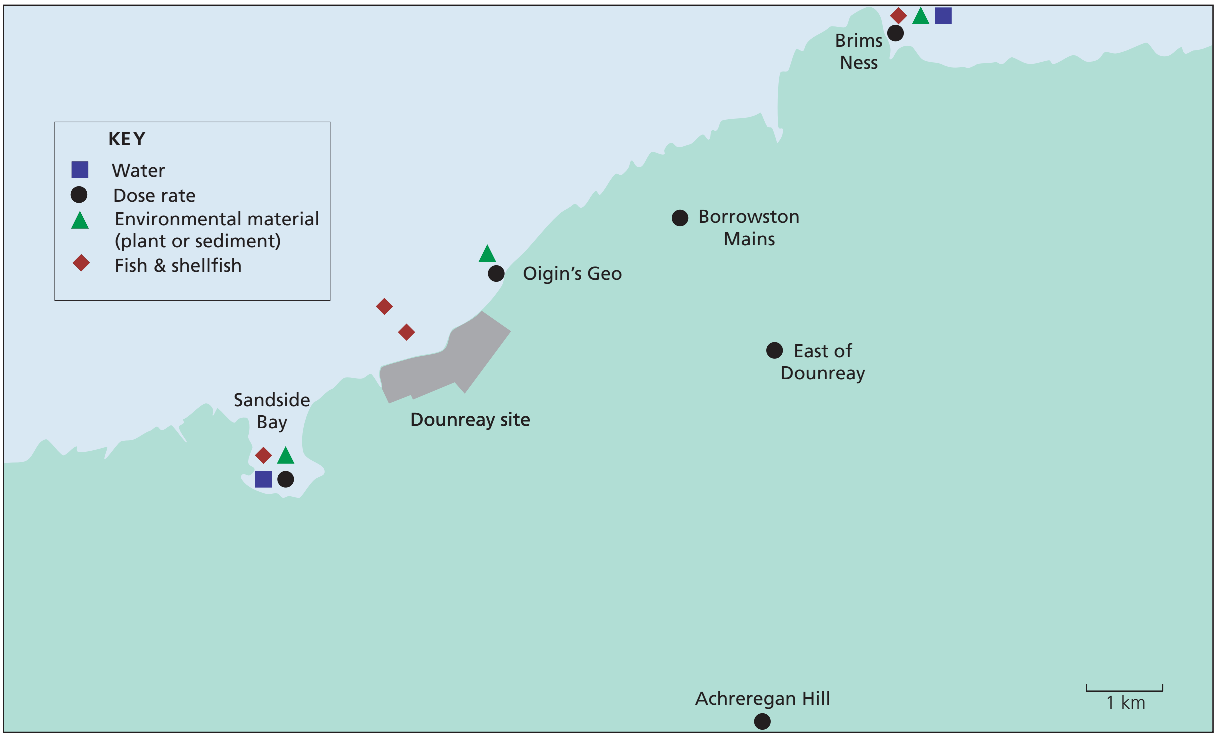


Figure 3.3. Monitoring locations at Dounreay, 2010 (not including farms)

rates (Tables 3.3(a) and (b)) generally show low concentrations of radioactivity in 2010 and are similar to those in recent years. Gamma dose rates in 2010 were generally similar to those in 2009, although rates decreased over the winkle bed at Sandside Bay in 2010. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were similar to those in 2009. Figure 3.2 also gives time trend information for technetium-99 concentrations (from Sellafield) in seaweed at Sandside Bay (location shown in Figure 3.3), Kinlochbervie and Burwick. They show an overall decline in concentrations over the period at all three locations. Beta dose measurements were less than the LoD (Table 3.3(b)).

During 2010, DSRL continued vehicle-based monitoring of local public beaches for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. At one of the beaches, monitoring for radioactive fragments is undertaken via an agreement between DRSL and the landowner. In 2010, access was periodically withdrawn and as a result monitoring was interrupted during the year.

In 2010, 12 fragments were recovered from Sandside Bay and 3 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 4.5 kBq and 270 kBq (similar to ranges observed in 2009).

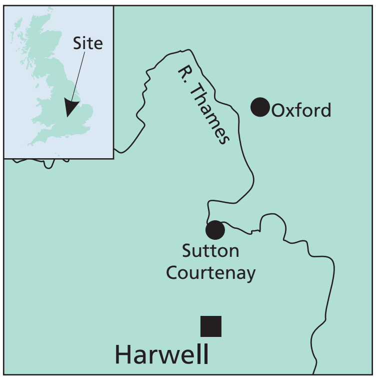
In April 2010, a single relevant particle[#] (fuel fragment) was detected and recovered from Landfill 42, a landfill adjacent to the nuclear licensed site. It was detected and removed as part of a surface survey of Landfill 42, undertaken for the purpose of informing DSRL's future proposals for the landfill. The caesium-137 activity measured in the fragment was 150 kBq.

During 2010, particle retrieval operations were undertaken to recover fragments from the seabed using a remotely operated vehicle. The retrieval operations undertaken between August and October recovered 429 fragments from an area of 16 hectares of the offshore seabed.

The previously conducted offshore survey work provided data on repopulation rates of particles to areas of the seabed previously cleared of particles. This work has improved the understanding of particle movements in the marine environment. The Dounreay Particles Advisory Group ([†]DPAG) completed its work following the production of its Fourth Report (Dounreay Particles Advisory Group, 2008). Since the work of DPAG was concluded, the Particles Retrieval Advisory Group (Dounreay) (†PRAG (D)) have published reports in March 2010 and March 2011 (Particles Retrieval Advisory Group (Dounreay), 2010; 2011).

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

3.3 Harwell, Oxfordshire



Harwell was established in 1946 as Britain's first Atomic Energy Research Establishment. The site accommodated five research reactors of various types. Decommissioning of redundant nuclear facilities is well underway. The Harwell nuclear licensed site now forms part of the Harwell Science and Innovation Campus and is situated approximately 5 km southwest of the town of Didcot. GE Healthcare occupies buildings in two small areas embedded within the licensed site, each with their own nuclear site licence. One of the buildings is in the process of being decommissioned and the other is an operating radioactive waste management and source refurbishment facility. The most recent habits survey was conducted during 2007 (Garrod *et al*., 2008).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was 0.018 mSv (Table 3.1), which is less than 2 per cent of the dose limit. The dominant contribution to this dose was direct radiation from the site and the most exposed people were the prenatal children of local inhabitants. The decrease in *total dose* from 0.023 mSv in 2009 is due to a lower estimate of the direct radiation from the site. The trend in *total dose* over the period 2004 – 2010 is given in Figure 1.1. The *total doses* remained broadly similar from year to year, and were very low.

Source specific assessments of exposures for high-rate consumers of terrestrial foods, and for anglers, were less than 0.018 mSv (Table 3.1). As in 2009, the dose to anglers was 0.006 mSv.

 # The term "relevant" relates to one of the categories developed by the Dounreay Particles Advisory Group to categorise Dounreay fuel fragments.

† 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.

Gaseous discharges and terrestrial monitoring

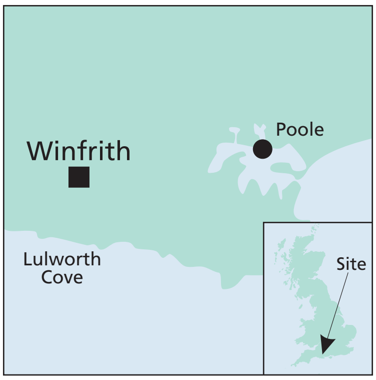
Gaseous wastes are discharged via stacks to the local environment. The monitoring programme sampled milk and other terrestrial foodstuffs. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 3.1. The results of the terrestrial programme are shown in Table 3.4(a).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

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive wastes from Harwell continued in 2010 to the River Thames at Sutton Courtenay and to the Lydebank Brook north of the site. Figure 3.4 shows trends of discharges over time (2000 – 2010) for cobalt-60 and caesium-137. There was an overall reduction in the discharges over the period, particularly for cobalt-60. The aquatic monitoring programme was directed at consumers of freshwater fish, sediments and external exposure close to the liquid discharge point.

Tritium and cobalt-60 concentrations in all aquatic samples, and caesium-137 concentrations in freshwater samples, were below the LoD. Caesium-137 concentrations in sediments were slightly enhanced close to the outfall at Sutton Courtenay and at Lydebank Brook but were small in terms of any radiological effect. Concentrations of transuranic elements and sediments were either very low or below the LoD. The concentrations of all radionuclides in flounder from the lower reaches of the Thames (from Beckton) were either very close to or below the LoD.

3.4 Winfrith, Dorset



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

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to have been less than 0.005 mSv (Table 3.1), or less than 0.5 per cent of the dose limit. The main component of this dose in 2010 was from external gamma radiation exposure. Adults spending time on local beaches were the most exposed people at this site. Trends in *total doses* in the area of the south coast (and the Severn Estuary) over time are shown in Figure 6.5. At Winfrith, *total doses* remained broadly similar from year to year, and were very low.

Source specific assessments of exposures for high-rate consumers of locally grown food, and for fish and shellfish, were also less than 0.005 mSv in 2010 (Table 3.1). Previous assessments have shown that other pathways are insignificant (Environment Agency, 2002a).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are disposed of from various stacks on site. Discharges of radioactive wastes from this site continued in 2010 at very low rates. The main focus of the terrestrial sampling was for the content of tritium and carbon-14 and sulphur-35 in milk, crops and fruit. Local freshwater samples were also analysed. Sampling locations at Winfrith are shown in Figure 3.6. Data for 2010 are given in Table 3.5(a). Results for terrestrial samples gave little indication of an effect due to gaseous discharges. Carbon-14 was detected in locally produced foods, at background concentrations, and these were lower in 2010 compared to 2009. This may be due to natural variation. Low concentrations of tritium were found in surface water to the north of the site, similar to previous years. In all cases the gross alpha and beta activities were below the WHO's screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are disposed of under permit to deep water in Weymouth Bay. Figure 3.5 shows trends of liquid discharges over time (2000 – 2010) for tritium and alpha emitting radionuclides. Over the period, alpha radionuclide discharges have generally decreased since the peak in 2003, whilst tritium discharges have varied more between years since declining from the peak in 2004.

Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Data for 2010 are given in Tables 3.5(a) and (b). Concentrations of radionuclides in the marine environment largely continued at the low levels found in recent years. Gamma dose rates were difficult to distinguish from natural background.

3.5 Imperial College Reactor Centre, Ascot, Berkshire

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

The Reactor Centre provided facilities for the University and other educational institutions for teaching and research in many

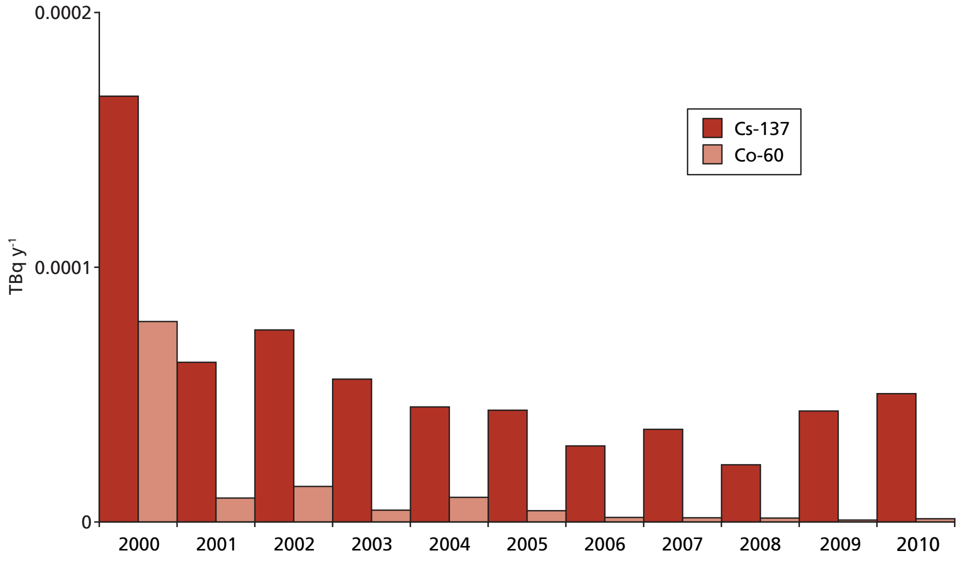


Figure 3.4. Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2000-2010

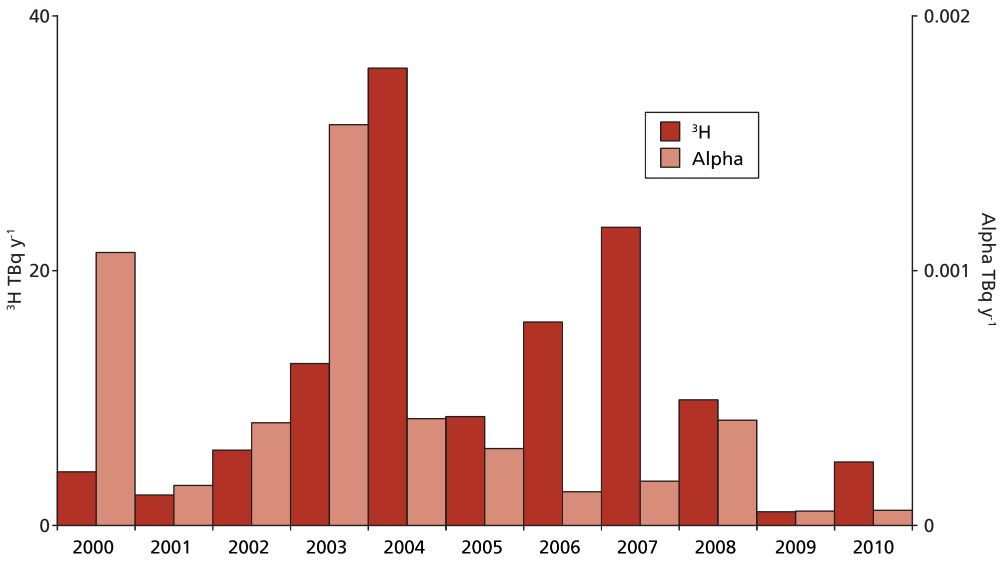


Figure 3.5. Trends in liquid discharges of tritium and alpha emitting radionuclides from Winfrith, Dorset 2000-2010

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

In 2010, gaseous and aqueous discharges were very low (Appendix 2) and environmental monitoring of their effects comprises analysing two grass samples by gamma-ray spectrometry. Both sets of results in 2010 were either close to or less than the limits of detection.

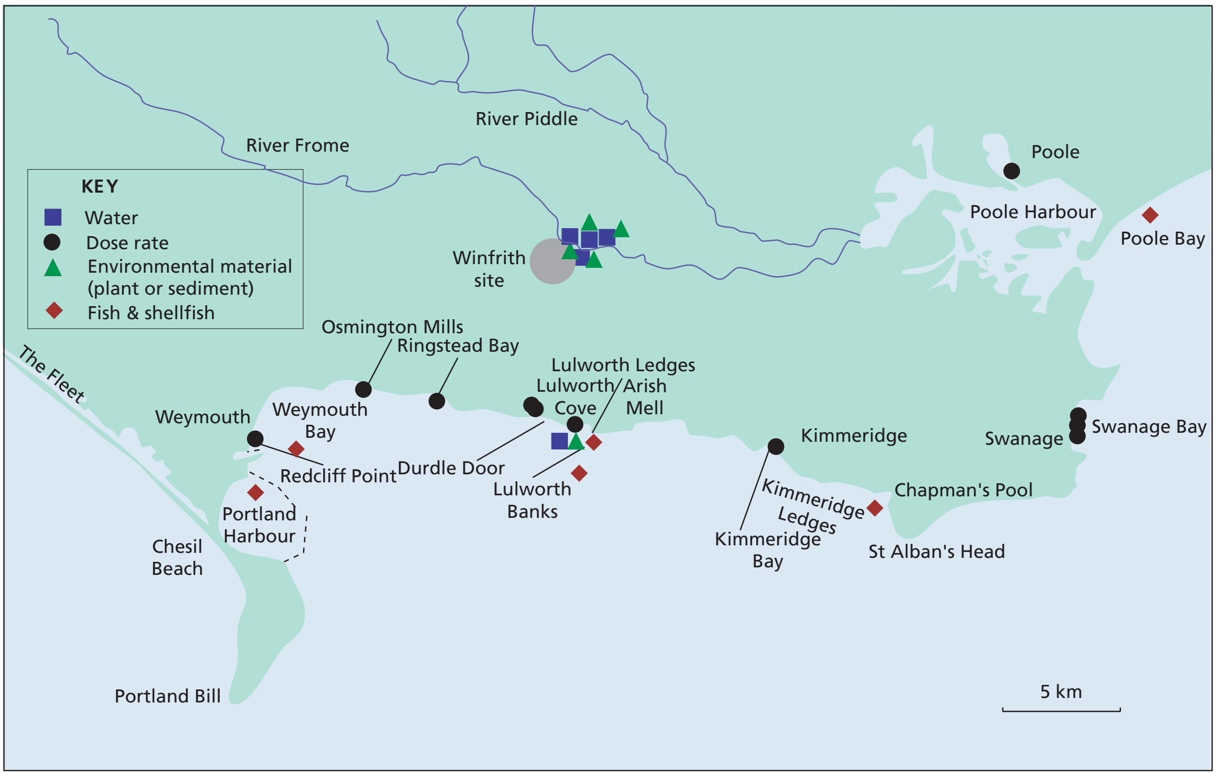


Figure 3.6. Monitoring locations at Winfrith, 2010 (not including farms)

Table 3.1. Individual radiation exposures - research sites, 2010

Site	Exposed population[a]	Exposure, mSv per year						
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, river banks or fishing gear	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
Culham								
Source specific dose	Drinkers of river water	<0.005	-	-	-	<0.005	-	-
Dounreay								
***Total dose* - all sources**	**Adult consumers of game meat**	**0.047**	**-**	**0.047**	**<0.005**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.006	<0.005	-	0.005	-	-	-
	Geo occupants[b]	<0.005	-	-	<0.005	-	-	-
	Consumers of locally grown food[c]	0.028	-	0.028	-	-	<0.005	-
Harwell								
***Total dose* - all sources**	**Prenatal children of local inhabitants (0 - 0.25km)**	**0.018**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.018**
Source specific doses	Anglers	0.006	<0.005	-	0.006	-	-	-
	Consumers of locally grown food[c]	<0.005	-	<0.005	-	-	<0.005	-
Winfrith								
***Total dose* - all sources**	**Adult occupants over sediment**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005	-

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

b *People who live at or regularly visit Oigin's Geo, a coastal feature to the east of Dounreay*

c *Children aged 1y*

Table 3.2. Concentrations of radionuclides in the environment near Culham, 2010

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	<2.9				<0.27	<0.050	0.30
Freshwater	River Thames (downstream)	2	<2.9				<0.27	<0.045	0.28
Grass	1 km East of site perimeter	1	<25	29	<1.5	<0.30	<0.92		230
Sediment	River Thames (upstream)	2					9.5		
Sediment	River Thames (downstream)	2					13		
Soil	1 km East of site perimeter	1	<5.1	8.1	2.5	<2.0	4.3		840

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

Table 3.3(a). Concentrations of radionuclides in food and the environment near Dounreay, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{58}Co	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples								
Cod	Scrabster	2		<0.18	<0.10			0.57
Crabs	Pipeline inner zone	4		<0.21	<0.13	<0.13	5.7	<0.12
Crabs	Pipeline outer zone	4		<0.34	<0.11	<0.10	2.0	<0.10
Crabs	Strathy	4		<0.32	<0.13			<0.14
Crabs	Kinlochbervie	4		<0.23	<0.11		0.30	<0.11
Crabs	Melvich Bay	4		<0.17	<0.10		0.86	<0.11
Winkles	Brims Ness	4		<0.15	<0.10	<0.15		<0.10
Winkles	Sandside Bay	4		<0.15	<0.10	<0.12	2.9	<0.10
Mussels	Echnaloch Bay	4		<0.16	<0.10		11	<0.10
Mussels	Thurso East Mains	4		<0.21	<0.13			0.55
Fucus vesiculosus	Kinlochbervie	4		<0.18	<0.10		55	0.53
Fucus vesiculosus	Brims Ness	4		<0.12	<0.10			<0.15
Fucus vesiculosus	Sandside Bay	4		<0.13	<0.10		34	0.18
Fucus vesiculosus	Burwick Pier	4		<0.14	<0.10		25	<0.17
Sediment	Oigins Geo	3		<0.36	<0.16			3.9
Sediment	Brims Ness	1		<0.10	<0.10			1.0
Sediment	Sandside Bay	1		<0.10	<0.10			2.2
Sediment	Rennibister	1		<0.19	<0.11			21
Seawater	Brims Ness	4	<1.1	<0.12	<0.10			<0.10
Seawater	Sandside Bay	4	<1.1	<0.13	<0.10			<0.10
Spume	Oigins Geo	1		<2.4	<1.1			16

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	<0.12	<0.21	<0.0012	0.0013	<0.0026		
Crabs	Pipeline inner zone	4	<0.11	<0.18	0.0025	0.013	0.030	<0.97	<200
Crabs	Pipeline outer zone	4	<0.12	<0.21	0.00093	0.0074	<0.0090	<1.3	<200
Crabs	Strathy	4	<0.14	<0.26	0.0016	0.0094	0.0067		
Crabs	Kinlochbervie	4	<0.13	<0.21	0.0013	0.0077	<0.10		
Crabs	Melvich Bay	4	<0.11	<0.18	0.0013	0.0094	0.0045		
Winkles	Brims Ness	4	<0.10	<0.16	0.015	0.071	0.064		
Winkles	Sandside Bay	4	<0.11	<0.16	0.013	0.059	<0.019		
Mussels	Echnaloch Bay	4	<0.11	<0.17	0.0093	0.071	0.026		
Mussels	Thurso East Mains	4	<0.14	<0.22	0.026	0.12	0.11		
Fucus vesiculosus	Kinlochbervie	4	<0.11	<0.20			<0.13		
Fucus vesiculosus	Brims Ness	4	<0.10	<0.14			<0.11	8.7	330
Fucus vesiculosus	Sandside Bay	4	<0.10	<0.13			<0.14	8.9	310
Fucus vesiculosus	Burwick Pier	4	<0.11	<0.17			<0.12		
Sediment	Oigins Geo	3	<0.28	<0.90	3.0	14	1.7		
Sediment	Brims Ness	1	0.18	<0.29	2.4	9.6	11		
Sediment	Sandside Bay	1	0.28	<0.14	3.1	14	14		
Sediment	Rennibister	1	<0.14	1.0	0.21	1.7	1.1		
Seawater	Brims Ness	4	<0.10	<0.13			<0.10		
Seawater	Sandside Bay	4	<0.10	<0.15			<0.11		
Spume	Oigins Geo	1	<0.89	<1.7	0.32	1.7	1.0		

Table 3.3(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{95}Nb	^{106}Ru	^{129}I	^{134}Cs	^{137}Cs	^{144}Ce
Terrestrial samples											
Barley		1	<5.0	<0.05	0.25	<0.13	<0.26	<0.050	<0.05	<0.05	<0.19
Beef muscle		1	<5.0	<0.05	<0.10	<0.37	<0.42	<0.050	<0.05	0.18	<0.26
Beef liver		1	<5.0	<0.05	<0.10	<0.21	<0.31	<0.050	<0.05	0.10	<0.21
Cabbage		1	<5.0	<0.05	0.39	<0.05	<0.26	<0.050	<0.05	<0.05	<0.14
Deer muscle		1	<5.0	<0.05	<0.10	<0.28	<0.50		<0.05	50	<0.38
Deer muscle[c]		3								48	
Deer muscle[c]	max									50	
Goats' milk		1	<5.0	<0.05	<0.10	<0.07	<0.35	<0.050	<0.05	<0.05	<0.19
Lamb muscle		1	<5.0	<0.05	<0.10	<0.20	<0.44	<0.050	<0.05	1.5	<0.24
Oats		1	<5.0	<0.05	0.31	<0.05	<0.36	<0.050	<0.05	0.12	<0.24
Pheasants		1	<5.0	<0.087	<0.10	<0.74	<0.84		<0.09	0.27	<0.52
Pheasants[c]		3								0.21	
Pheasants[c]	max									0.29	
Potatoes		1	<5.0	<0.05	<0.10	<0.05	<0.14	<0.050	<0.05	<0.05	<0.07
Rosehips		2	<5.0	<0.05	0.48	<0.05	<0.30	<0.050	<0.05	1.6	<0.20
Rosehips	max				0.66					2.7	<0.22
Swede		1	<5.0	<0.05	0.49	<0.05	<0.28	<0.050	<0.05	0.07	<0.15
Wild mushrooms		2	<5.0	<0.05	<0.10	<0.14	<0.24	<0.050	<0.05	0.48	<0.14
Wild mushrooms	max					<0.19	<0.26			0.73	<0.16
Grass		6	<5.0	<0.05	0.28	<0.11	<0.28	<0.050	<0.05	<0.11	<0.18
Grass	max				0.51	<0.17	<0.40			0.18	<0.23
Soil		6	<5.0	<0.07	1.3	<0.16	<0.66	<0.073	<0.09	18	<0.62
Soil	max			<0.09	2.0	<0.29	<0.77	<0.094	<0.11	22	<0.70
Freshwater	Loch Calder	1	<1.1							<0.01	
Freshwater	Loch Shurrery	1	<1.1							<0.01	
Freshwater	Loch Baligill	1	<1.1							<0.01	
Freshwater	Heldale Water	1	<1.1							<0.01	

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											
Barley		1					<0.050	<0.050	<0.050		
Beef muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	0.0022		
Beef liver		1		0.054	<0.050	<0.050	<0.050	<0.050	0.0071		
Cabbage		1					<0.050	<0.050	<0.050		
Deer muscle		1							<0.16		
Goats' milk		1							<0.06		
Lamb muscle		1		<0.050	<0.050	<0.050	<0.050	<0.050	0.015		
Oats		1					<0.050	<0.050	<0.050		
Pheasants		1							<0.12		
Potatoes		1					<0.050	<0.050	<0.050		
Rosehips		2					<0.050	<0.050	<0.050		
Rosehips	max										
Swede		1					<0.050	<0.050	<0.050		
Wild mushrooms		2					<0.050	<0.050	<0.050		
Wild mushrooms	max										
Grass		6		<0.085	<0.043	<0.087	<0.052	<0.050	<0.074		
Grass	max			0.22	<0.050	0.23	0.064		0.17		
Soil		6	0.95	32	1.5	33	<0.052	0.34	<0.21		
Soil	max		1.0	53	2.5	57	0.060	0.48	<0.36		
Freshwater	Loch Calder	1								<0.010	0.015
Freshwater	Loch Shurrery	1								<0.010	0.017
Freshwater	Loch Baligill	1								<0.010	0.018
Freshwater	Heldale Water	1								<0.010	0.016

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

Table 3.3(b). Monitoring of radiation dose rates near Dounreay, 2010

Location	Material or ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sand	2	0.059
Sandside Bay	Winkle bed	2	0.098
Oigin's Geo	Spume/sludge	4	0.15
Brims Ness	Shingle and stones	2	0.10
Melvich	Salt Marsh	2	0.066
Melvich	Sand	2	0.055
Strathy	Sand	2	<0.047
Thurso	Riverbank	2	0.079
Achreregan Hill	Soil	2	<0.047
Thurso Park	Soil	2	0.084
Borrowston Mains	Soil	2	0.10
East of Dounreay	Soil	2	0.084
Castletown Harbour	Sand	2	0.076
Dunnet	Sand	2	<0.050
Mean beta dose rates			μSv h^{-1}
Sandside Bay	Sediment	4	<1.0
Oigin's Geo	Surface sediment	4	<1.0
Thurso	Riverbank	2	<1.0
Castletown Harbour	Surface sediment	2	<1.0

Table 3.3(c). Radioactivity in air near Dounreay, 2010

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Shebster	12	<0.010	<0.0087	<0.18
Reay	12	<0.010	<0.0081	<0.19
Balmore	11	<0.010	<0.0084	<0.18

Table 3.4(a). Concentrations of radionuclides in food and the environment near Harwell, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			Organic ^{3}H	^{3}H	^{60}Co	^{131}I	^{137}Cs
Freshwater samples							
Flounder	Beckton	1		<25	<0.05	<0.84	0.09
Sediment	Appleford	4[E]			<0.61	2.3	8.3
Sediment	Outfall (Sutton Courtenay)	4[E]			<0.78		21
Sediment	Day's Lock	4[E]			<1.1		20
Sediment	Lydebank Brook	4[E]			<1.1		4.6
Freshwater	Day's Lock	4[E]		<3.7	<0.28		<0.24
Freshwater	Lydebank Brook	4[E]		<4.0	<0.24		<0.21
Freshwater	R Thames (above discharge point)	4[E]		<3.4	<0.30		<0.25
Freshwater	R Thames (below discharge point)	4[E]		<3.0	<0.28		<0.24

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross Beta
Freshwater samples							
Flounder	Beckton	1			<0.04		
Sediment	Appleford	4[E]	<1.2	<0.50	<0.70	210	330
Sediment	Outfall (Sutton Courtenay)	4[E]	<0.60	0.56	<0.80	190	410
Sediment	Day's Lock	4[E]	<0.50	0.57	1.6	<190	410
Sediment	Lydebank Brook	4[E]	<0.50	<0.70	1.3	<120	400
Freshwater	Day's Lock	4[E]				<0.060	0.28
Freshwater	Lydebank Brook	4[E]				<0.055	0.17
Freshwater	R Thames (above discharge point)	4[E]				<0.070	0.25
Freshwater	R Thames (below discharge point)	4[E]				<0.048	0.24

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			Organic ^{3}H	^{3}H	^{137}Cs
Terrestrial samples					
Milk		4	<4.3	<4.3	<0.20
Apples		1	<5.0	5.0	<0.20
Blackberries		1	<5.0	<5.0	<0.20
Honey		1		<7.0	<0.10
Marrow		1	<4.0	<4.0	<0.20
Potatoes		1	<5.0	<5.0	<0.20
Spinach		1	<4.0	<4.0	<0.20

* *Not detected by the method used.*
[a] *Except for milk where units are Bq l^{-1}, and for sediment where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 3.4(b). Monitoring of radiation dose rates near Harwell, 2010

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Appleford	Mud	2	0.068
Sutton Courtenay	Mud	1	0.083
Sutton Courtenay	Grass and mud	1	0.083
Day's Lock	Grass and mud	1	0.076
Day's Lock	Grass	1	0.072

Table 3.5 (a). Concentrations of radionuclides in food and the environment near Winfrith, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{14}C	^{60}Co	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples							
Plaice	Weymouth Bay	2		<0.05		0.08	
Bass	Weymouth Bay	2		<0.05		0.24	
Crabs	Chapman's Pool	1		<0.10		<0.08	0.000051
Crabs	Lulworth Banks	1	63	<0.08		<0.06	0.00010
Pacific Oysters	Poole	1		<0.04		<0.03	
Cockles	Poole	1		0.10		<0.04	
Whelks	Poole Bay	1		<0.04		<0.03	0.00023
Whelks	Lyme Regis	1		<0.18		<0.14	0.00015
Scallops	Lulworth Ledges	1		<0.04		<0.03	0.00055
Clams	Portland Harbour	1		<0.10		<0.08	
Seaweed	Lulworth Cove	1[E]		<0.80	6.3	<0.61	
Seaweed	Bognor Rock	2[E]		<0.67	3.4	<0.48	
Seawater	Lulworth Cove	1[E]		<0.31		<0.26	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Weymouth Bay	2		<0.07				
Bass	Weymouth Bay	2		<0.04				
Crabs	Chapman's Pool	1	0.00045	0.00062	*	*		
Crabs	Lulworth Banks	1	0.00045	0.0011	*	*		
Pacific Oysters	Poole	1		<0.03				
Cockles	Poole	1		<0.04				
Whelks	Poole Bay	1	0.0014	0.0013	*	0.000017		
Whelks	Lyme Regis	1	0.0016	0.00098	*	0.000013		
Scallops	Lulworth Ledges	1	0.0031	0.0017	*	0.000020		
Clams	Portland Harbour	1		<0.18				
Seaweed	Lulworth Cove	1[E]		<0.91				
Seaweed	Bognor Rock	2[E]		<0.56				
Seawater	Lulworth Cove	1[E]		<0.31			<0.90	4.2

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		4	<4.3	<4.3	14	<0.19	<0.20		
Milk	max				15	<0.20			
Apples		1	<5.0	<5.0	7.0	<0.20	<0.20		
Beetroot		1	<4.0	<4.0	4.0	<0.20	<0.20		
Blackberries		1	<5.0	<5.0	14	<0.20	<0.20		
Chard		1	<4.0	<4.0	6.0	<0.30	<0.30		
Honey		1		<8.0	69	<0.10	0.10		
Potatoes		1	<4.0	<4.0	18	<0.20	<0.20		
Grass		2	<5.0	<5.0	32	<0.20	<0.15		
Grass	max				36		<0.20		
Sediment	North of site (Stream A)	1[E]				<0.67	8.8	<100	330
Sediment	R Frome (upstream)	1[E]				<0.23	1.1	<100	250
Sediment	R Frome (downstream)	1[E]				<0.30	2.1	230	280
Sediment	R Win, East of site	1[E]				<0.17	0.35	220	98
Freshwater	North of site (Stream A)	2[E]		18		<0.25	<0.21	<0.050	0.18
Freshwater	R Frome (upstream)	2[E]		<3.4		<0.25	<0.21	<0.030	<0.15
Freshwater	R Frome (downstream)	2[E]		<3.5		<0.25	<0.21	<0.030	0.16
Freshwater	R Win, East of site	2[E]		<5.0		<0.24	<0.21	<0.070	0.27

* *Not detected by the method used.*

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

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

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

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

Table 3.5(b). Monitoring of radiation dose rates near Winfrith, 2010

Location	Ground type	No. of sampling observ-ations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand and shingle	1	0.057
Red Cliffe Point to Black Head	Shingle	1	0.055
Osmington Mills	Rock and stones	1	0.067
Ringstead Bay	Shingle	1	0.057
Durdle Door	Shingle	1	0.055
St Oswald's Head	Shingle	1	0.057
Lulworth Cove	Pebbles and sand	1	0.067
Kimmeridge Bay	Rock and stones	1	0.082
Swanage Bay 1	Sand	1	0.055
Swanage Bay 2	Sand	1	0.060
Swanage Bay 3	Sand	1	0.067
Poole Harbour	Pebbles and sand	1	0.056

4. Nuclear power stations

Key points

- Public radiation doses from all sources were less than 5 per cent of the dose limit (exceptions stated below)
- Electricity production continued at two Magnox stations (Oldbury and Wylfa) and all the British Energy power stations in 2010
- Discharges, environmental concentrations and dose rates in 2010 were broadly similar to those in 2009
- 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

- The dose to consumers of fish and shellfish was the highest dose
- At Oldbury, power generation is to continue beyond 2010
- There were small decreases in public radiation doses from liquid discharges due to lower gamma dose rates in intertidal areas

Bradwell, Essex

- Public radiation doses from all sources were less than 13 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Liquid caesium-137 and other radionuclides discharges decreased

Chapelcross, Dumfries and Galloway

- As in 2009, tritium was detected in surface water around the site in 2010

Dungeness, Kent

- Public radiation doses from all sources decreased. This was due to cessation of power production by Magnox reactors
- Gaseous tritium and sulphur-35 discharges, and liquid discharges of tritium and cobalt-60, decreased from Dungeness B

Hartlepool, Cleveland

- There were small decreases in public radiation doses from liquid discharges due to lower gamma dose rates in intertidal areas
- Gaseous discharges of carbon-14 and sulphur-35, and liquid discharges of tritium and sulphur-35, increased in 2010, but had no measurable effect off-site.

Heysham, Lancashire

- Public radiation doses from all sources were less than 6 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Gaseous discharges of argon-41 decreased from Heysham 2. Liquid discharges of tritium decreased from both stations

Hinkley Point, Somerset

- Minor variations made to the existing operator permit at Hinkley A
- There were decreases in public radiation doses due to lower gamma dose rates in intertidal areas and reduced occupancy rates
- Liquid discharges of tritium decreased from Hinkley A and gaseous and liquid discharges of tritium decreased from Hinkley B

Hunterston, North Ayrshire

- Public radiation doses from all sources were less than 7 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Liquid discharges of sulphur-35 increased from Hunterston B, but had no measurable effect off-site.
- Concentrations of technetium-99 in crustacean samples were the lowest values in recent years

Sizewell, Suffolk

- Minor variations made to the existing operator permit at Sizewell A
- New source specific assessment undertaken to determine dose to houseboat dwellers
- Gaseous discharges of carbon-14 decreased from Sizewell A. Gaseous discharges of carbon-14, and liquid discharges of tritium, decreased from Sizewell B

Torness, East Lothian

- Two variations to the site's discharge authorisation were granted (in 2011), allowing an additional disposal route and waste to be transferred to other locations for treatment and disposal.

Trawsfynydd, Gwynedd

- There were small increases in public radiation doses due to higher direct radiation
- Gaseous discharges of carbon-14 and tritium increased, and liquid discharges of strontium-90 reduced to nil

Wylfa, Isle of Anglesey

- Power generation is to continue beyond 2010
- There were small decreases in public radiation doses due to lower direct radiation

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

Eleven of the 19 nuclear power stations are older Magnox power stations, owned by the NDA. From 2005, the NDA was formed and became responsible for the UK's civil nuclear liabilities. The NDA is a non-departmental public body, set up under the Energy Act 2005, with a remit to secure the decommissioning and clean-up of the UK's civil public sector nuclear sites. In 2011, the NDA published their strategy for long-term development, and in March 2011 a business plan for 2011/14 was published (Nuclear Decommissioning Authority, 2011a; 2011b).

In 2008, Magnox Electric Limited (the nuclear site licence holder) split into two Site Licence Companies: Magnox North Limited and Magnox South Limited. Magnox North Limited became the operator for Chapelcross, Hunterston A, Oldbury, Trawsfynydd and Wylfa and Magnox South Limited became the operator for Berkeley, Bradwell, Dungeness A, Hinkley Point A and Sizewell A. Calder Hall is operated by Sellafield Limited. In 2010, only two of these Magnox stations (Oldbury and Wylfa) continued to generate electricity, others are in the process of decommissioning. Discharges from one of the Magnox stations (Calder Hall) are considered in Section 2 because it is located at Sellafield.

Seven advanced gas-cooled reactor (AGR) power stations and one pressurised water reactor (PWR) power station were owned and operated by British Energy Generation Limited in 2010. British Energy Group plc (the parent company) is a wholly owned subsidiary of Électricité de France (EDF) Energy. British Energy Generation Limited, which operates Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B and Sizewell B Power Stations in England, and Hunterston B and Torness Power Stations in Scotland, became a subsidiary of EDF in early 2009. All of these were generating electricity during 2010.

Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency for England and Wales, and by SEPA for Scotland. In 2010, gaseous and liquid discharges were below regulated limits for each of the power stations (see Appendix 2). Independent monitoring of the environment around each of the power stations is conducted by the Food Standards Agency and the Environment Agency for England and Wales, and by SEPA for Scotland.

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

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

ENGLAND

4.1 Berkeley, Gloucestershire and Oldbury, South Gloucestershire

Berkeley and Oldbury are both Magnox power stations. Berkeley Power Station is situated on the eastern bank of the River Severn and was powered by two Magnox reactors. Berkeley was the first commercial power station in the UK to enter into decommissioning, when it ceased electricity generation in 1989. Defuelling was completed in 1992. Decommissioning is still in progress and radioactive wastes are still generated by these operations. In addition, there is a component of the discharge from the operation of the adjoining Berkeley Centre. Berkeley Centre acts as the headquarters for the generating Magnox stations and provides support functions including radiochemical laboratories used for analysis of liquid effluents and environmental samples.

The Oldbury Power Station, located on the south bank of the River Severn close to the village of Oldbury-on-Severn has continued operation and has two Magnox reactors. The site has gained approval from the NDA to pursue the opportunity of further power generation from Reactor 1 beyond June 2011 (the date previously scheduled for the cessation of generating electricity of both reactors). Reactor 2 at Oldbury Nuclear Power Station will continue to generate until the end of June 2011. In 2010, Magnox North Limited lodged a FEPA licensing application to carry out a dredging program, involving the disposal at sea of sediment from Oldbury Power Station (see Appendix 5).

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

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.011 mSv in 2010 (Table 4.1), which was approximately 1 per cent of the dose limit. This was mostly due to direct radiation from the Berkeley site, and the dose assessment identifies the prenatal children of local inhabitants as the most exposed age group. The reduction from 0.058 mSv in 2009 was due to a decrease in the estimate of direct radiation from the site in 2010. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. Any variations in *total doses* with time were attributed to changes in direct radiation.

The source specific assessment of exposure for consumers of locally grown foods, at high-rates, was less than *total dose* in 2010. The dose to consumers of fish and shellfish was estimated to be 0.012 mSv, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). This includes external radiation, a component due to the tritium originating from GE Healthcare, and a component of the dose resulting from an increased tritium dose coefficient (see Appendix 1). The dose in 2009 was 0.025 mSv, and the decrease in 2010 was due to a decrease in gamma dose rates.

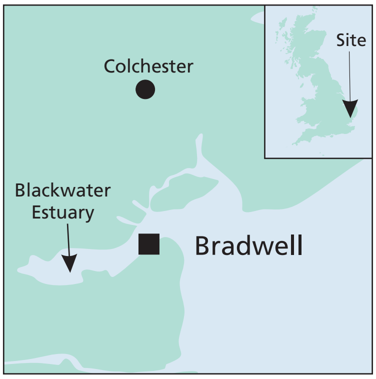
Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Local freshwater samples were also analysed. Data for 2010 are given in Table 4.2(a). Tritium and sulphur-35 were detected at very low levels in some of the terrestrial food samples monitored. Carbon-14 was detected in locally produced foods, at concentrations just above background values, although this may be due to natural variation. Gross alpha and beta activities in surface waters were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Liquid radioactive wastes are discharged to the Severn estuary. Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. Measurements of tritium in seafood were made in order to monitor the additional local effects of discharges from the GE Healthcare radiopharmaceutical plant in Cardiff (see Section 6). Data for 2010 are given in Tables 4.2(a) and (b). Where comparisons can be drawn concentrations in the aquatic environment were generally similar to those in recent years, although gamma dose rates were smaller in 2010 compared to 2009 at some sites (1 km south of Oldbury and Lydney Rocks). Most of the artificial radioactivity detected was due to tritium and radiocaesium. Concentrations of radiocaesium represent the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have remained reasonably consistent for the last decade (Figure 4.1), with a suggestion of a small peak in 2004 and subsequently decreasing with time. Relatively high concentrations of tritium were detected in fish and shellfish and these were likely to be mainly due to discharges from GE Healthcare, Cardiff. Very small concentrations of other radionuclides were detected but, taken together, were of low radiological significance.

4.2 Bradwell, Essex



The Bradwell site is located on the south side of the Blackwater Estuary. This Magnox power station ceased electricity production in 2002 after 40 years of operation, and defuelling was completed in 2006. The focus for the site is now the completion of decommissioning projects. The most recent habits survey was undertaken in 2007 (Tipple *et al*., 2008).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to have been 0.13 mSv (Table 4.1), which was 13 per cent of the dose limit for members of the public of 1 mSv, and an increase from 0.098 mSv in 2009. Direct radiation was the dominant contributor to this dose, and the dose assessment identifies prenatal children of local inhabitants as the most exposed age group. The higher value in 2010 was due to an increase in the estimate of direct radiation from the site. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. Any variations in *total dose* with time were attributed to changes in direct radiation.

Source specific assessments of exposures for both consumers of locally grown foods and for fish and shellfish, at high-rates, were less than the *total dose* in 2010 (Table 4.1).

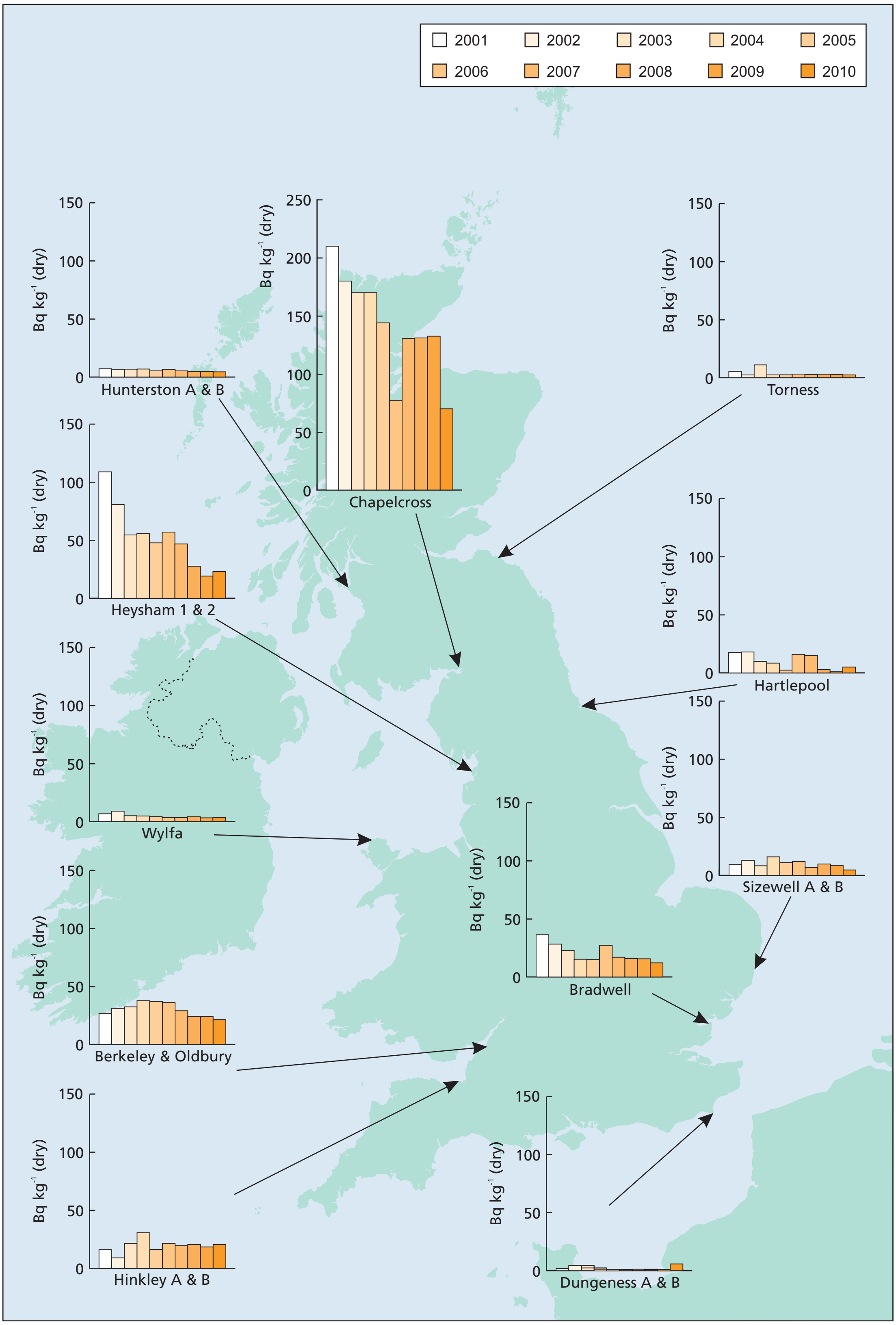


Figure 4.1. Caesium-137 concentration in marine sediments near nuclear power stations between 2001-2010

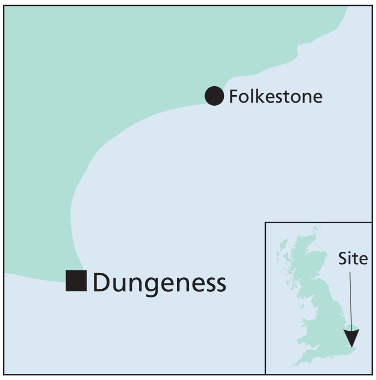
Gaseous discharges and terrestrial monitoring

This power station is permitted to discharge gaseous wastes to the local environment via stacks to the atmosphere. Terrestrial sampling is similar to that for other power stations including analyses of milk, fruit and crop samples for tritium, carbon-14 and sulphur-35. Samples of water are also taken from a coastal ditch and public supplies. Data for 2010 are given in Table 4.3(a). Concentrations of activity were low in terrestrial food samples, though some enhancements of carbon-14 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water. The gross beta activities in water from the coastal ditch continued to be enhanced above background levels, and these were in excess of the WHO screening level for drinking water (1 Bq l^{-1}). Tritium concentrations in coastal ditches were similar to those in 2009, and were substantially below the EU reference level for tritium of 100 Bq l^{-1}. The water in the ditches is not known to be used as a source of drinking water.

Liquid waste discharges and aquatic monitoring

Liquid wastes are discharged into the River Blackwater estuary. Discharges of caesium-137 and other radionuclides were decreased, in comparison to releases in 2009. Aquatic sampling was directed at consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Monitoring included the commercial oyster fishery of importance in the northern part of the estuary. Seaweeds were analysed as an environmental indicator material and leaf beet was collected because it is eaten locally and grows in areas that become tidally inundated. Data for 2010 are given in Tables 4.3(a) and (b). Low concentrations of artificial radionuclides were detected in aquatic materials as a result of discharges from the station, discharges from Sellafield and weapons testing. Apportionment of the effects of these sources is difficult because of the low levels detected; however concentrations were generally similar to those for 2009. There is an overall decline in caesium-137 concentrations in sediments (Figure 4.1). The technetium-99 detected in seaweeds at Bradwell was likely to be due to the long distance transfer of Sellafield derived activity. Gamma dose rates on beaches were difficult to distinguish from natural background.

4.3 Dungeness, Kent



The Dungeness power stations are located on the south Kent coast between Folkestone and Rye. There are two separate A and B nuclear power stations on this site; the A station was powered by two Magnox reactors and the B station has two AGRs. Discharges are made via separate but adjacent outfalls and stacks, and for the purposes of environmental monitoring these are considered together. Dungeness A ceased generating electricity in 2006. As part of the decommissioning process, both Magnox reactors are currently being defuelled with the spent fuel being dispatched to Sellafield (Cumbria) for reprocessing. It is estimated that Dungeness B will end power generation by 2018. During June 2010, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al*., 2011d). An increase in the fish and crustacean consumption rates have been observed, together with a decrease in the mollusc consumption and occupancy rates, in comparison with those of the previous survey in 2005. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.022 mSv (Table 4.1), or approximately 2 per cent of the dose limit of 1 mSv. As in recent years, this is almost entirely due to direct radiation from the site. Adults living near to the site were the most exposed people. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* ranged between 0.022 and 0.63 mSv, over the time period and were dominated by direct radiation. Following 2006, this dose has significantly declined, particularly in 2010, due to the end of power generation of the Magnox reactors.

Source specific assessments for high-rate consumers of locally grown foodstuffs, for local bait diggers and houseboat occupants, were less than the *total dose*. The dose to local bait diggers (who consume large quantities of fish and shellfish and spend long periods of time in the location being assessed) was 0.014 mSv, which was approximately 1 per cent of the annual dose limit for members of the public of 1 mSv (Table 4.1). Despite a reduced dose contribution from the lower occupancy rate (using new habits data) in 2010, there was small increase in dose (from 0.012 mSv in 2009). This was due to adopting other locations in the dose assessment (informed from the habits survey), that had higher gamma dose rate measurements than the previous location used in 2009.

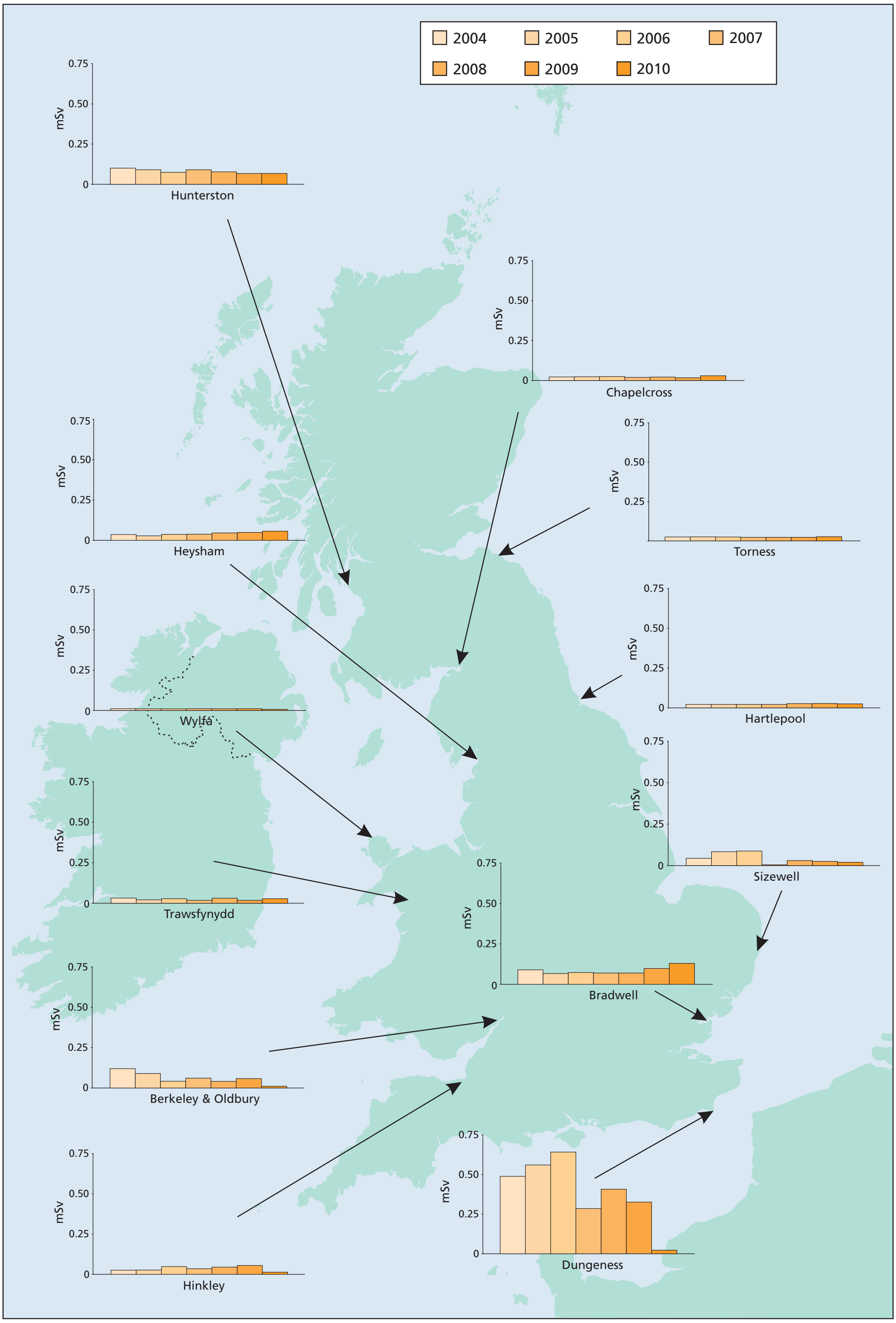


Figure 4.2. *Total dose* at nuclear power stations in England, Wales, and South Scotland, 2004-2010 (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)

Gaseous discharges and terrestrial monitoring

Discharges of tritium and sulphur-35 were decreased from Dungeness B, in comparison to releases in 2009. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. The results of monitoring for 2010 are given in Tables 4.4(a). Activity concentrations in many terrestrial foods were below or close to the limits of detection. Concentrations of carbon-14 were generally within the range of observed background activity concentrations. Low concentrations of sulphur-35 were detected in some samples. Gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Discharges of tritium and cobalt-60 decreased from Dungeness B, in comparison to releases in 2009. Marine monitoring included gamma and beta dose rate measurements and analysis of seafood and sediments. The results of monitoring for 2010 are given in Tables 4.4(a) and (b). Caesium-137 concentrations in marine materials are attributable to discharges from the stations and to weapon test fallout with a long distance contribution from Sellafield and Cap de la Hague. Apportionment is difficult at these low levels. The low concentrations of transuranic nuclides in scallops were typical of levels expected at sites remote from Sellafield. No tritium was detected in seafood. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.1); the apparent increase in 2009 was due to the inclusion of a value (< 5.8 Bq kg^{-1}) which was reported as below the analytical limit of detection. Gamma dose rates were generally difficult to distinguish from the natural background.

4.4 Hartlepool, Cleveland

Hartlepool Power Station is situated on the mouth of the Tees estuary, on the north east coast of England, and is powered by twin AGRs. It is estimated that its power generation will end by 2019. The most recent habits survey was conducted in 2008 (Garrod *et al.*, 2009).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to have been 0.025 mSv (Table 4.1), which was less than 3 per cent of the dose limit. This dose was very similar to that in 2009 (0.026 mSv). The most exposed people were adults living near to the site whose dose was from direct radiation from the site and, to lesser extent, external exposure from activity in sand and sediment on local beaches. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments for both consumers of locally grown foodstuffs and for fish and shellfish, at high-rates, were less than *total dose*. The dose to local fish and shellfish consumers, including external radiation, was 0.008 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). The dose in 2009 was 0.011 mSv and the reduction in 2010 was due to lower gamma dose rates reported. Lower gamma dose rates in 2010 also reduced the dose received from people collecting sea coal at Carr House from 0.014 mSv in 2009 to 0.007 mSv in 2010.

Gaseous discharges and terrestrial monitoring

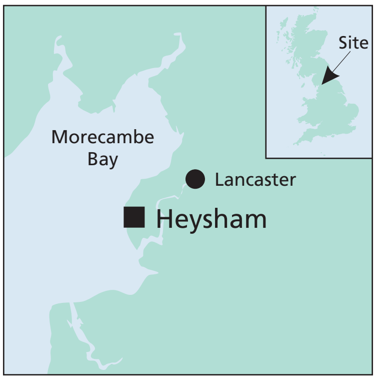
Gaseous radioactive waste is discharged via stacks to the local environment. Discharges of carbon-14 and sulphur-35 increased in 2010, compared with 2009, discharges of other radionuclides were broadly comparable. Analyses of tritium, carbon-14 and sulphur-35 were made in terrestrial samples, including milk, crops and fruit. Samples of water are also taken from a borehole and public supplies. Data for 2010 are given in Table 4.5(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, though small enhancements of sulphur-35 concentrations in a few terrestrial samples were apparent. The gross alpha and beta activities in freshwater were less than the WHO screening levels for drinking water.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Liquid discharges of tritium and sulphur-35 increased in 2010, in comparison to releases in 2009.

Results of the aquatic monitoring programme conducted in 2010 are shown in Tables 4.5(a) and (b). The small enhancements of carbon-14 concentrations above expected background, observed in seafood samples in previous years, were generally lower in 2010. Enhancements are most likely to be due to carbon-14 discharges from a non-nuclear site since carbon-14 discharges from the power station are low. The reported carbon-14 concentration in mussels is the lowest value in recent years. Technetium-99 analysis in seaweed is used as a specific indication of the far-field effects of disposals to sea from Sellafield. Concentrations in seaweed (Fucus vesiculosus) were low and much less than the peak observed in 1998 (see also Figure 2.20). They are less than 1 per cent of the equivalent concentrations near Sellafield. As in 2009, iodine-131 was positively detected in samples of seaweed collected around the bottom of the River Tees Estuary in 2010 The detected values are believed to originate from the therapeutic use of this radionuclide in a local hospital. Concentrations of radiocaesium and transuranics were mainly due to disposals from Sellafield and to weapon test fallout. In 2010, the lead-210 and polonium-210 concentrations were close to natural background. Gamma dose rates were generally lower in 2010, compared to those in 2009.

4.5 Heysham, Lancashire



Heysham Power Station is situated on the Lancashire coast to the south of Morecambe and near the port of Heysham. This establishment comprises two separate nuclear power stations, both powered by two AGRs. It is estimated that Heysham 1 and 2 will end power generation by 2019 and 2023, respectively. Disposals of radioactive waste from both stations are made under permit via adjacent outfalls in Morecambe Bay and stacks but for the purposes of environmental monitoring both stations are considered together. The most recent habits survey was conducted in 2006 (McTaggart *et al*., 2007).

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.057 mSv in 2010 (Table 4.1), up from 0.049 mSv in 2009. This was less than 6 per cent of the dose limit for members of the public. The most exposed people are those adults who spend a large amount of time on sand and sediments. The increase in *total dose* in 2010 was due to higher mean gamma dose rates over local beaches. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. Any changes in *total doses* with time were attributed to environmental variability (in measurements of gamma dose rates).

Source specific assessments for both high-rate terrestrial food consumers and fisherman were less than *total dose*. The dose in 2010 to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.046 mSv, which was less than 5 per cent of the dose limit for members of the public of 1 mSv (Table 4.1). In 2009, the dose was 0.041 mSv, and the increase in 2010 was due to not including the relatively low gamma dose measurement at Heysham pipeline in the assessment.

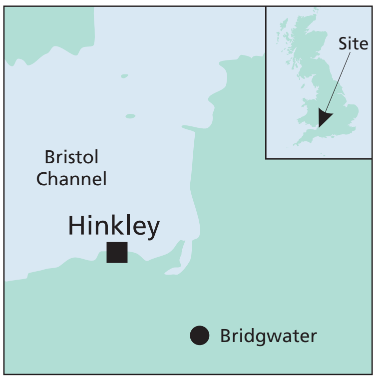
Gaseous discharges and terrestrial monitoring

Discharges of argon-41 at Heysham 2 decreased in 2010, compared with 2009; discharges of other 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 2010 are given in Table 4.6(a). The effects of gaseous disposals were difficult to detect in 2010, and measured activities of cobalt-60 were below the LoD. Small enhancements of concentrations of sulphur-35 were apparent in some samples.

Liquid waste discharges and aquatic monitoring

Liquid discharges of tritium at both Heysham 1 and Heysham 2 decreased in 2010, compared with 2009, discharges of other radionuclides were broadly comparable at both stations. 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 2010 are given in Tables 4.6(a) and (b). In general, similar levels to those for 2009 were observed and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. Concentrations of tritium in flounder and mussels were not sufficiently high to demonstrate that any originated as a result of discharges from Heysham. Concentrations of technetium-99 in marine samples remained at levels typical of recent years, caused by discharges from Sellafield. Concentrations of caesium-137 in sediments, largely due to Sellafield, are in decline (Figure 4.1). Gamma dose rates over intertidal sediment were generally similar to measurements in recent years. No gamma dose measurements were taken at Heysham pipelines in 2010.

4.6 Hinkley Point, Somerset



Hinkley Point Power Station is situated on the Somerset coast, west of the River Parrett estuary. There are two separate A and B nuclear power stations which comprise of two Magnox reactors and two AGRs, respectively. Hinkley Point A started electricity generation in 1965 and ceased in 2000. This station completed defuelling in 2004 and is undergoing decommissioning. It is estimated that Hinkley Point B will end power generation by 2016. Environmental monitoring covers the effects of the two power stations together. In January 2010, the Environment Agency issued variations in permits to reduce limits of gaseous discharges of tritium and all liquid discharges at Hinkley Point A. During September 2010, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al*, 2011e). A slight increase in the crustacean consumption rate has been observed, together with a decrease in the fish, mollusc and occupancy rates, in comparison with those of the previous survey in 2006. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to be 0.014 mSv (Table 4.1), or less than 2 per cent of the dose limit. Adults who spend a large amount of time on local beaches were the most exposed people. The decrease in *total dose* from 0.055 mSv in 2009 was mostly due to lower gamma dose rate on beaches in the area. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2.

Source specific assessments for consumers of locally grown food (including that consumed crops grown in soil using seaweeds as fertilisers and soil conditioners) and for fish and shellfish, at high rates, were less than the *total dose* (Table 4.1). Assuming that high-rate vegetable consumers obtain all of their supplies from monitored plots near Hinkley Point, the dose in 2010 from the use of seaweeds as fertilisers and soil conditioners was estimated to be 0.007 mSv. The increase in dose from less than 0.005 mSv (in 2009) was largely attributed to the inclusion of a higher LoD result for americium-241 in potatoes in 2010.

The dose to local fishermen, who consume a large amount of seafood and are exposed to external radiation over intertidal areas, was 0.020 mSv, which was 2 per cent of the dose limit for members of the public of 1 mSv. This estimate also includes the effects of discharges of tritium and carbon-14 from Cardiff and uses an increased tritium dose coefficient (see Appendix 1). The decrease in dose, from 0.046 mSv (in 2009), was mostly due to the reduced gamma dose rates at Stolford, and to a lesser extent from the reduced occupancy rate used in 2010 assessment (using new habits data).

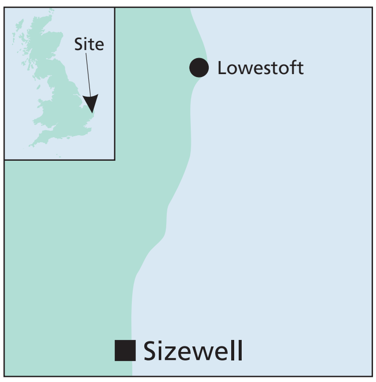
Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Discharges of tritium from Hinkley Point B decreased in 2010 in comparison to 2009. Analyses of milk, crops and fruit were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma emitters. Local reservoir water samples were also taken and analysed. The use of seaweeds as fertilisers and soil conditioners was assessed to investigate transfer of radionuclides from sea to land. Data for 2010 are given in Table 4.7(a). Activity concentrations of tritium and gamma emitters (including caesium-137) in terrestrial materials were below, or at, the limits of detection. Sulphur-35 from Hinkley Point B was detected at low concentrations in some of the food samples. A few of the carbon-14 concentrations were higher than the default values used to represent background levels (apples and blackberries), but this did not include samples in milk in 2010. Reservoir water contained alpha and beta activities less than WHO screening levels for drinking water. Sea to land transfer data for vegetables and soil which had added seaweed (as compost) showed no evidence for uptake of activity concentrations in foodstuffs.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent from both power stations are made via separate outfalls into the Bristol Channel. Discharges of tritium decreased from both stations in 2010, in comparison to 2009. Analyses of seafood and marine indicator materials and measurements of external radiation over intertidal areas were conducted. Measurements of tritium and carbon-14 are made primarily to establish the local effects of discharges from the GE Healthcare plant at Cardiff. The environmental results for 2010 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 4.1). Concentrations of tritium in fish were significantly decreased in comparison to recent years. Further information on tritium concentrations in seawater from the Bristol Channel is given in Section 8. Concentrations of other radionuclides in the aquatic environment represent the combined effect of releases from these stations, plus other establishments that discharge into the Bristol Channel. Other contributors to the aquatic environment are Sellafield, GE Healthcare at Cardiff, weapons tests and Chernobyl fallout. Apportionment is generally difficult at the low concentrations detected. However, the majority of tritium and carbon-14 in seafood was likely to have been due to disposals from GE Healthcare, Cardiff. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. Overall, gamma radiation dose rates over intertidal sediment were generally similar to measurements in recent years. The dose rates at Stolford were marginally decreased in comparison to 2009, but generally similar to those measurements observed in recent years (prior to 2009).

4.7 Sizewell, Suffolk



The two Sizewell Power Stations are located on the Suffolk coast, near Leiston. The A station has two Magnox reactors whilst the B station is the UK's only commercial PWR power station. The B station began operation in 1995 and it is estimated that it will end power generation by 2035. Sizewell A power station ceased to be an electricity generator in 2006 and is due to be decommissioned. In March 2010, the Environment Agency issued variations in permits to reduce limits of gaseous discharges of carbon-14 and tritium discharges at Sizewell A; sulphur 35 and argon-41 are no longer measured. During June and July 2010, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Garrod *et al*., 2011). An increase in the fish and mollusc consumption rates has been observed, together with a decrease in the crustacean and occupancy rates, in comparison with those of the previous survey in 2006. In 2010, the predominant mollusc consumed by the high-rate groups was whelks, and the intertidal occupancy was over sand. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

Doses to the public

The *total dose* from all pathways and sources was assessed of radiation to be 0.020 mSv in 2010 (Table 4.1) or approximately 2 percent of the dose limit, and a decrease from 0.026 mSv in 2009. The dominant contribution to *total dose* at this site was from direct radiation. Dose from this pathway has reduced by a factor of three since Sizewell A ceased generation in 2006. The most exposed people were adults living in the vicinity of the site. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. The *total dose* declined at the end of 2006, following the closure of the Magnox reactors at Sizewell A.

Source specific assessments of exposures for high-rate consumers of locally grown foodstuffs and for consumers of fish and shellfish were less than the *total dose* in 2010 (Table 4.1). In 2010, a new assessment was undertaken to determine the external exposure for houseboat dwellers at Sizewell (as identified in the recent habits survey). The estimated dose was 0.005 mSv for this activity (Table 4.1).

Gaseous discharges and terrestrial monitoring

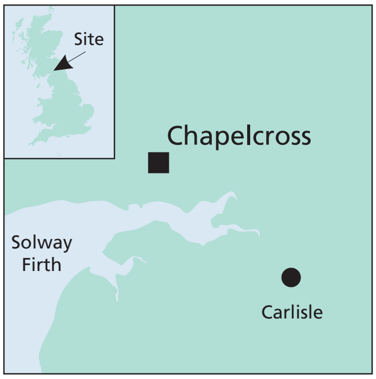
Gaseous wastes are discharged via separate stacks to the local environment. Discharges of sulphur 35 and argon-41 were no longer measured from Sizewell A in 2010. Carbon-14 discharges in 2010 decreased from both stations in comparison to 2009. The results of the terrestrial monitoring in 2010 are shown in Table 4.8 (a). Gamma-ray spectrometry and analysis of tritium, carbon-14 and sulphur-35 in milk, crops and fruit generally showed very low concentrations of artificial radionuclides near the power stations in 2010. Tritium concentrations in local freshwater were all low, although activities at the Leisure Park were positively detected above the LoD. Generally carbon-14 concentrations in foods were lower in 2010 compared to 2009. 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 in 2010 decreased from Sizewell B in comparison to 2009. In the aquatic programme, analysis of seafood, sediment, and seawater, and measurements of gamma dose rates in intertidal areas were conducted. Data for 2010 are given in Tables 4.8(a) and (b). Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and to weapons testing. Tritium concentrations in seafood were all below the limits of detection. Measured gamma dose rates in intertidal areas were difficult to distinguish from the natural background. .

SCOTLAND

4.8 Chapelcross, Dumfries and Galloway



Chapelcross was Scotland's first commercial nuclear power station and has four Magnox reactors located near the town of Annan in Dumfries and Galloway. After 45 years of continuous operation, electricity generation ceased in 2004 and the station has been preparing for decommissioning. Defuelling of the reactors began in 2008 and completion is expected during 2012. The major hazards on the site will now be decommissioned early, by 2017. The application for a revised authorisation for the disposal of radioactive waste arising from the decommissioning of Chapelcross was subject to discretionary and public consultation during 2010 and is in the process of being determined.

Last year, SEPA reported that a major improvement to the effluent pipeline was undertaken by Magnox North towards the end of 2009. The old pipeline was relined with a plastic pipe routinely used within the water industry and grouted in place at strategic points. Initial inspection by SEPA noted that the constant discharge from the pipeline (exposed around low water tide times) had ceased. Since then the Site Operator has noted a small volume of liquid from the pipeline and has detected the presence of radioactivity. This is being investigated further by the Site Operator and SEPA. During 2010 the site informed SEPA of a leak of contaminated groundwater being stored in a tank, and following investigation, SEPA issued a Final Warning letter to the Site Operator. A disposal of liquid effluent outside the tidal window set in the Authorisation was notified to SEPA. The improvements put in place by the Site Operator, and the demonstration of compliance with the requirements of the Authorisation, were inspected by SEPA and further work was highlighted to the Site Operator.

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. During August 2010, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Clyne *et al*., in press). Increases in the consumption of wildfowl and crustaceans rates and occupancy rates over saltmash have been observed, together with decreases in fish consumption and occupancy rates over mud, in comparison with those of the previous survey in 2005. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1. In 2007, a habits survey of consumption and occupancy, by members of the public, was completed on the Dumfries and Galloway coast (Clyne *et al*., 2011b). The results of this survey are used to determine the potential exposure pathways relating to permitted liquid discharges from the Sellafield nuclear site in Cumbria (see Section 2.3.1).

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.029 mSv in 2010 (Table 4.1), which is less than 3 per cent of the dose limit. Infants consuming milk at high-rates were the most exposed people and a change from 2009 (adults spending time on local beaches), resulting from recent habits information. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments of exposures for high-rate consumers of seafood (crustaceans), and for wildfowlers, were less than the *total dose* in 2010 (Table 4.1). These assessments were amended to take account of current pathways (identified in the recent habits survey for high-rate crustacean consumers and wildfowlers who also consume salmonids) and therefore are not comparable with previously reported dose values. The annual dose for high-rate terrestrial food consumers was estimated to be 0.021 mSv in 2010. The increase in dose from 0.008 mSv (in 2009) was mostly attributable to the inclusion of the LoD for americium-241 activity in food in the 2010 assessment. In line with the rules on use of results for dose calculations, americium-241 was included because detectable activity was observed in other samples (soil) from the terrestrial environment in 2010. An increased value for the maximum carbon-14 activity in milk contributed to the remainder of the increase in the dose.

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

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Argon-41 was not discharged in 2010, as in recent years, following the end of power generation. Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit, crops and game, as well as grass and soil samples, for a range of radionuclides. Air samples at three locations were also monitored to investigate the inhalation pathway.

The results of terrestrial food and air monitoring in 2010 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 2009. The maximum concentration of carbon-14 in milk was 28 Bq l^{-1} and higher than the value in 2009 (20 Bq l^{-1}). The results for terrestrial foods show the effects of discharges from Chapelcross in the concentrations of tritium and sulphur-35 in a range of foods, and these are mostly below the LoD. Measured concentrations of radioactivity in air samples at locations near to the site were below the LoD

Further sampling and analysis of the local surface waters in and around the Chapelcross site showed comparable results with those found in 2009 (Scottish Environment Protection Agency, 2009b). Analysis of a peat sample from Creca Moss gave a tritium value consistent with current rates of deposition from authorised disposals to air. Analysis of samples of sediment obtained from burns local to the site (Gullielands Burn) showed tritium values of around half that detected in the corresponding water sample. Little evidence for organically bound tritium (OBT) was found in the environmental samples analysed for OBT (tritium mostly determined as tritiated water). Weekly sampling and analysis for tritium of rainwater deposited close to the village of Creca was carried out during the final quarter of 2010. The levels of tritium were measured above the detection limit, but do not account for the current levels of tritium observed in local surface waters. Rainfall sampling is being added to the routine monitoring programme.

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 2010 are given in Tables 4.9(a) and (b). Concentrations of artificial radionuclides in marine materials in the Chapelcross vicinity are mostly due to the effects of Sellafield discharges and are consistent with values expected at this distance from Sellafield. Concentrations of most radionuclides remained at similar levels to those detected in recent years. Progressive reductions in concentrations of technetium-99 in biota were observed again in 2010. Measurements of the contact beta dose rate on stake nets were below the LoD.

Since 1992, a number of particles have been found at the end of the discharge outfall. Most of these particles are limescale and originate from deposits within the pipeline. Magnox North Limited monitors this area frequently. In 2010, no particles were detected during the year's routine monitoring. The relining of the pipeline, and grouting at strategic points, has reduced the potential for particles to be released. In comparison, one particle with activity above background was detected in 2009, with a total of 131 particles during the period 2000 to 2009. The relatively high number found in 2005 (95 particles) was due to a series of incidents including a flooding event that was the result of exceptionally heavy rainfall in the area. All contaminated items detected are removed.

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 is operated by Magnox North Limited and owned by the NDA. It was powered by twin Magnox reactors until it ceased electricity power production in 1990. Hunterston B is owned and operated by British Energy Generation Limited, part of EDF, and is powered by a pair of AGRs. Hunterston B is expected to have an operational life to 2016 and may seek to extend this further. Environmental monitoring in the area considers the effects of both sites together.

In April 2010, SEPA varied the authorisation for Hunterston A to allow solid low-level waste to be consigned to the Low Level Waste Repository (LLWR), near Drigg in Cumbria, for disposal in accordance with the permit held by the operator of LLWR. This variation permits the possible onward consignment of waste to a disposal site authorised to receive such waste.

In September 2010, contaminated silt, from the Hunterston A site, was washed out of two coastline outfalls during a period of extremely high rainfall. Although the hazards to which the environment and the public were exposed were negligible, this event constituted a contravention of the limitations and conditions of the RSA 93 authorisation held by the operator. SEPA issued a Final Warning Letter to Magnox North Limited in December 2010 in response to this event.

In September 2010, British Energy Generation Limited applied to SEPA to vary the authorisation for Hunterston B in order to remove the requirement for the final disposal of solid Low Level Waste at the Low Level Waste Repository. This application had not been determined by the end of 2010.

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

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.067 mSv in 2010 (Table 4.1), which is less than 7 per cent of the dose limit, and unchanged from 2009. The dose was mainly from direct radiation from the site, and the most exposed people were the prenatal children of local inhabitants. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. The decrease in *total dose* in recent years reflected a downward trend in the reported direct radiation.

Source specific assessments of exposures for consumers of both locally grown food and for seafood consumers, at high-rates, were less than the *total dose* in 2010 (Table 4.1).

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. There is a substantial terrestrial monitoring programme which includes the analyses of a comprehensive range of wild and locally produced foods. In addition, air, grass and soil are sampled to provide background information. The results of terrestrial food and air monitoring in 2010 are given in Tables 4.10(a) and (c). The concentrations of radionuclides in air, milk, crops and fruit were generally low and, where comparisons can be drawn, similar to concentrations in previous years. Additional monitoring for caesium-137 in pheasant samples was carried out to determine typical background concentration in the vicinity of the site. Measured concentrations of radioactivity in air at locations near to the site were below the LoD (Table 4.10(c)).

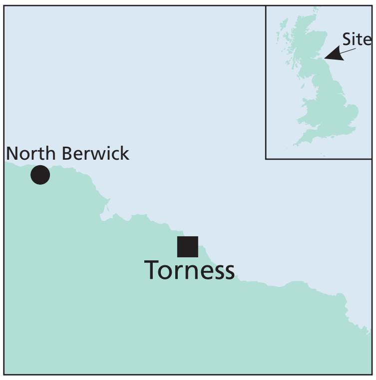
Liquid waste discharges and aquatic monitoring

Authorised liquid discharges are made to the Firth of Clyde by Hunterston B via the stations' cooling water outfall. Discharges from Hunterston B increased for sulphur-35 in comparison to 2009. Authorised liquid discharges from Hunterston A are also made via the same outfall. The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials.

A new modular active effluent treatment plant has been designed and installed at Hunterston A to provide improved treatment of effluent prior to discharge. Commissioning trials commenced during 2008, were continued in 2009 and 2010 before the plant's adoption into full operation service.

The results of aquatic monitoring in 2010 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 and lobsters around Hunterston were very low (at or below the LoD). The technetium-99 concentration in all crustacean samples were significantly decreased in 2010, and were the lowest values reported in recent years. Small concentrations of activation products (silver-110m and cobalt-60) that are likely to have originated from the site were also detected (in lobster and seaweed, respectively), but were of negligible radiological significance. Gamma dose rates were similar to those in 2009.

4.10 Torness, East Lothian



Torness Power Station is located near Dunbar on the east coast of Scotland. This station, which is powered by two AGRs, began operation at the end of 1987 and it is estimated that its power generation will end by 2023. Disposals and discharges of radioactive waste from the site are made in accordance with the Radioactive Substances Act authorisation issued to the site by SEPA in 2007. The liquid and gaseous discharges from the site are given in Appendix 2. The most recent habits survey was conducted in 2006 (Tipple *et al*., 2010).

During 2010, SEPA was involved in the determination of two applications made by British Energy Generation Limited for variations to the authorisation. The variations requested an additional disposal route for desiccant and an amendment to the low level waste repository route. These variations allowed greater flexibility and the ability to use the new services provided by LLWR, but did not did not change gaseous and liquid discharge limits. These variations were granted by SEPA early in 2011 (Scottish Environment Protection Agency, 2011).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to have been 0.025 mSv (Table 4.1), which is less than 3 per cent of the dose limit. Direct radiation was the dominant contributor to this dose, and the most exposed people were adults consuming local root vegetables. In 2009, the *total dose* was less at 0.022 mSv, and the most exposed people were prenatal children of local root vegetable consumers. The increase (and change in age group), was due to the inclusion of a positively detected americium-241 concentration in onions in 2010. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments of exposures for consumers of locally grown foods and consumers of fish and shellfish, at high-rates, were less than the *total dose* in 2010 (Table 4.1). The estimated dose to terrestrial food consumers was 0.014 mSv, which was approximately 1 per cent of the dose limit for members of the public of 1 mSv. The increase in dose from 0.005 mSv (in 2009), was due to the inclusion of a positively detected americium-241 concentration in onions in 2010. The dose to consumers of fish and shellfish was less than 0.005 mSv.

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops and fruit as well as grass and soil samples, were measured for a range of radionuclides. Due to supplier issues, goats' milk samples (which have been analysed in previous years), were not sampled in 2010. Air sampling at two locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2010 are given in Tables 4.11(a) and (c). As in 2009, the effects of discharges from the power station were not observed for concentrations of sulphur-35, which were below the LoD in terrestrial foods and environmental indicator materials. In 2010, americium-241 was positively detected in onions by gamma–ray spectrometry just above the LoD. Measured concentrations of radioactivity in air at locations near to the site were very low (Table 4.11(c)).

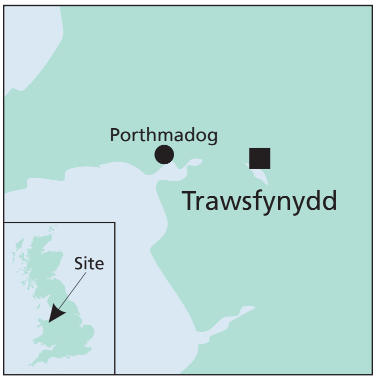
Liquid waste discharges and aquatic monitoring

Samples of seawater and Fucus vesiculosus, as useful environmental indicators, were collected in addition to seafood. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and beta dose rates on fishing gear.

The results of the aquatic monitoring in 2010 are shown in Tables 4.11(a) and (b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges and to weapon testing and Chernobyl fallout. As in recent years, a few very low concentrations of activation products were detected. These were likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in 2009. Beta radiation from fishermen's nets and pots was below the LoD. Gamma dose rates over intertidal areas were generally indistinguishable from natural background, although slightly higher rates were measured at Thornton Loch and Heckies Hole in 2010, in comparison to those measured in recent years.

WALES

4.11 Trawsfynydd, Gwynedd



Trawsfynydd Power Station is located in the heart of Snowdonia National Park, North Wales. At this establishment, there are twin Magnox reactors. Trawsfynydd ceased to generate electricity in 1991. Defuelling of the reactors was completed in 1995 and the station is being decommissioned. Monitoring is conducted on behalf of the Welsh Government. The most recent habits survey was undertaken in 2005 (Tipple *et al.*, 2006).

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.028 mSv in 2010 (Table 4.1), which was less than 3 per cent of the dose limit. The majority of this dose was direct radiation from the site, with a small contribution from locally produced milk. The increase in *total dose* from 0.017 mSv in 2009 was due to enhanced direct radiation in 2010. As in 2009, infants living near to the site were the most exposed people. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* remained broadly similar from year to year, and were low.

Source specific assessments of exposures for consumers of both locally grown foods and for anglers, at high-rates, were less than the *total dose* in 2010 (Table 4.1). The dose to anglers (who consume quantities of fish and spend long periods of time in the location being assessed) was 0.006 mSv in 2010, which was approximately 0.5 per cent of the dose limit for members of the public of 1 mSv. The observed concentrations in lake sediments are used as the basis for external radiation calculations in view of the difficulty in establishing the increase in measured dose rates above natural background levels. The decrease from the estimate of 0.011 mSv in 2009 was mostly due to decreased caesium-137 concentrations in rainbow trout in 2010.

Gaseous discharges and terrestrial monitoring

In 2010, the discharges of tritium, and carbon-14 (to a lesser extent), were increased in comparison to 2009. The results of the terrestrial programme, including those for local milk, crops and animal samples, are shown in Table 4.12(a). Concentrations of activity in all terrestrial foods were low. As in previous years, caesium-137 was detected in some of the terrestrial foods (blackberries and swede in 2010), at concentrations just above the LoD. The most likely source is fallout from Chernobyl and weapon tests, though it is conceivable that a small contribution may be made by resuspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also conducted in crop and animal samples. Detected activities were low and generally similar to observations in other areas of England and Wales, where activity was attributable to weapon test fallout. There was no evidence of resuspension of activity in sediment from the lake shore contributing to increased exposure from transuranic radionuclides in 2010.

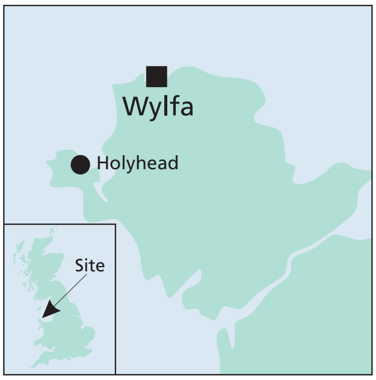
Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake making the power station unique in UK terms. In 2010, discharges of strontium-90 reduced to nil. The aquatic monitoring programme was directed at consumers of freshwater fish caught in the lake and external exposure over the lake shoreline; the important radionuclides are radiocaesium and, to a lesser extent, strontium-90. Freshwater and sediment samples are also analysed. Habits surveys have established that species of fish regularly consumed are brown and rainbow trout. Perch and most brown trout are indigenous to the lake but rainbow trout are introduced from a hatchery. Because of the limited period that they spend in the lake, introduced fish generally exhibit lower radiocaesium concentrations than indigenous fish.

Data for 2010 are given in Tables 4.12(a) and (b). Concentrations of radiocaesium in fish were generally similar to those in previous years; although concentrations of caesium-137 in rainbow trout reduced to levels prior to 2009 (local engineering works may have disturbed sub-surface sediment, releasing small amounts of activity into the lake water in 2009). The majority of activity concentrations in sediments, and in the fish, result from discharges from much earlier years. Concentrations in the water column are predominately maintained by processes that release activity (such as remobilisation) from near surface sediments. Low concentrations of other radionuclides including transuranics are also detected, particularly in lake sediments (in recent years' monitoring, it has been demonstrated that these increase with depth beneath the sediment surface). However, the transuranic concentrations in fish are very low and it is the effects of caesium-137 that dominate the fish consumption and external radiation pathways.

In the lake itself, there remains clear evidence for the effects of discharges from the power station. However, gamma dose rates found on the shoreline where anglers' fish were difficult to distinguish from background levels and were similar to those in earlier years. The predominant radionuclide is caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.3. A substantial decline in levels was observed in the late 1990s in line with reducing discharges. In the earlier part of the last decade, the observed concentrations were mainly affected by sample variability. In more recent years, with sustained reductions in discharges of caesium-137, there is now a suggestion of progressive decreases in these concentrations in sediments, with the lowest concentrations reported in 2010.

4.12 Wylfa, Isle of Anglesey



Wylfa Power Station is located on the north coast of Anglesey and generates electricity from two Magnox reactors. It was the last and largest power station of its type to be built in the UK and commenced electricity generation in 1971. Magnox North Limited has requested a short-term life extension (for a few additional years) to continue power generation at Wylfa beyond December 2010 (the date previously scheduled for the cessation of generating electricity). Environmental monitoring of the effects of discharges on the Irish Sea and the local environment is conducted on behalf of the Welsh Government. The most recent habits survey was undertaken in 2009 (Garrod *et al*., 2010).

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.007 mSv in 2010 (Table 4.1), which was less than 1 per cent of the dose limit. The most exposed people were local adults consuming marine plants and algea. The decrease in *total dose* from 0.011 mSv in 2009 was due to reduced direct radiation in 2010. The trend in *total dose* over the period 2004 – 2010 is given in Figure 4.2. *Total doses* remained broadly similar from year to year, and were low. Source specific assessments of exposures for both consumers of locally grown foods and for fish and shellfish, at high-rates, were less than the *total dose* in 2010 (Table 4.1). The dose to high-rate consumers of fish and shellfish was 0.009 mSv, which was less than 1 per cent of the dose limit for members of the public of 1 mSv.

Gaseous discharges and terrestrial monitoring

The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops and fruit. Data for 2010 are given in Table 4.13(a). Sulphur-35 was detected at very low concentrations in some of the food samples. Carbon-14 was detected in locally produced foods, but mostly at concentrations expected for background levels. Overall the effects of discharges are very low. Gross alpha and beta activities in surface water 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 fish, shellfish, sediment, seawater and measurements of gamma dose rates. The results of the programme in 2010 are given in Tables 4.13 (a) and (b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges. The concentrations were similar to those for 2009, and continued to show the effects of technetium-99 from Sellafield, albeit at lower concentrations than in previous years. Gamma dose rates, measured using portable instruments, were generally similar to those found in 2009.

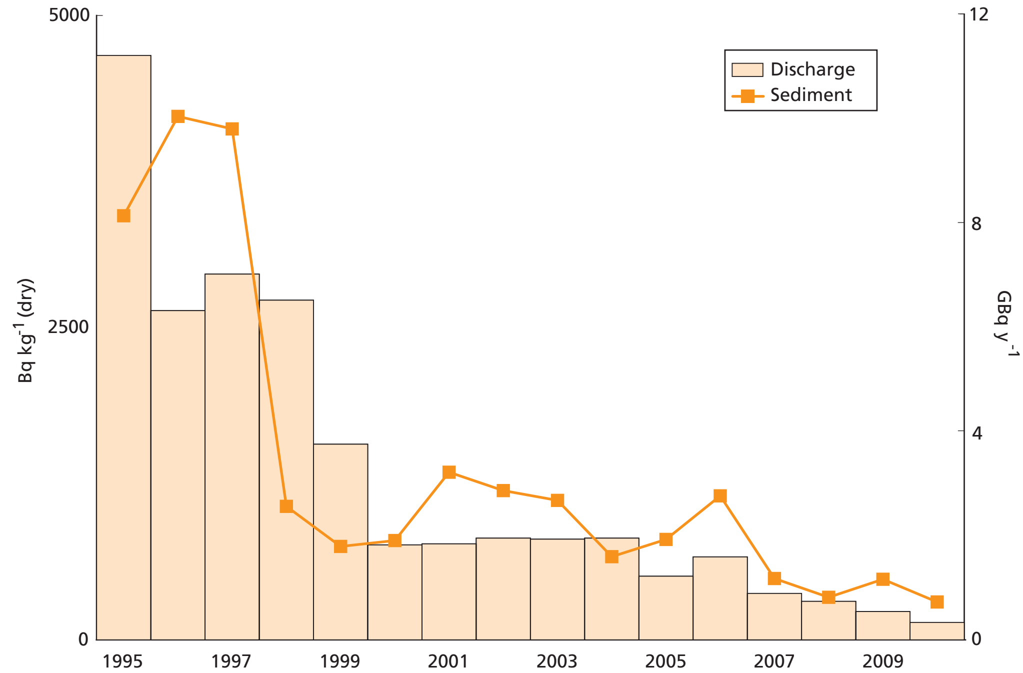


Figure 4.3. Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1995-2010

Table 4.1. Individual radiation exposures - nuclear power stations, 2010

Site	Exposed population[a]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, or the shoreline	Gaseous plume related pathways	Direct radiation from site
England							
Berkeley and Oldbury							
***Total dose* - all sources**	**Prenatal children of local inhabitants (0 - 0.25km)**	**0.011**	**-**	**<0.005**	**-**	**<0.005**	**0.010**
Source specific doses	Seafood consumers	0.012	<0.005	-	0.011	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005	-
Bradwell							
***Total dose* - all sources**	**Prenatal children of local inhabitants (0 - 0.25km)**	**0.13**	**-**	**<0.005**	**-**	**<0.005**	**0.13**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Prenatal children of inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Dungeness							
***Total dose* - all sources**	**Local adult inhabitants (0.5 - 1km)**	**0.022**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers	0.014	<0.005	-	0.012	-	-
	Houseboat occupants	0.015	-	-	0.015	-	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005	-
Hartlepool							
***Total dose* - all sources**	**Local adult inhabitants (0 - 0.25km)**	**0.025**	**-**	**-**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers[c]	0.008	<0.005	-	0.007	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005	-
	Sea coal collectors	0.007	-	-	0.007	-	-
Heysham							
***Total dose* - all sources**	**Adult occupants over sediment**	**0.057**	**<0.005**	**-**	**0.057**	**-**	**-**
Source specific doses	Seafood consumers	0.046	0.011	-	0.035	-	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005	-
Hinkley Point							
***Total dose* - all sources**	**Adult occupants over sediment**	**0.014**	**<0.005**	**<0.005**	**0.013**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers	0.020	<0.005	-	0.020	-	-
	Inhabitants and consumers of locally grown food[b]	0.005	-	<0.005	-	<0.005	-
	Local consumers of vegetables grown on land with seaweed added	0.007	-	0.007	-	-	-
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 consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	0.005	-	-	0.005	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005	-

Table 4.1. continued

Site	Exposed population[a]	Exposure, mSv per year					
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas, or the shoreline	Gaseous plume related pathways	Direct radiation from site
Scotland							
Chapelcross							
***Total dose* - all sources**	**Infant milk consumers**	**0.029**	**-**	**0.029**	**-**	**-**	**-**
Source specific doses	Salmon and wildfowl consumers	<0.005	<0.005	-	<0.005	-	-
	Crustacean consumers	<0.005	-	<0.005	-	-	-
	Inhabitants and consumers of locally grown food[b]	0.021	-	0.021	-	<0.005	-
Hunterston							
***Total dose* - all sources**	**Prenatal children of local inhabitants (0.25 - 0.5km)**	**0.067**	**-**	**<0.005**	**-**	**<0.005**	**0.066**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Inhabitants and consumers of locally grown food[b]	0.008	-	0.007	-	<0.005	-
Torness							
***Total dose* - all sources**	**Adult root vegetable consumers**	**0.025**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.020**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Inhabitants and consumers of locally grown food[b]	0.014	-	0.014	-	<0.005	-
Wales							
Trawsfynydd							
***Total dose* - all sources**	**Local inhabitants aged 1y (0.25 - 0.5km)**	**0.028**	**-**	**<0.005**	**-**	**<0.005**	**0.027**
Source specific doses	Anglers	0.006	<0.005	-	<0.005	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005	-
Wylfa							
Total dose - all sources	**Adult consumers of marine plants and algae**	**0.007**	**<0.005**	**<0.005**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.009	<0.005	-	0.006	-	-
	Inhabitants and consumers of locally grown food[b]	<0.005	-	<0.005	-	<0.005	-

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

[b] *Children aged 1y*

[c] *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, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu
Marine samples								
Salmon	Beachley	2	<25			<0.06	0.17	
Bass	River Severn	2	180			<0.06	1.7	
Elvers	River Severn	1	<25			<0.13	<0.12	
Shrimps	Guscar	1	190	40		<0.04	0.50	0.00064
Seaweed	Pipeline	2[E]			3.9	<0.81	<1.1	
Sediment	Hills Flats	2[E]					23	
Sediment	1 km south of Oldbury	2[E]				<0.79	25	
Sediment	2 km south west of Berkeley	2[E]				<0.62	25	
Sediment	Sharpness	2[E]					14	
Seawater	Local beach	2[E]				<0.23	<0.21	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Salmon	Beachley	2		<0.12				
Bass	River Severn	2		<0.10				
Elvers	River Severn	1		<0.09				
Shrimps	Guscar	1	0.0038	0.0035	*	0.000073		
Seaweed	Pipeline	2[E]		<0.83				
Sediment	Hills Flats	2[E]		<1.2				
Sediment	1 km south of Oldbury	2[E]		<1.2				
Sediment	2 km south west of Berkeley	2[E]		<1.3				
Sediment	Sharpness	2[E]		<0.71				
Seawater	Local beach	2[E]		<0.34			<3.4	10

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		8	<4.3	14	<0.32	<0.20		
Milk	max		<5.3	17	<0.53			
Apples		1	5.0	6.0	<0.20	<0.40		
Blackberries		1	<4.0	18	0.30	<0.20		
Cabbage		1	<4.0	4.0	1.7	<0.20		
Honey		1	8.0	59	<0.20	<0.20		
Onions		1	<4.0	6.0	0.40	<0.20		
Potatoes		1	<4.0	10	0.50	<0.20		
Runner beans		1	<4.0	<3.0	0.40	<0.20		
Wheat		1	<7.0	53	1.0	<0.20		
Freshwater	Gloucester and Sharpness Canal	2[E]	<3.0		<1.0	<0.45	<0.030	0.24
Freshwater	Public supply	2[E]	<3.0		<1.0	<0.27		

* *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, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
1 km south of Oldbury	Mud and salt marsh	2	0.085
2 km south west of Berkeley	Mud and stones	2	0.076
Guscar Rocks	Mud and salt marsh	2	0.086
Lydney Rocks	Mud	1	0.087
Lydney Rocks	Mud and salt marsh	1	0.087
Sharpness	Mud and salt marsh	2	0.080
Hills Flats	Mud and salt marsh	2	0.079

Table 4.3(a). Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$
Marine samples							
Sole	Bradwell	2			0.23		
Bass	Pipeline	1			0.77		
Thornback ray	Pipeline	1			0.46		
Lobsters	West Mersea	1			0.11		
Native oysters	Tollesbury N. Channel	1			0.14	0.00020	0.0012
Pacific oysters	Goldhanger Creek	2			<0.09		
Winkles	Pipeline	2			<0.11		
Winkles	Heybridge Basin	2			<0.14		
Seaweed	Bradwell	2^E		6.0	<0.44		
Leaf beet	Tollesbury	1			<0.02		
Samphire	Tollesbury	1			0.15		
Sediment	Pipeline	2^E	<1.1		6.3		
Sediment	Waterside	2^E	<1.0		12		
Sediment	West Mersea Beach Huts	2^E	<1.5		3.5		
Sediment	West Mersea Boatyard	2^E	<1.0		8.2		
Sediment	Maldon	2^E	<2.4		32		
Sediment	N side Blackwater Estuary	2^E	<2.5		11		
Seawater	Bradwell	2^E			<0.21		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples							
Sole	Bradwell	2	<0.18				
Bass	Pipeline	1	<0.03				
Thornback ray	Pipeline	1	<0.10				
Lobsters	West Mersea	1	<0.04				
Native oysters	Tollesbury N. Channel	1	0.0031	*	0.00010		
Pacific oysters	Goldhanger Creek	2	<0.05				
Winkles	Pipeline	2	<0.08				
Winkles	Heybridge Basin	2	<0.18				
Seaweed	Bradwell	2^E	<0.63				
Leaf beet	Tollesbury	1	<0.02				
Samphire	Tollesbury	1	<0.04				
Sediment	Pipeline	2^E	<1.4				
Sediment	Waterside	2^E	<1.5				
Sediment	West Mersea Beach Huts	2^E	<0.92				
Sediment	West Mersea Boatyard	2^E	<1.5				
Sediment	Maldon	2^E	<1.6				
Sediment	N side Blackwater Estuary	2^E	<1.6				
Seawater	Bradwell	2^E	<0.35			<3.5	12

Table 4.3(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		4	<4.2	15		<0.20		
Milk	max		<4.3					
Apples		1	5.0	8.0		<0.20		
Blackberries		1	<4.0	20		<0.20		
Cabbage		1	<4.0	3.0		<0.20		
Carrots		1	<5.0	<3.0		<0.20		
Lucerne		1	<5.0	10		<0.20		
Potatoes		1	<5.0	9.0		<0.20		
Rabbit		1	7.0	22		<0.20		
Wheat		1	<8.0	73		<0.20		
Freshwater	Public supply, both sides of Estuary	1[E]	<2.9		<1.0	<0.19	<0.050	0.33
Freshwater	Public supply, N side Estuary	1[E]	<4.0		<1.0	<0.21	<0.030	0.41
Freshwater	Coastal ditch 1	1[E]	<4.7		0.90	<0.22	<0.80	1.6
Freshwater	Coastal ditch 2	1[E]	<4.2		<1.0	<0.22	<0.50	4.1
Freshwater	Coastal ditch 3	1[E]	13		0.90	<0.21	<0.50	12
Freshwater	Coastal ditch 4	1[E]	7.9		0.90	<0.21	<0.50	8.7

* *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, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and sand	2	0.074
Beach opposite power station, N side of estuary	Mud	1	0.075
Beach opposite power station, N side of estuary	Mud and salt marsh	1	0.078
Waterside	Mud	1	0.068
Waterside	Mud and salt marsh	1	0.067
Maldon	Mud	2	0.072
West Mersea Beach Huts	Mud and sand	2	0.065
West Mersea	Mud and sand	2	0.061

Table 4.4(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Pipeline	2		<25		<0.05			0.25
Bass	Pipeline	1		<25		<0.06			0.28
Sole	Pipeline	2	<25	<25		<0.05			0.05
Crabs	Eastbourne / Folkestone landed	1				<0.07			<0.07
Shrimps	Pipeline	2	<25	<25	22	<0.07			<0.11
Scallops	Pipeline	2				<0.04	<0.030		0.04
Sea kale	Dungeness Beach	1				<0.04			0.12
Seaweed	Folkestone	2[E]				<0.47		3.1	<0.36
Sediment	Rye Harbour 1	2[E]				<1.4			<5.8
Sediment	Camber Sands	2[E]				<0.68			<0.56
Sediment	Pilot Sands	2[E]				<0.72			<0.56
Seawater	Dungeness South	2[E]		<15		<0.25			<0.22

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples									
Cod	Pipeline	2			<0.11				
Bass	Pipeline	1			<0.04				
Sole	Pipeline	2			<0.04				
Crabs	Eastbourne / Folkestone landed	1			<0.06				
Shrimps	Pipeline	2			<0.12				
Scallops	Pipeline	2	0.00056	0.0026	0.0014	*	0.000071		
Sea kale	Dungeness Beach	1			<0.03				
Seaweed	Folkestone	2[E]			<0.55				
Sediment	Rye Harbour 1	2[E]	<0.60	0.74	<1.5				700
Sediment	Camber Sands	2[E]			<0.88				
Sediment	Pilot Sands	2[E]			<0.79				
Seawater	Dungeness South	2[E]			<0.34			<4.0	15

Material	Location selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<4.3	14	<0.21	<0.18	<0.19		
Milk	max			15	<0.23	<0.20	<0.20		
Beans (dried)		1	<9.0	32	1.7	<0.20	<0.20		
Blackberries		1	<4.0	13	0.20	<0.20	<0.20		
Cauliflower		1	9.0	<3.0	0.30	<0.20	<0.20		
Potatoes		1	<5.0	15	0.50	<0.30	<0.20		
Sea kale		1	<4.0	12	1.5	<0.10	0.40		
Wheat		1	<8.0	75	1.8	<0.20	<0.20		
Grass		1				<0.10	<0.20		
Freshwater	Long Pits	2[E]	<2.9		<1.0	<0.24	<0.22	<0.070	0.23
Freshwater	Pumping station Well number 1	1[E]	<4.7		<1.0	<0.40	<0.34	<0.020	0.13
Freshwater	Pumping station Well number 2	1[E]	<3.0		<1.0	<0.26	<0.21	<0.030	0.13
Freshwater	Reservoir	1[E]	<4.0		<1.0	<0.30	<0.26	<0.020	0.20

* *Not detected by the method used*

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

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

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

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

Table 4.4(b). Monitoring of radiation dose rates near Dungeness nuclear power stations, 2010

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone-on-Sea	Sand and shingle	2	0.066
Greatstone-on-Sea	Sand	2	0.063
Dungeness East	Sand and shingle	2	0.066
Dungeness South	Sand and shingle	2	0.059
Jury's Gap	Sand and shingle	2	0.062
Rye Bay	Sand and shingle	2	0.059

Table 4.5 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I
Marine samples								
Plaice	Pipeline	2	<25	<25	19	<0.07		<0.64
Cod	Pipeline	2				<0.06		*
Crabs	Pipeline	2			32	<0.05		*
Winkles	South Gare	2	<25	<25		<0.04		<0.47
Mussels	South Gare	2				<0.04		<0.26
Mussels	Seal Sands	1			73			
Seaweed	Pilot Station	2[E]				<0.50	24	18
Sediment	Old Town Basin	2[E]				<0.82		
Sediment	Seaton Carew	2[E]				<0.76		
Sediment	Paddy's Hole	2[E]				<0.92		
Sediment	North Gare	2[E]				<0.77		
Sediment	Greatham Creek	2[E]				<1.1		
Sea coal	Old Town Basin	2[E]				<1.1		
Sea coal	Carr House Sands	2[E]				<1.1		
Seawater	North Gare	2[E]		<4.8		<0.25		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{137}Cs	^{210}Pb	^{210}Po	^{238}Pu	$^{239}Pu+^{240}Pu$
Marine samples							
Plaice	Pipeline	2	0.23				
Cod	Pipeline	2	0.35				
Crabs	Pipeline	2	<0.05			0.00029	0.0020
Winkles	South Gare	2	0.09	0.78	8.6	0.0031	0.023
Mussels	South Gare	2	<0.05				
Seaweed	Pilot Station	2[E]	<0.40				
Sediment	Old Town Basin	2[E]	1.6				
Sediment	Seaton Carew	2[E]	<0.63				
Sediment	Paddy's Hole	2[E]	5.0				
Sediment	North Gare	2[E]	<0.67				
Sediment	Greatham Creek	2[E]	2.7				
Sea coal	Old Town Basin	2[E]	<1.1				
Sea coal	Carr House Sands	2[E]	<1.4				
Seawater	North Gare	2[E]	<0.20				

Table 4.5 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Plaice	Pipeline	2	<0.19				
Cod	Pipeline	2	<0.17				
Crabs	Pipeline	2	0.0022	*	*		
Winkles	South Gare	2	0.015	*	0.000062		
Mussels	South Gare	2	<0.03				
Seaweed	Pilot Station	2[E]	<0.55				
Sediment	Old Town Basin	2[E]	<1.2				
Sediment	Seaton Carew	2[E]	<0.89				
Sediment	Paddy's Hole	2[E]	<1.4				
Sediment	North Gare	2[E]	<1.0				
Sediment	Greatham Creek	2[E]	<1.6				
Sea coal	Old Town Basin	2[E]	<1.2				
Sea coal	Carr House Sands	2[E]	<1.2				
Seawater	North Gare	2[E]	<0.30			<5.5	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		7	<4.3	13	<0.26	<0.19	<0.20		
Milk	max		<4.5	14	<0.35	<0.20			
Apples		1	<5.0	12	<0.20	<0.20	<0.20		
Beetroot		1	<5.0	<3.0	<0.20	<0.20	<0.20		
Blackberries		1	<4.0	11	<0.20	<0.20	<0.20		
Cabbage		1	<5.0	<3.0	0.40	<0.20	<0.30		
Honey		1	<7.0	65	<0.20	<0.10	<0.10		
Potatoes		1	<5.0	15	0.30	<0.20	<0.20		
Runner beans		1	<4.0	4.0	0.30	<0.30	<0.20		
Wheat		1	<9.0	72	1.2	<0.20	<0.20		
Freshwater	Public supply	2[E]	<3.0		<1.0	<0.25	<0.21	<0.11	0.16
Freshwater	Borehole, Dalton Piercy	2[E]	<3.0		<1.0	<0.25	<0.22	<0.14	<0.12

* *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, 2010

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand	1	0.068
Fish Sands	Pebbles and rock	1	0.066
Old Town Basin	Sand	2	0.072
Carr House	Sand and coal	2	0.067
Seaton Carew	Sand	1	0.059
Seaton Carew	Pebbles and sand	1	0.067
Seaton Sands	Sand	1	0.062
Seaton Sands	Pebbles and sand	1	0.071
North Gare	Sand	2	0.063
Paddy's Hole	Pebbles and stones	2	0.18
Greatham Creek Bird Hide	Mud	2	0.091

Table 4.6 (a). Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2010

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Marine samples									
Flounder	Flookburgh	4			92	<0.10			<0.93
Flounder	Morecambe	4	<25	32		<0.08	<0.029	0.86	<0.72
Whiting	Morecambe	4				<0.08			<0.68
Bass	Morecambe	2				<0.11			<1.0
Whitebait	Sunderland Point	1				<0.07	0.066		<0.73
Shrimps	Flookburgh	4			88	<0.09		0.61	<0.73
Shrimps	Morecambe	2				<0.06			<0.54
Cockles	Middleton Sands	2				<0.22			<0.92
Cockles[b]	Flookburgh	2			74	0.29	0.20	1.6	<0.55
Winkles	Red Nab Point	4				<0.14			<0.77
Mussels	Morecambe	4	60	66	76	<0.07		15	<0.58
Wild fowl	Morecambe	1				<0.06			<0.54
Samphire	Cockerham Marsh	1				<0.06			<0.59
Seaweed	Half Moon Bay	2[E]				<0.58		290	<3.4
Sediment	Half Moon Bay	2[E]				<0.82			
Sediment	Pott's Corner	2[E]				<0.92			
Sediment	Morecambe Central Pier	2[E]				<0.94			
Sediment	Red Nab Point	2[E]				<1.1			
Sediment	Sunderland Point	4[E]				<0.87			<6.1
Sediment	Conder Green	4[E]				<0.87			<6.0
Sediment	Sand Gate Marsh	4[E]				<0.86			<5.8
Seawater	Heysham Harbour	2[E]		<7.3		<0.33			<2.4

Material	Location	No. of sampling observ- ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{125}Sb	^{137}Cs	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu
Marine samples								
Flounder	Flookburgh	4	<0.26	10	<0.19	0.00025	0.0017	
Flounder	Morecambe	4	<0.20	6.9	<0.18			
Whiting	Morecambe	4	<0.19	6.4	<0.15			
Bass	Morecambe	2	<0.28	11	<0.26			
Whitebait	Sunderland Point	1	<0.21	4.6	<0.20	0.0028	0.17	0.65
Shrimps	Flookburgh	4	<0.20	4.9	<0.15	0.0036	0.021	<0.58
Shrimps	Morecambe	2	<0.14	3.6	<0.13			
Cockles	Middleton Sands	2	<0.20	2.0	<0.14	0.13	0.77	
Cockles[b]	Flookburgh	2	<0.14	2.8	<0.12	0.21	1.4	8.4
Winkles	Red Nab Point	4	<0.26	2.6	<0.20	0.17	1.1	
Mussels	Morecambe	4	<0.18	2.0	<0.12	0.21	1.2	
Wild fowl	Morecambe	1	<0.13	0.74	<0.10			
Samphire	Cockerham Marsh	1	<0.14	0.80	<0.13			
Seaweed	Half Moon Bay	2[E]	<1.9	3.3				
Sediment	Half Moon Bay	2[E]		44				
Sediment	Pott's Corner	2[E]		20				
Sediment	Morecambe Central Pier	2[E]		5.1				
Sediment	Red Nab Point	2[E]		21				
Sediment	Sunderland Point	4[E]	<3.4	81	<1.6			
Sediment	Conder Green	4[E]	<3.2	79	<1.5			
Sediment	Sand Gate Marsh	4[E]	<3.0	60	<1.3			
Seawater	Half Moon Bay	1		0.09				
Seawater	Heysham Harbour	2[E]		<0.27				

Table 4.6 (a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	$^{243}Cm + ^{244}Cm$	Gross alpha	Gross beta
Marine samples							
Flounder	Flookburgh	4	0.0030	*	*		
Flounder	Morecambe	4	<0.19				
Whiting	Morecambe	4	<0.13				
Bass	Morecambe	2	<0.28				
Whitebait	Sunderland Point	1	0.31	*	0.00032		
Shrimps	Flookburgh	4	0.040	*	*		
Shrimps	Morecambe	2	<0.13				
Cockles	Middleton Sands	2	2.5	*	*		
Cockles[b]	Flookburgh	2	4.8	*	0.0042		
Winkles	Red Nab Point	4	2.0	*	*		
Mussels	Morecambe	4	2.1	*	*		
Wild fowl	Morecambe	1	<0.06				
Samphire	Cockerham Marsh	1	0.42				33
Seaweed	Half Moon Bay	2[E]	<0.59				
Sediment	Half Moon Bay	2[E]	51				
Sediment	Pott's Corner	2[E]	12				
Sediment	Morecambe Central Pier	2[E]	<2.1				
Sediment	Red Nab Point	2[E]	23				
Sediment	Sunderland Point	4[E]	72			380	720
Sediment	Conder Green	4[E]	82			330	690
Sediment	Sand Gate Marsh	4[E]	51			190	650
Seawater	Heysham Harbour	2E	<0.33			<3.5	11

Material	Location or selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<4.6	15	<0.30	<0.18	<0.19		
Milk	max		<5.5	16	<0.38	<0.20	<0.20		
Apples		1	<5.0	8.0	<0.20	<0.20	<0.20		
Barley		1	<8.0	55	1.0	<0.20	0.30		
Beetroot		1	<5.0	<3.0	<0.20	<0.30	<0.30		
Blackberries		1	<5.0	10	<0.20	<0.10	<0.20		
Cabbage		1	<4.0	8.0	<0.30	<0.20	<0.20		
Honey		1	<8.0	65	0.20	<0.30	<0.20		
Potatoes		1	<5.0	12	<0.20	<0.20	<0.20		
Sprouts		1	<4.0	<3.0	1.9	<0.30	<0.30		
Freshwater	Lancaster	2[E]	<3.5		<1.0	<0.25	<0.21	<0.12	<0.11

* *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 *The concentration of ^{210}Po was 13 Bq kg^{-1}*

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

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

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

Table 4.6(b). Monitoring of radiation dose rates near Heysham nuclear power stations, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Greenodd Salt Marsh	Grass	2	0.085
Sand Gate Marsh	Grass	4	0.086
High Foulshaw	Grass and mud	2	0.084
High Foulshaw	Grass	2	0.086
Arnside 1	Mud	3	0.086
Arnside 1	Mud and sand	1	0.087
Arnside 2	Grass	4	0.098
Morecambe Central Pier	Sand	1	0.072
Morecambe Central Pier	Pebbles and sand	1	0.082
Half Moon Bay	Sand	1	0.079
Half Moon Bay	Sand and stones	1	0.089
Red Nab Point	Sand	2	0.088
Middleton Sands	Sand	2	0.079
Sunderland	Salt marsh	4	0.099
Sunderland Point	Mud	4	0.11
Colloway Marsh	Salt marsh	2	0.12
Colloway Marsh	Grass	2	0.14
Lancaster	Grass	4	0.085
Aldcliffe Marsh	Grass and mud	1	0.13
Aldcliffe Marsh	Grass and salt marsh	1	0.10
Aldcliffe Marsh	Grass	2	0.11
Conder Green	Mud	1	0.095
Conder Green	Grass and mud	2	0.088
Conder Green	Grass	1	0.095

Table 4.7(a). Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{134}Cs
Marine samples									
Cod	Stolford	1	28	26	22	<0.04			<0.04
Bass	Stolford	1	<25	<25	24	<0.06			<0.06
Shrimps	Stolford	2	110	120	38	<0.13			<0.13
Limpets	Stolford	1		44	18	<0.03			<0.03
Porphyra	Stolford	2				<0.08			<0.08
Seaweed	Pipeline	2[E]				<0.87		5.8	<0.69
Carrots[d]	Stolford	1			17	<0.09			<0.08
Potatoes[d]	Stolford	1			17	<0.12			<0.12
Soil[d]	Stolford	1			6.4	<0.28			<0.38
Mud	Watchet Harbour	2[E]				<0.81	<1.4		
Sediment	Pipeline	2[E]				<0.94	<2.5		
Sediment	Stolford	2[E]				<1.3	<1.6		
Sediment	Steart Flats	2[E]				<1.2	<1.5		
Sediment	River Parrett	2[E]				<1.3	<2.1		
Sediment	Weston-Super-Mare	2[E]				<0.75	<0.90		
Sediment	Burnham-On-Sea	2[E]				<0.70	<1.3		
Sediment	Kilve	2[E]				<1.2	<1.8		
Sediment	Blue Anchor Bay	2[E]				<0.61	<1.4		
Seawater	Pipeline	2[E]				<0.33	<0.045		<0.31

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples										
Cod	Stolford	1	0.31			<0.11				
Bass	Stolford	1	0.77			<0.16				
Shrimps	Stolford	2	0.20	0.00015	0.00080	0.00086	*	0.000037		
Limpets	Stolford	1	0.12			<0.03				
Porphyra	Stolford	2	0.60			<0.07				
Seaweed	Pipeline	2[E]	<1.0			<0.79				
Carrots[d]	Stolford	1	<0.07			<0.07				
Potatoes[d]	Stolford	1	<0.10			<0.23				
Soil[d]	Stolford	1	6.5			<1.0				
Mud	Watchet Harbour	2[E]	6.9			<1.1				
Sediment	Pipeline	2[E]	23			<1.3				
Sediment	Stolford	2[E]	22			<1.8				
Sediment	Steart Flats	2[E]	17			<1.6				
Sediment	River Parrett	2[E]	20			<1.7				
Sediment	Weston-Super-Mare	2[E]	10			<1.1				
Sediment	Burnham-On-Sea	2[E]	8.0			<0.92				
Sediment	Kilve	2[E]	19			<1.7				
Sediment	Blue Anchor Bay	2[E]	3.8			<0.93				
Seawater	Pipeline	2[E]	<0.27			<0.33			<2.5	14

Table 4.7(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		6	<4.3	16	<0.31	<0.17	<0.20		
Milk	max		<5.0	17	<0.38	<0.20			
Apples		1	<4.0	17	<0.10	<0.30	<0.20		
Blackberries		1	<5.0	17	0.50	<0.30	<0.30		
Carrots		1	<4.0	3.0	<0.20	<0.20	<0.20		
Honey		1	<8.0	61	0.30	<0.30	0.20		
Lettuce		1	<4.0	4.0	<0.20	<0.10	<0.20		
Potatoes		1	<4.0	16	0.30	<0.20	<0.20		
Runner beans		1	<4.0	<3.0	<0.10	<0.20	<0.30		
Wheat		1	<9.0	85	0.60	<0.20	<0.20		
Freshwater	Durleigh Reservoir	2[E]	<3.0		<1.0	<0.23	<0.20	<0.065	0.16
Freshwater	Ashford Reservoir	2[E]	<3.0		<1.0	<0.25	<0.21	<0.040	0.11

* *Not detected by the method used*
[a] *Except for milk and water where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *Used to determine sea to land transfer*
[E] *Measurements labelled "E" are made on behalf of the Environment Agency, all other measurements are made on behalf of the Food Standards Agency*

Table 4.7(b). Monitoring of radiation dose rates near Hinkley Point nuclear power stations, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-Super-Mare	Mud and sand	4	0.070
Burnham	Mud and sand	4	0.065
River Parrett	Mud and stones	3	0.075
River Parrett	Mud and rock	1	0.067
Steart Flats	Mud	4	0.079
Stolford	Mud	2	0.088
Stolford	Mud and rock	2	0.088
Hinkley Point	Mud and rock	2	0.095
Hinkley Point	Pebbles and sand	2	0.097
Kilve	Mud and rock	3	0.093
Kilve	Mud and pebbles	1	0.099
Watchet Harbour	Mud and sand	3	0.091
Watchet Harbour	Mud and pebbles	1	0.095
Blue Anchor Bay	Mud and sand	4	0.082

Table 4.8(a). Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu
Marine samples							
Cod	Sizewell	2	<25		0.26		
Sole	Sizewell	2	<25		0.14		
Crabs	Sizewell	2		35	0.07	0.00010	0.00079
Lobsters	Sizewell	1			0.30	0.000074	0.00051
Pacific oysters	Butley Creek	1			<0.08		
Pacific oysters	Blyth Estuary	1			<0.07		
Mussels	River Alde	2	<25		<0.04		
Sediment	Rifle range	2[E]			<0.36		
Sediment	Aldeburgh	2[E]			<0.49		
Sediment	Southwold	2[E]			4.7		
Seawater	Sizewell	2[E]	<2.9		<0.20		

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples							
Cod	Sizewell	2	<0.05				
Sole	Sizewell	2	<0.08				
Crabs	Sizewell	2	0.0013	*	*		
Lobsters	Sizewell	1	0.0019	*	0.000021		
Pacific oysters	Butley Creek	1	<0.06				
Pacific oysters	Blyth Estuary	1	<0.06				
Mussels	River Alde	2	<0.04				
Sediment	Rifle range	2[E]	<0.57				
Sediment	Aldeburgh	2[E]	<0.72				
Sediment	Southwold	2[E]	<1.2				930
Seawater	Sizewell	2[E]	<0.31			<3.0	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	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		6	<4.3	13	<0.23	<0.20		
Milk	max		<4.5	15	<0.33			
Apples		1	<4.0	12	<0.20	<0.20		
Blackberries		1	<4.0	14	0.20	<0.20		
Cabbage		1	<5.0	<3.0	<0.30	<0.20		
Honey		1	<6.0	80	<0.20	<0.20		
Onions		1	<5.0	3.0	0.30	<0.20		
Potatoes		1	<5.0	6.0	<0.20	<0.20		
Runner beans		1	<4.0	6.0	<0.20	<0.20		
Wheat		1	<7.0	75	3.1	<0.20		
Freshwater	Nature Reserve	2[E]	<3.0		<1.0	<0.20	<0.045	0.36
Freshwater	The Meare	2[E]	<3.5		<1.0	<0.26	<0.065	0.24
Freshwater	Leisure Park	2[E]	7.6		<1.0	<0.28	<0.040	0.24

* *Not detected by the method used.*

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

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

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

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

Table 4.8(b). Monitoring of radiation dose rates near Sizewell, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell Beach	Shingle	1	0.052
Sizewell Beach	Sand and shingle	1	0.051
Dunwich	Sand and shingle	1	0.055
Dunwich	Shingle	1	0.055
Rifle Range	Sand and shingle	1	0.058
Rifle Range	Shingle	1	0.056
Aldeburgh	Sand and shingle	2	0.054
Southwold Harbour	Mud	2	0.072

Table 4.9(a). Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{99}Tc
Marine samples									
Flounder	Inner Solway	1		30	<0.12	<0.30	<0.11		<0.28
Salmon	Inner Solway	1	12		<0.10	<0.18		<0.36	
Trout	Inner Solway	1			<0.10	<0.26		<0.29	
Shrimps	Inner Solway	2	<7.2		<0.10	<0.23	<0.11	<0.46	1.4
Cockles	North Solway	1			0.41	<0.10		<0.10	
Mussels	North Solway	4	<5.5	79	0.19	<0.13	0.50	<0.12	77
Winkles	Southerness	4	<5.0		<0.16	<0.14	0.12	<0.13	37
Fucus vesiculosus	Pipeline	4			<0.16	<0.15		<0.21	71
Fucus vesiculosus	Browhouses	4			0.21	<0.15		<0.33	
Sediment	Pipeline	4	<5.0		0.78	<0.28		<0.41	
Sediment	Powfoot	1			0.22	<0.31		<0.34	
Sediment	Redkirk	1			0.18	<0.27		<0.19	
Sediment	Southerness	1			0.16	<0.25		<0.30	
Seawater	Pipeline	4	<1.6		<0.10	<0.20		<0.32	
Seawater	Southerness	4	<6.2		<0.10	<0.18		<0.23	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{106}Ru	^{110m}Ag	^{125}Sb	^{134}Cs	^{137}Cs	^{154}Eu
Marine samples								
Flounder	Inner Solway	1	<1.1	<0.17	<0.29	<0.11	7.2	<0.14
Salmon	Inner Solway	1	<0.53	<0.10	<0.14	<0.10	0.18	<0.10
Trout	Inner Solway	1	<0.81	<0.10	<0.23	<0.10	0.31	<0.11
Shrimps	Inner Solway	2	<0.72	<0.12	<0.20	<0.10	3.4	<0.10
Cockles	North Solway	1	<0.18	<0.10	0.11	<0.10	2.8	<0.10
Mussels	North Solway	4	<0.37	<0.10	<0.19	<0.10	2.6	<0.10
Winkles	Southerness	4	<0.49	<0.11	<0.18	<0.10	1.2	<0.10
Fucus vesiculosus	Pipeline	4	<0.40	<0.10	<0.17	<0.10	7.0	<0.10
Fucus vesiculosus	Browhouses	4	<0.41	<0.10	<0.15	<0.10	11	<0.10
Sediment	Pipeline	4	<1.2	<0.13	0.95	<0.11	150	<0.40
Sediment	Powfoot	1	<0.87	<0.13	<0.31	<0.11	69	<0.19
Sediment	Redkirk	1	<0.70	<0.11	<0.24	<0.10	41	<0.15
Sediment	Southerness	1	<0.65	<0.11	0.39	<0.10	20	<0.16
Seawater	Pipeline	4	<0.54	<0.11	<0.18	<0.10	<0.17	<0.10
Seawater	Southerness	4	<0.56	<0.10	<0.17	<0.10	<0.13	<0.10

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples									
Flounder	Inner Solway	1	<0.26	<0.00050	0.0022		0.00088		
Salmon	Inner Solway	1	<0.16				<0.14		
Trout	Inner Solway	1	<0.21				<0.12		
Shrimps	Inner Solway	2	<0.18	0.0024	0.012		0.043		
Cockles	North Solway	1	<0.10				11		
Mussels	North Solway	4	<0.12	0.81	4.6	2.1	9.7		
Winkles	Southerness	4	<0.14	0.17	0.97		1.7		
Fucus vesiculosus	Pipeline	4	<0.26	0.39	2.3		<0.10	22	280
Fucus vesiculosus	Browhouses	4	0.33				9.3	34	270
Sediment	Pipeline	4	1.0	10	57		110		
Sediment	Powfoot	1	0.84	6.0	34		58		
Sediment	Redkirk	1	<0.29	2.3	13		21		
Sediment	Southerness	1	<0.44				21		
Seawater	Pipeline	4	<0.17				<0.11		
Seawater	Southerness	4	<0.16	0.00055	0.0033		0.0013		

Table 4.9(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial samples								
Milk		12	<5.9	<15	<0.53	<0.05	<0.10	<0.19
Milk	max		14	28	<0.63			<0.21
Apples		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Blackberries		1	<5.0	<15	<0.50	<0.09	0.22	<0.34
Cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Carrots		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Crab apples		1	<5.0	15	<0.50	<0.05	<0.10	<0.05
Goose		3	<5.0	29	<0.59	<0.09	<0.10	<0.19
Goose	max			30	<0.77	<0.12		<0.27
Leeks		1	<5.0	18	<0.50	<0.07	<0.10	<0.15
Mallard		1	<5.0	35	<0.75	<0.06	0.18	<0.20
Onions		1	<18	10	<0.50	<0.05	<0.10	<0.07
Potatoes		2	<5.0	<20	<0.50	<0.05	<0.10	<0.06
Potatoes	max			26				
Rosehips		1	<5.0	40	<0.50	<0.05	0.50	<0.06
Turnips		2	<5.0	<15	<0.50	<0.05	0.17	<0.09
Turnips	max							<0.13
Widgeon		1	<5.0	19	<0.50	<0.11	<0.10	<0.87
Grass		4	<9.2	<15	<0.69	<0.05	0.28	<0.05
Grass	max		22		1.0		0.55	<0.07
Peat	Creca Moss	1	16					
Sediment		4	62					
Sediment	max		110					
Soil		4	<5.7	<15	<1.3	<0.07	1.6	<0.22
Soil	max		7.6		<2.8	<0.10	2.3	<0.42
Freshwater	Purdomstone	1	<1.2					
Freshwater	Winterhope	1	<1.1					
Freshwater	Black Esk	1	<1.1					
Freshwater	Gullielands Burn	1	31					
Freshwater	Turbine Hall	1	450					
Rainwater	Creca	12	<7.8					
Rainwater	max		37					
Surface water	Location 1	1	<5.0					
Surface water	Location 2	1	120					
Surface water	Location 3	1	83					
Surface water	Location 4	1	45					
Surface water	Location 5	1	86					
Surface water	Location 6	1	30					
Surface water	Location 7	1	15					
Surface water		26	<47					
Surface water	max		210					

Table 4.9(a). continued

Material	Location or selection[b]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{106}Ru	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Terrestrial samples							
Milk		12	<0.34	<0.05	<0.06		
Milk	max		<0.36				
Apples		1	<0.26	<0.05	<0.08		
Blackberries		1	<0.76	<0.08	<0.11		
Cabbage		1	<0.18	<0.05	<0.07		
Carrots		1	<0.24	<0.05	<0.05		
Crab apples		1	<0.23	<0.05	<0.06		
Goose		3	<0.76	0.40	<0.13		
Goose	max		<1.1	0.90	<0.17		
Leeks		1	<0.56	<0.06	<0.09		
Mallard		1	<0.48	0.29	<0.12		
Onions		1	<0.43	<0.05	<0.07		
Potatoes		2	<0.25	<0.05	<0.07		
Potatoes	max		<0.35		<0.10		
Rosehips		1	<0.33	0.17	<0.09		
Turnips		2	<0.30	<0.05	<0.06		
Turnips	max		<0.42		<0.07		
Widgeon		1	<1.4	2.3	<0.20		
Grass		4	<0.24	<0.17	<0.09	4.6	280
Grass	max		<0.31	0.51	<0.12	5.4	430
Soil		4	<0.62	10	<0.45	200	1200
Soil	max		<0.91	13	0.75	220	1600
Freshwater	Purdomstone	1		<0.01		<0.010	0.063
Freshwater	Winterhope	1		<0.01		<0.010	0.042
Freshwater	Black Esk	1		<0.01		<0.010	0.015
Freshwater	Gullielands Burn	1		<0.01		<0.014	0.36
Freshwater	Turbine Hall	1		<0.10			

[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, 2010

Location	Material or Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Southerness	Winkle bed	4	0.061
Glencaple Harbour	Mud and sand	4	0.068
Priestside Bank	Salt marsh	4	<0.057
Powfoot Merse	Mud	4	0.061
Pipeline	Sand	4	0.079
Pipeline	Salt marsh	4	0.078
Dumbretton	NA	1	0.068
Battlehill	Sand	4	0.067
Dornoch Brow	Mud and sand	4	0.072
Dornoch Brow	Salt marsh	4	0.070
Browhouses	NA	4	0.069
Redkirk	NA	4	0.059
Mean beta dose rates			µSv h^{-1}
Pipeline 500m east	NA	4	<1.0
Pipeline 500m west	NA	4	<1.0
Pipeline	Stake nets	3	<1.0

NA *Not available*

Table 4.9(c). Radioactivity in air near Chapelcross, 2010

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.010	<0.0097	<0.19
Kirtlebridge	12	<0.010	<0.0087	<0.19
Brydekirk	11	<0.011	<0.013	<0.22

Table 4.10(a). Concentrations of radionuclides in food and the environment near Hunterston nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{125}Sb
Marine Samples								
Cod	Millport	2		<0.10	<0.10		<0.10	<0.11
Hake	Millport	1		<0.10	<0.10		<0.10	<0.12
Crabs	Millport	1		<0.10	<0.10	<0.12	<0.10	<0.19
Nephrops	Millport	2		<0.11	<0.10		<0.11	<0.18
Lobsters	Largs	1		<0.10	<0.10	1.0	0.10	<0.10
Squat lobsters	Largs	3		<0.11	<0.11	<0.18	<0.12	<0.19
Winkles	Pipeline	2		<0.12	<0.21		<0.16	<0.27
Scallops	Largs	4		<0.10	<0.10		<0.10	<0.15
Oysters	Hunterston	1		<0.10	<0.10		<0.10	<0.10
Fucus vesiculosus	N of pipeline	2		<0.14	0.40		<0.14	<0.25
Fucus vesiculosus	S of pipeline	2		<0.10	<0.11		<0.10	<0.16
Sediment	Millport	1		<0.10	<0.10		<0.10	<0.14
Sediment	Gull's Walk	1		<0.10	<0.10		<0.10	0.27
Sediment	Ardneil Bay	1		<0.10	<0.10		<0.10	<0.11
Sediment	Fairlie	1		<0.10	<0.10		<0.10	<0.10
Sediment	Pipeline	1		<0.10	<0.10		<0.10	0.21
Seawater	Pipeline	2	2.8	<0.10	<0.10		<0.10	<0.16
Seawater	S of pipeline	2	2.3	<0.10	<0.10		<0.10	<0.14

Material	Location	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
Marine Samples							
Cod	Millport	2	1.1	<0.12			<0.12
Hake	Millport	1	2.0	<0.14			<0.12
Crabs	Millport	1	0.22	<0.18	<0.010	<0.010	<0.010
Nephrops	Millport	2	0.86	<0.17			<0.16
Lobsters	Largs	1	0.28	<0.11			<0.10
Squat lobsters	Largs	3	0.85	<0.17	0.0019	0.018	0.035
Winkles	Pipeline	2	0.41	<0.24	<0.010	<0.010	<0.010
Scallops	Largs	4	0.23	<0.15	0.018	0.068	0.028
Oysters	Hunterston	1	0.33	<0.10			<0.10
Fucus vesiculosus	N of pipeline	2	1.2	<0.26			<0.73
Fucus vesiculosus	S of pipeline	2	0.56	<0.16			<0.11
Sediment	Millport	1	3.9	<0.21			0.23
Sediment	Gull's Walk	1	4.3	<0.22			0.55
Sediment	Ardneil Bay	1	2.1	<0.16			<0.16
Sediment	Fairlie	1	2.9	<0.17			0.27
Sediment	Pipeline	1	9.2	0.41			0.37
Seawater	Pipeline	2	<0.10	<0.16			<0.12
Seawater	S of pipeline	2	<0.10	<0.13			<0.10

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		5	<5.0	<15	<0.50	<0.05	<0.10	<0.16
Milk	max				<0.51			<0.24
Beef muscle		1	<5.0	25	<0.50	<0.05	<0.10	<0.05
Blackberries		1	<5.0	21	<0.50	<0.05	0.31	<0.05
Carrots		1	<5.0	<15	<0.50	<0.05	<0.10	<0.10
Crab apples		1	<5.0	26	<0.50	<0.05	0.13	<0.05
Eggs		1	<5.0	35	<0.50	<0.05	<0.10	<0.05
Honey		1	<5.0	99	<0.51	<0.16	<0.10	<0.41
Pheasant		4	<5.0	<30	<0.50	<0.05	<0.10	<0.06
Pheasant	max			43				<0.09
Pig muscle		1	<5.0	39	<0.50	<0.05	<0.10	<0.05
Potatoes		1	<5.0	19	<0.50	<0.05	<0.10	<0.13
Rosehips		1	<5.0	<15	<0.50	<0.05	1.1	<0.05
Rowan berries		1	<5.0	<15	<0.50	<0.05	0.10	<0.06
Turnips		2	<5.0	14	<0.50	<0.05	0.20	<0.05
Turnips	max						0.26	
Grass		3	<5.0	17	<0.50	<0.05	0.39	<0.07
Grass	max			21	<0.51		0.74	<0.08
Soil		3	<5.0	<15	<1.1	<0.07	1.1	<0.14
Soil	max				<1.5	<0.10		<0.23
Freshwater	Knockenden	1	<1.0					
Freshwater	Loch Ascog	1	<1.2					
Freshwater	Munnoch Reservoir	1	<1.2					
Freshwater	Camphill	1	<1.2					
Freshwater	Outerwards	1	<1.2					

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		5	<0.05	<0.05		<0.05		
Milk	max		<0.06	<0.06		<0.06		
Beef muscle		1	<0.05	0.14		<0.15		
Blackberries		1	<0.05	<0.05		<0.06		
Carrots		1	<0.05	<0.05		<0.06		
Crab apples		1	<0.05	<0.05		<0.09		
Eggs		1	<0.05	<0.05		<0.05		
Honey		1	<0.16	0.27		<0.21		
Pheasant		4	<0.05	0.41		<0.10		
Pheasant	max		<0.06	1.0		<0.12		
Pheasant[d]		3		0.22				
Pheasant[d]	max			0.24				
Pig muscle		1	<0.05	<0.05		<0.06		
Potatoes		1	<0.05	<0.05		<0.09		
Rosehips		1	<0.05	0.07		<0.09		
Rowan berries		1	<0.05	<0.05		<0.09		
Turnips		2	<0.05	<0.05		<0.08		
Turnips	max					<0.09		
Grass		3	<0.05	<0.20		<0.10	4.6	210
Grass	max			0.49		<0.11	6.5	260
Soil		3	<0.08	15	0.43	<0.20	140	680
Soil	max		<0.10	23		<0.27	170	890
Freshwater	Knockenden	1		<0.01			<0.010	0.038
Freshwater	Loch Ascog	1		<0.01			<0.011	0.10
Freshwater	Munnoch Reservoir	1		<0.01			<0.012	0.069
Freshwater	Camphill	1		<0.01			<0.010	0.022
Freshwater	Outerwards	1		<0.01			<0.010	0.019

[a] *Except for milk and water where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments*
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *Ad hoc monitoring to determine typical background caesium-137 in the vicinity of the site*

Table 4.10(b). Monitoring of radiation dose rates near Hunterston nuclear power station, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Largs Bay	Stones	2	0.059
Kilchatten Bay	Sand	2	0.053
Millport	Sand	2	<0.047
Gulls Walk	Mud	2	0.059
0.5 km north of pipeline	Sand	2	0.052
0.5 km south of pipeline	Sand and stones	2	0.064
Ardneil Bay	NA	2	<0.047
Ardrossan Bay	NA	2	<0.047
Milstonford	NA	2	0.051
Biglies	NA	2	0.051
Beta dose rates			μSv h^{-1}
Millport	Sand	1	<1.0
0.5 km north of pipeline	Sand	1	<1.0
0.5 km south of pipeline	Sand and stones	1	<1.0

NA *Not available*

Table 4.10(c). Radioactivity in air near Hunterston, 2010

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Fencebay	11	<0.010	<0.011	<0.18
West Kilbride	12	<0.010	<0.012	<0.18
Low Ballees	11	<0.011	<0.0085	<0.18

Table 4.11(a). Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{54}Mn	^{60}Co	^{95}Nb	^{99}Tc	^{110m}Ag
Marine Samples								
Cod	White Sands	2		<0.13	<0.12	<0.95		<0.14
Cod	Pipeline	1		<0.20	<0.17	<2.4		<0.20
Bass	Pipeline	1		<0.10	<0.10	<0.11		<0.10
Crabs[d]	Torness	1		<0.10	<0.10		5.4	<0.10
Lobsters	Torness	1		<0.10	<0.10	<0.11	6.2	<0.10
Nephrops	Dunbar	2		<0.10	<0.10	<0.17		<0.10
Winkles	Pipeline	2		<0.18	0.58	<0.69		5.6
Fucus vesiculosus	Pipeline	2		<0.32	0.88	<0.24		0.67
Fucus vesiculosus	Thornton Loch	2		<0.20	0.28	<0.60	46	<0.34
Fucus vesiculosus	White Sands	2		<0.10	<0.10	<0.32		<0.10
Fucus vesiculosus	Pease Bay	2		<0.10	<0.10	<0.13		<0.10
Fucus vesiculosus	Coldingham Bay	2		<0.10	<0.10	<0.19		<0.10
Sediment	Dunbar	1		<0.10	<0.10	<0.25		<0.15
Sediment	Barns Ness	1		<0.10	<0.10	<0.19		<0.10
Sediment	Thornton Loch	1		<0.10	<0.10	<0.13		<0.10
Sediment	Heckies Hole	1		<0.10	<0.10	<0.20		<0.10
Sediment	Belhaven Bay	1		<0.10	<0.10	<0.18		<0.11
Salt marsh	Coldingham Bay	1		<0.10	<0.10	<0.15		<0.10
Seawater	Pipeline	2	<4.1	<0.10	<0.10	<0.10		<0.10

Material	Location	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	Gross alpha	Gross beta
Marine Samples									
Cod	White Sands	2	0.34	<0.23			<0.15		
Cod	Pipeline	1	0.44	<0.32			<0.18		
Bass	Pipeline	1	0.48	<0.15			<0.10		
Crabs	Torness	1	0.13	<0.17			0.15		
Lobsters	Torness	1	<0.10	<0.18			<0.10		
Nephrops	Dunbar	2	<0.19	<0.13	0.0019	0.013	0.014		
Winkles	Pipeline	2	0.37	<0.39			<0.35	11	110
Fucus vesiculosus	Pipeline	2	0.18	<0.13			<0.10		
Fucus vesiculosus	Thornton Loch	2	<0.12	<0.16			<0.12		
Fucus vesiculosus	White Sands	2	<0.13	<0.16			<0.12		
Fucus vesiculosus	Pease Bay	2	<0.10	<0.10			<0.10		
Fucus vesiculosus	Coldingham Bay	2	<0.10	<0.13			<0.10		
Sediment	Dunbar	1	3.7	1.2			<0.38		
Sediment	Barns Ness	1	2.0	0.36			<0.31		
Sediment	Thornton Loch	1	0.85	<0.19			<0.18		
Sediment	Heckies Hole	1	5.5	0.77			<0.32		
Sediment	Belhaven Bay	1	1.7	0.78			<0.33		
Salt marsh	Coldingham Bay	1	0.92	0.36			<0.21		
Seawater	Pipeline	2	<0.10	<0.12			<0.10		

Table 4.11(a). continued

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb
Terrestrial Samples								
Milk		1	<5.0	<16	<0.51	<0.05	<0.10	<0.18
Beetroot		1	<5.0	<15	<0.50	<0.05	<0.10	<0.08
Blackberries		1	<5.0	<15	<0.50	<0.05	0.25	<0.05
Cauliflower		1	<5.0	19	<0.50	<0.05	<0.10	<0.05
Crab apples		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Onions		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Plums		1	<5.0	<15	<0.50	<0.05	<0.10	<0.05
Potatoes		2	<5.0	19	<0.50	<0.05	<0.10	<0.06
Potatoes	max			20				<0.07
Pumpkin		1	<5.0	<15	<0.50	<0.05	<0.10	<0.09
Rabbit		1	<5.0	42	<0.76	<0.32		1.7
Rhubarb		1	<5.0	<15	<0.50	<0.05	0.14	<0.07
Rosehips		1	<5.0	30	<0.50	<0.05	0.57	<0.07
Rowan berries		1	<5.0	30	<0.50	<0.05	0.17	<0.05
Wood pigeon		1	89	43	<0.50	<0.05	<0.10	<0.08
Grass		3	<5.0	40	<1.1	<0.05	0.48	<0.37
Grass	max			46	<2.2		0.80	<0.42
Soil		3	<5.5	<15	<2.7	<0.08	1.1	<1.3
Soil	max		<5.8		<3.0	<0.10	1.6	<1.8
Freshwater	Hopes Reservoir	1	<1.2					
Freshwater	Thorter's Reservoir	1	<1.2					
Freshwater	Whiteadder	1	<1.2					
Freshwater	Thornton Loch Burn	1	<1.0					

Material	Selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples								
Milk		1	<0.05	<0.05		<0.05		
Beetroot		1	<0.05	<0.05		<0.05		
Blackberries		1	<0.05	<0.05		<0.05		
Cauliflower		1	<0.05	<0.05		<0.05		
Crab apples		1	<0.05	<0.05		<0.05		
Onions		1	<0.05	<0.05		0.08		
Plums		1	<0.05	<0.05		<0.05		
Potatoes		2	<0.05	<0.05		<0.10		
Potatoes	max					<0.14		
Pumpkin		1	<0.05	<0.05		<0.06		
Rabbit		1	<0.30	<0.28		<0.33		
Rhubarb		1	<0.05	<0.05		<0.09		
Rosehips		1	<0.05	<0.05		<0.15		
Rowan berries		1	<0.05	<0.05		<0.05		
Wood pigeon		1	<0.05	0.14		<0.07		
Grass		3	<0.05	<0.05		<0.11	5.3	300
Grass	max					<0.12	6.0	360
Soil		3	<0.13	7.3	1.6	<0.31	290	1200
Soil	max		<0.17	12		<0.41	310	1400
Freshwater	Hopes Reservoir	1		<0.01			<0.010	<0.014
Freshwater	Thorter's Reservoir	1		<0.01			<0.010	<0.014
Freshwater	Whiteadder	1		<0.01			<0.010	<0.014
Freshwater	Thornton Loch Burn	1		<0.01			<0.011	0.15

[a] *Except for milk and water where units are Bq l^{-1} and for sediment and soil where dry concentrations apply*
[b] *Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima.*
If no 'max' value is given the mean value is the most appropriate for dose assessments
[c] *The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime*
[d] *The concentration of ^{14}C was 38 Bq kg^{-1}*

Table 4.11(b). Monitoring of radiation dose rates near Torness nuclear power station, 2010

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over intertidal areas			
Heckies Hole	Sediment	2	0.091
Dunbar Inner Harbour	Sand	2	0.089
Belhaven Bay	Salt marsh	2	0.065
Barns Ness	Mud, sand and stones	2	0.066
Skateraw	Sand	2	<0.055
Thornton Loch	Sand	2	0.068
Pease Bay	Sand	2	0.061
St Abbs Head	Mud	2	0.091
West Meikle Pinkerton	Sediment	2	0.068
Mean beta dose rates on fishing gear			µSv h^{-1}
Torness	Lobster Pots	2	<1.0
Dunbar Harbour	Nets	2	<1.0

Table 4.11(c). Radioactivity in air near Torness, 2010

Location	No. of sampling observa-tions	Mean radioactivity concentration, mBq m^{-3}		
		^{137}Cs	Gross alpha	Gross beta
Innerwick	11	<0.010	0.013	<0.17
Cockburnspath	12	<0.010	0.013	<0.17

Table 4.12(a). Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{35}S	^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{154}Eu
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6			<0.13	0.70	<0.13	39	<0.43
Rainbow trout	Trawsfynydd Lake	6			<0.09		<0.09	1.5	<0.29
Perch	Trawsfynydd Lake	6			<0.24	0.52	<0.24	57	<0.73
Pike	Trawsfynydd Lake	1			<0.11		<0.11	68	<0.34
Sediment	Lake shore	2[E]			<0.75	<3.0	<0.62	330	
Sediment	Bailey Bridge	2[E]			<1.8	15	<1.0	310	
Sediment	Fish farm	2[E]			<3.5	9.0	<0.93	730	
Sediment	Footbridge	2[E]			<0.99	<2.0	<1.0	33	
Sediment	Cae Adda	2[E]			<0.46	<2.0	<0.44	110	
Freshwater	Public supply	2[E]	<4.1	<1.0	<0.25		<0.23	<0.21	
Freshwater	Gwylan Stream	2[E]	<3.1	<1.0	<0.33		<0.31	<0.29	
Freshwater	Hot Lagoon	2[E]	<3.6	<1.0	<0.25		<0.25	<0.21	
Freshwater	Afon Prysor	2[E]	<3.1	<1.0	<0.25		<0.24	<0.21	
Freshwater	Trawsfynydd Lake	2[E]	<3.1	<1.0	<0.11		<0.10	<0.10	
Freshwater	Afon Tafarn-helyg	2[E]	<3.5	<1.0	<0.30		<0.28	<0.24	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples									
Brown trout[b]	Trawsfynydd Lake	6	0.00010	0.00035	0.00070	*	*		
Rainbow trout	Trawsfynydd Lake	6			<0.14				
Perch	Trawsfynydd Lake	6	0.000067	0.00017	0.00052	*	*		
Pike	Trawsfynydd Lake	1			<0.45				
Sediment	Lake shore	2[E]	<1.1	1.5	2.1				
Sediment	Bailey Bridge	2[E]	3.7	10	16				
Sediment	Fish farm	2[E]	4.1	11	21				
Sediment	Footbridge	2[E]	<1.4	<0.67	<1.9				
Sediment	Cae Adda	2[E]	<1.6	1.4	<1.2				
Freshwater	Public supply	2[E]						<0.060	<0.10
Freshwater	Gwylan Stream	2[E]						<0.020	<0.10
Freshwater	Hot Lagoon	2[E]						<0.030	<0.10
Freshwater	Afon Prysor	2[E]						<0.020	<0.10
Freshwater	Trawsfynydd Lake	2[E]						<0.045	<0.10
Freshwater	Afon Tafarn-helyg	2[E]						<0.040	<0.10

Table 4.12(a). continued

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs
Terrestrial Samples							
Milk		2	<4.3	13	<0.20	0.039	
Milk	max		<4.5			0.041	
Apples		1	10	7.0	<0.20		<0.30
Blackberries		1	<4.0	14	<0.20		0.30
Eggs		1	<5.0	33	<0.20		<0.20
Marrow		1	<4.0	<2.0	<0.20		<0.20
Runner beans		1	<4.0	<3.0	<0.10		<0.20
Sheep muscle		2	<5.5	18	<0.25	0.0095	
Sheep muscle	max		<6.0	19	<0.30	0.011	
Sheep offal		2	<12	<9.5	<0.20	0.41	
Sheep offal	max		16	10		0.46	
Swede		1	<5.0	<3.0	<0.10		0.20

Material	Selection[c]	No. of sampling observ-ations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial Samples						
Milk		2	0.11			
Milk	max		0.13			
Apples		1		<0.00010	<0.00010	0.00020
Blackberries		1		<0.00010	0.00020	0.00050
Eggs		1		0.00010	<0.00020	0.00060
Marrow		1				
Runner beans		1		<0.00010	0.00020	0.00030
Sheep muscle		2	1.8	<0.00015	0.00015	0.00015
Sheep muscle	max		2.6	0.00020	0.00020	0.00020
Sheep offal		2	0.74	<0.00010	0.00020	0.00020
Sheep offal	max		0.80	0.00010		
Swede		1		<0.00010	0.00010	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 37 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, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Footbridge	Grass and stones	1	0.094
Footbridge	Pebbles and stones	1	0.10
Lake shore	Pebbles and stones	2	0.099
Bailey Bridge	Grass and stones	1	0.069
Bailey Bridge	Grass and asphalt	1	0.079
Fish Farm	Stones	1	0.11
Fish Farm	Rock and stones	1	0.099
Cae Adda	Stones	1	0.096
Cae Adda	Pebbles and stones	1	0.084

Table 4.13(a). Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{125}Sb	^{137}Cs	^{238}Pu
Marine samples									
Plaice	Pipeline	2	<25	<28	45		<0.12	1.4	
Bass	Outfall	1					<0.09	3.4	
Crabs	Pipeline	2				0.88	<0.12	0.37	0.0031
Lobsters	Pipeline	2				21	<0.11	0.27	
Winkles	Cemaes Bay	2	<27	<25	39		<0.12	0.27	0.019
Seaweed	Cemaes Bay	2^{E}				39	<2.0	<0.44	
Sediment	Cemaes Bay	2^{E}						3.9	
Sediment	Cemlyn Bay West	2^{E}						3.1	
Seawater	Cemaes Bay	2^{E}		<2.9				<0.28	
Seawater	Cemlyn Bay West	2^{E}						<0.20	

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples									
Plaice	Pipeline	2			<0.14				
Bass	Outfall	1			<0.04				
Crabs	Pipeline	2	0.019		0.063	*	0.00015		
Lobsters	Pipeline	2			<0.14				110
Winkles	Cemaes Bay	2	0.11	<2.1	0.17	*	*		
Seaweed	Cemaes Bay	2^{E}			<0.65				
Sediment	Cemaes Bay	2^{E}			<1.2				
Sediment	Cemlyn Bay West	2^{E}			<1.6				
Seawater	Cemaes Bay	2^{E}			<0.38			<2.0	9.8
Seawater	Cemlyn Bay West	2^{E}			<0.31			<4.0	19

Table 4.13(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		5	<4.3	16	<0.38	<0.20		
Milk	max		<4.5	19	<0.48	<0.20		
Apples		1	10	9.0	<0.20	<0.20		
Barley		1	<9.0	74	1.4	<0.20		
Blackberries		1	<4.0	19	2.0	<0.20		
Broad beans		1	<5.0	<4.0	0.90	<0.20		
Cabbage		1	<5.0	<2.0	0.60	<0.20		
Honey		1	<7.0	48	<0.20	0.10		
Potatoes		1	7.0	6.0	0.20	<0.20		
Swede		1	<4.0	<3.0	0.60	<0.30		
Freshwater	Public supply	1[E]	<2.9		<1.0	<0.21	<0.060	0.21

* *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, 2010

Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	2	0.068
Cemlyn Bay West	Pebbles and sand	1	0.077
Cemlyn Bay West	Pebbles	1	0.072

5. Defence establishments

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

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

Key points

- Public radiation doses from all sources were less than 0.5 per cent of the dose limit at all those sites assessed
- Discharges, environmental concentrations and dose rates in 2010 were broadly similar to those in 2009 at all establishments

Aldermaston, Berkshire

- Gaseous discharges of carbon-14, and liquid discharges of tritium, decreased
- Discharges, concentrations and public dose rates in 2010 were broadly similar to those in 2009

Devonport, Devon

- Gaseous discharges of carbon-14, and all permitted liquid discharges, decreased
- Environmental concentrations of radionuclides were generally below the limits of detection

5.1 Aldermaston, Berkshire

The Atomic Weapons Establishment (AWE) at Aldermaston provides and maintains the fundamental components of the UK's nuclear deterrent (Trident). The site and facilities at Aldermaston remain in Government ownership under a Government Owned Contractor Operator (GOCO) arrangement. The day-to-day operations and the maintenance of Britain's nuclear stockpile are managed, on behalf of the MoD, by AWE plc. The site is regulated by the Environment Agency to discharge low concentrations of radioactive waste to the environment. The most recent habits survey was undertaken in 2002 (Tipple *et al.*, 2003),

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been less than 0.005 mSv in 2010 (Table 5.1), or less than 0.5 per cent of the dose limit. As in 2009, the most exposed people in this assessment were adults spending time on the local riverbank.

Source specific assessments of exposures for high- rates consumers of locally grown foods and locally harvested crayfish, and for anglers, were also less than 0.005 mSv in 2010 (Table 5.1). Estimates of activity concentrations in pike have been based on earlier data for dose determination, and for anglers the assessment has conservatively included consumption of fish at a low rate of 1 kg per year.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks on the site. In comparison to 2009, the carbon-14 releases decreased (to nil) and krypton-85 slightly increased. Furthermore, all discharges remained low in 2010. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the site (Figure 3.1). Activity concentrations in milk and foodstuffs (Table 5.2(a)) were generally below the limits of detection, as in 2009. The tritium concentrations in all samples were below the LoD (including grass) in 2010. These data (and gullypot data) are consistent with reduced discharges of gaseous tritium in recent years. In soil samples, where comparisons can be drawn at the same location, concentrations of caesium-137 were similar to values in 2009. Levels of uranium isotopes also remained similar to 2009. Natural background or weapon test fallout would have made a significant contribution to the levels detected.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made to the sewage works at Silchester (Figure 3.1), and to the

Aldermaston Stream. Discharges to Silchester remained at the low levels reported in 2009, albeit with increased discharges of alpha emitting radionuclides in 2010; the discharge of tritium to Aldermaston Stream was also low. There are two factors behind the longer-term decline in discharges of tritium from Aldermaston (Figure 5.1). These are the closure and decommissioning of the original tritium facility (the replacement facility uses sophisticated abatement technology that results in the discharge of significantly less tritium into the environment), and historical contamination of groundwater. The historical contamination has been reduced in recent years by radioactive decay and dilution by natural processes.

Activity concentrations for freshwater, fish and sediments samples, and measurements of dose rates, are given in Tables 5.2(a) and (b). The concentrations of artificial radioactivity detected in the Thames catchment were very low and similar to those for 2009. Concentrations of tritium in freshwater samples were below the LoD. No pike were sampled from the outfall in 2010. As in 2009, no enhancements of tritium (all below LoD) were observed in sediments collected from road gullypots close to the site. Caesium-137 concentrations were again detected in sediment from the River Thames, at similar concentrations to 2008. Currently, routine discharges from AWE do not include significant concentrations of radiocaesium and AWE no longer discharges into the River Thames since the closure of the Pangbourne pipeline in 2005. The presence of radiocaesium may be as a result of historical discharges or may be from other sources such as Harwell upstream on the Thames. Iodine-131 was positively detected at low concentrations in sediment, which were most likely to have originated from the therapeutic use of this radionuclide in a local hospital. Gamma dose rates on the riverbanks at Pangbourne and Mapledurham were similar to measurements in 2009. 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 Ltd (BAESM) builds, tests and commissions new nuclear powered submarines. During 2010, permitted discharges from Barrow continued to be very low or were below the LoD. The Food Standards Agency's monitoring is limited to grass sampling, and in 2010 tritium activity in these samples was below the LoD (Table 5.3(a)). Any significant effects of discharges from Barrow in the marine environment would be detected in the far-field monitoring of Sellafield (Section 2) and as such the aquatic programme for Barrow has been subsumed into the Sellafield programme. No such effects were found in 2010.

5.3 Derby, Derbyshire

Rolls-Royce Marine Power Operations Limited (RRMPOL), a subsidiary of Rolls-Royce plc, carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its two adjacent sites in Derby. Small discharges of liquid effluent are made via the Megaloughton Lane Sewage Treatment Works to the River Derwent and very low concentrations of alpha activity are present in releases to atmosphere. Other wastes are disposed of by transfer to other sites, including the LLWR near Drigg. The only habits survey undertaken at Derby was in 2009 (Elliott *et al*., 2010).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation (based on a limited amount of monitoring data with which to perform the assessment) was assessed to be less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. The most exposed people were infants consuming water extracted from the river. Although this pathway was not quantified during the 2009 habits survey, it has been included in the *total dose* assessment as river water is known to be extracted.

Source specific assessments of exposures for consumption of fish and drinking river water at high-rates, and for local residents exposed to external and inhalation pathways from gaseous discharges, were also less than 0.005 mSv in 2010 (Table 5.1). In 2010, a new assessment was undertaken, to determine the specific exposure for consumption of terrestrial food (based on very limited data, one food sample only), and this was determined to be much less than 0.005 mSv.

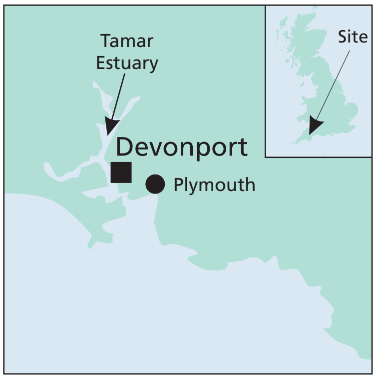
Results of the routine monitoring programme at Derby are given in Table 5.3(a). Analysis of uranium activity in grass and soil samples taken around the site in 2010 found levels broadly consistent with previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. Gross alpha and beta activities in water from the River Derwent were less than the WHO screening levels for drinking water, and the dose from using the river as a source of drinking water was much less than 0.005 mSv per year (Table 5.1).

Table 5.3(a) also includes analysis results from a water sample taken from Fritchley Brook, downstream of Hilts Quarry. RRMPOL formerly used the quarry for the controlled burial of

Figure 5.1. Trends in liquid discharges of tritium and plutonium-241 from Aldermaston, Berkshire 1990-2010 (including discharges to River Thames at Pangbourne, Silchester sewer and Aldermaston Stream)

solid low level radioactive waste. Uranium isotopes detected in the sample were similar to those levels elsewhere in Derbyshire (Table 8.14).

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. The most recent habits survey was carried out in 2004 (Tipple *et al.*, 2005). The routine monitoring programme in 2010 consisted of measurements of gamma dose rate and analysis of fruit, vegetables, fish, shellfish and other marine indicator materials (Tables 5.3(a) and (b)).

Doses to the public

In 2010, the *total dose* from all pathways and sources of radiation was assessed to be less than 0.005 mSv (Table 5.1), which is less than 0.5 per cent of the dose limit. Adults spending a long time over riverside sediments were the most exposed people but the radiological significance of this site continued to be low. Trends in *total doses* in the area of the south coast (and the Severn Estuary) are shown in Figure 6.5.

Source specific assessments of exposures for high-rate consumers of locally grown food and for fish and shellfish, and for occupants of houseboats, 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

Particulate beta/gamma, tritium, carbon-14 and argon-41 are permitted to be discharged to the atmosphere. The discharge of carbon-14 decreased significantly from 2009 because there was no Primary Circuit Decontamination of a Vanguard class submarine in 2010. Almost all of Devonport's elevated gaseous carbon-14 discharge in 2009 was from this process. Samples of fruit and vegetables were analysed for a number of radionuclides, and concentrations were below the limits of detection in all terrestrial foods.

Liquid waste discharges and marine monitoring

Discharges of all four permitted radionuclides to the Hamoaze decreased in 2010, subsequent to the submarine re-fit and other maintenance work carried out in 2009. Figure 5.2 shows the discharge history of tritium and cobalt-60 since 1990. The main contributor to the variations in tritium discharges over time has been the re-fitting of Vanguard class submarines. These submarines have a higher tritium inventory in their primary circuit as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. The underlying reason for the overall decrease in cobalt-60 discharges over this period was the improvement in submarine reactor design so that less cobalt-60 was produced during

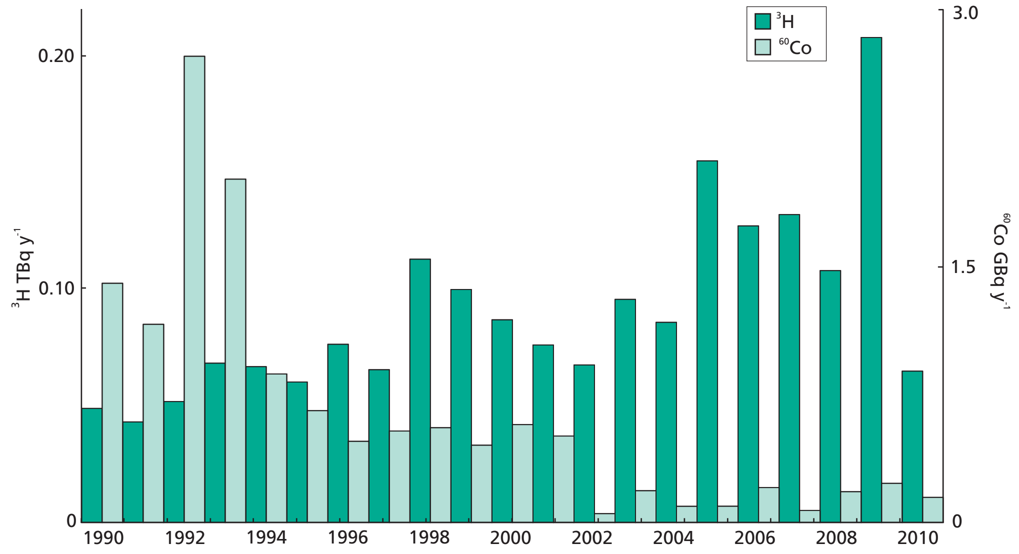
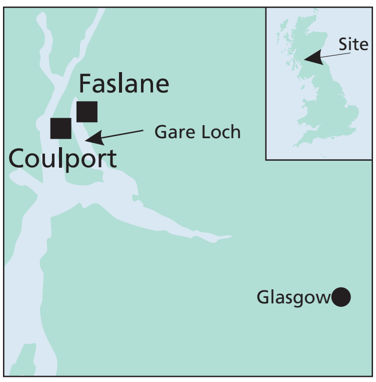


Figure 5.2. Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 1990-2010

operation, and therefore less was released during submarine maintenance operations. In marine samples, concentrations of tritium and cobalt-60 were below limits of detection. Trace amounts of caesium-137, likely to originate from Chernobyl and global weapons test fallout, were measured in fish samples. The seaweed samples contained very low concentrations of iodine-131 in 2010, which were most likely to have originated from the therapeutic use of this radionuclide in a local hospital. Gamma dose rates in the vicinity of Devonport were similar to 2009, although some small changes (at the same locations) were noted because rates were measured on different types of substrate from one year to the next.

5.5 Faslane and Coulport, Argyll and Bute



The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Marine, a subsidiary of Babcock International Group plc, operates HMNB Clyde in partnership with the MoD. However, the MoD remains in control of the undertaking, through the Naval Base Commander, Clyde, in relation to radioactive waste disposal.

Discharges of liquid radioactive waste into Gare Loch from Faslane and the discharge of gaseous radioactive waste in the form of tritium to the atmosphere from Coulport are made under letters of agreement between SEPA and the MoD. The discharges released during 2010 are shown in Appendix 2. The disposal of solid radioactive waste from each site is also made under letters of agreement between SEPA and the MoD. Disposals of solid waste from the sites continued during 2010.

At Faslane, works to remove the redundant plant from the recently upgraded effluent treatment facility were carried out in 2010. Work is ongoing to improve the civil structure of the facility building. In addition, the introduction of new sorting facilities for solid waste continued to significantly reduce the amount of solid low level radioactive waste generated on the site. There were no significant changes to operations or procedures at Coulport in relation to radioactive waste disposal.

The *total dose* from all pathways and sources of radiation was assessed to be less than 0.005 mSv in 2010 (Table 5.1). The most exposed people were adults spending time on the shores of the loch, but as in 2009 the dose was less than 0.5 per cent of the dose limit for members of the public. The source specific assessment of exposures for high-rate consumers of fish and shellfish (using seafood concentrations based on earlier data) was also less than 0.005 mSv. In 2010, a new assessment was undertaken, to determine the specific exposure for consumption of terrestrial food (based on very limited data, beef muscle only), and this was assessed to be much less than 0.005 mSv.

The routine monitoring programme consisted of the analysis of seawater, seaweed and sediment samples, and gamma dose rate measurements. Samples of non-migratory fish species were not available in 2010. Mollusc samples collected included the separate radioanalysis of mussel flesh and mussel shell (to assess the impact of utilising the latter as a fertiliser). The results are given in Tables 5.3(a) and (b) and were similar to those in 2009. Radionuclide concentrations were generally below the limits of detection, with caesium-137 concentrations in sediment consistent with the distant effects of discharges from Sellafield, and with weapons testing and Chernobyl fallout. Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background. The most recent habits survey was undertaken in 2006 (Sherlock *et al*., 2009).

5.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued during 2010 in order to determine the effects of past discharges from the US submarine support facilities which closed in 1992. Radionuclide concentrations were below detection limits (Table 5.3(a)). Gamma dose rate measurements from intertidal areas (Table 5.3(b)) showed elevated levels compared with previous years. The external radiation dose to people spending time on the loch shore was 0.007 mSv in 2010, which was less than 1 per cent of the dose limit for members of the public of 1 mSv (Table 5.1). The increase in dose, from less than 0.005 mSv in 2009, was due to increased dose rates at Kilmun Pier.

5.7 Rosyth, Fife

The site is operated by Babcock Marine, a division of Babcock International Group plc, who are responsible for the management of radioactive waste that was generated when the site supported the nuclear submarine fleet. Site decommissioning started in April 2006, and is expected to continue until 2013. To date, more than 99 per cent of the waste arising as a result of site decommissioning is being recycled.

Radioactive waste produced during decommissioning will be disposed of under the conditions of an authorisation granted to Rosyth Royal Dockyard Limited (RRDL) in November 2004. Operational wastes continue to be discharged under separate, continuing, authorisations for such wastes. RRDL has applied for authorisation to dispose of radioactive waste by transfer from RRDL to the processing facility in Sweden and an initial consignment was made in May 2009. Following volume reduction and the recovery of reusable metals, the radioactive waste will be returned to Rosyth for disposal by authorised routes. Radioactive waste from the initial consignment was returned to RRDL in March 2011.

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

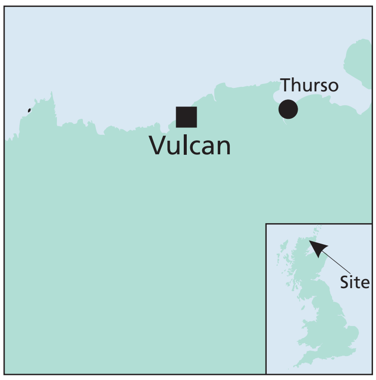
During July and August 2010, a habits survey was conducted to determine the consumption and occupancy rates by members of the public (Rumney *et al*., in press). Decreases in the fish, crustacean and mollusc consumption rates, together with occupancy rates, have been observed, in comparison with those of the previous survey in 2005. Revised figures for consumption rates, together with handling and occupancy rates, are provided in Appendix 1.

The *total dose* from all pathways and sources was assessed to be less than 0.005 mSv in 2010 (Table 5.1), which is less than 0.5 per cent of the dose limit. The most exposed people were adults spending time on shoreline sediments. The source specific assessment of exposures for local fishermen and beach users was also less than 0.005 mSv in 2010.

In 2010, authorised gaseous discharges from Rosyth were below the LoD. Liquid wastes are discharged via pipeline to the Firth of Forth. Tritium releases during 2010 were typical of the low levels discharged since 2000, and cobalt-60 discharges continued to decline. In all cases the activities in the liquid discharged were below authorised limits.

SEPA's routine monitoring programme included analysis of crabs and whelks, as well as environmental indicator materials, and measurements of gamma dose rates in intertidal areas. Results are shown in Tables 5.3(a) and (b). The radioactivity levels detected were at similar low levels to 2009, and in most part due to the combined effects of Sellafield, weapons testing and Chernobyl. Gamma dose rates were difficult to distinguish from natural background.

5.8 Vulcan NRTE, Highland



The Vulcan Nuclear Reactor Test Establishment operated by the MoD (Procurement Executive), acting as the test bed for prototype submarine nuclear reactors, is located adjacent to the DSRL Dounreay site and the impact of its discharges is considered along with those from Dounreay in Section 3.

Table 5.1. Individual radiation exposures - defence sites, 2010

Site	Exposed population[a,e]	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**	**Adult occupants over riverbank**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**
Source specific doses	Anglers[b]	<0.005	<0.005	-	<0.005	-	-
	Consumers of locally harvested crayfish[b]	<0.005	<0.005	-	-	-	-
	Consumers of locally grown food[d]	<0.005	-	<0.005	-	-	<0.005
Derby							
***Total dose* - all sources**	**Consumers of locally sourced water aged 1y**	**<0.005**	**-**	**-**	**<0.005**	**<0.005**	**-**
Source specific doses	Anglers consuming fish and drinking water[c]	<0.005	<0.005	-	-	<0.005	-
	Consumers of locally grown food[d]	<0.005	-	<0.005	-	-	<0.005
Devonport							
***Total dose* - all sources**	**Adult occupants over sediment**	**<0.005**	**-**	**-**	**<0.005**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-
	Prenatal children of consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005
Faslane							
***Total dose* - all sources**	**Adult occupants over sediment**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
Holy Loch							
Source specific doses	Anglers	0.007	-	-	0.007	-	-
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.
Adults are the most exposed group unless otherwise stated

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

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

[d] *Children aged 1y*

[e] *None of the people represented in this table were considered to receive direct radiation from the site*

Table 5.2(a). Concentrations of radionuclides in food and the environment near Aldermaston, 2010

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	Beckton	1		<25	<0.84	0.09			
Signal crayfish	Ufton Bridge - Theale	1	<25	<25	*	<0.04	0.029	0.00037	0.021
Sediment	Pangbourne	4[E]				2.8	13	<0.90	14
Sediment	Mapledurham	4[E]				11	9.7	<1.0	10
Sediment	Aldermaston	4[E]				<5.1	13	<0.95	13
Sediment	Spring Lane	4[E]				<1.2	11	<0.80	11
Sediment	Stream draining south	4[E]			26	2.0	18	<1.3	18
Sediment	Reading (Kennet)	4[E]				4.2	15	<1.3	13
Gullypot sediment	Falcon Gate	1[E]		<10		2.1	15	<1.1	14
Gullypot sediment	Main Gate	1[E]		<17		<0.94	15	<1.1	16
Gullypot sediment	Tadley Entrance	1[E]		<10		19	18	<1.4	22
Gullypot sediment	Burghfield Gate	1[E]		<8.4		<0.86	17	<1.2	17
Freshwater	Pangbourne	4[E]		<3.2		<0.24	<0.011	<0.0050	<0.011
Freshwater	Mapledurham	4[E]		<4.4		<0.22	0.012	<0.0050	0.0095
Freshwater	Aldermaston	4[E]		<5.0		<0.28	<0.013	<0.0050	<0.0070
Freshwater	Spring Lane	4[E]		<3.1		<0.23	<0.0055	<0.0050	<0.0053
Freshwater	Reading (Kennet)	4[E]		<3.2		<0.26	<0.0085	<0.0050	<0.0065
Crude liquid effluent	Silchester treatment works	4[E]		<11		<0.27	<0.012	<0.0095	<0.013
Final Liquid effluent	Silchester treatment works	4[E]		<18		<0.24	<0.014	<0.0050	<0.011
Sewage sludge	Silchester treatment works	4[E]		<13		<0.52	0.51	<0.035	0.45

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	Beckton	1			<0.04				
Signal crayfish	Ufton Bridge - Theale	1	0.000049	0.000073	0.000093	*	*		
Sediment	Pangbourne	4[E]	<0.54	<0.45	<2.3			310	<470
Sediment	Mapledurham	4[E]	<0.56	<0.56	<2.0			180	320
Sediment	Aldermaston	4[E]	<0.46	1.2	<1.5			170	520
Sediment	Spring Lane	4[E]	<0.54	<0.37	<1.5			<170	510
Sediment	Stream draining south	4[E]	<0.51	<0.60	<1.4			270	780
Sediment	Reading (Kennet)	4[E]	<0.54	<0.45	<1.3			140	490
Gullypot sediment	Falcon Gate	1[E]	<0.50	<0.30	<0.68			440	890
Gullypot sediment	Main Gate	1[E]	<0.40	0.74	<1.3			320	800
Gullypot sediment	Tadley Entrance	1[E]	<1.2	<1.0	<0.78			300	860
Gullypot sediment	Burghfield Gate	1[E]	<0.38	0.41	<1.2			260	680
Freshwater	Pangbourne	4[E]	<0.0093	<0.0053	<0.017			<0.060	0.24
Freshwater	Mapledurham	4[E]	<0.012	<0.0050	<0.013			<0.048	0.29
Freshwater	Aldermaston	4[E]	<0.0070	<0.0053	<0.013			<0.057	0.27
Freshwater	Spring Lane	4[E]	<0.0070	<0.0050	<0.017			<0.035	0.17
Freshwater	Reading (Kennet)	4[E]	<0.0093	<0.0058	<0.018			<0.050	0.11
Crude liquid effluent	Silchester treatment works	4[E]	<0.015	<0.0012	<0.36			<0.14	<0.71
Final Liquid effluent	Silchester treatment works	4[E]	<0.013	<0.0095	<0.36			<0.098	<0.61
Sewage sludge	Silchester treatment works	4[E]	<0.049	<0.045	<0.54			<6.2	<14

Table 5.2(a). continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U
Terrestrial samples							
Milk		4	<4.4	<0.19	<0.0012	<0.00073	<0.0012
Milk	max		<4.8	<0.20	<0.0018	<0.0011	<0.0016
Blackberries		1	<4.0	<0.20	0.0076	0.0011	0.0046
Broad beans		1	<6.0	<0.20	0.0015	0.00080	<0.00080
Cabbage		1	<5.0	<0.20	0.0024	0.00060	0.0016
Carrots		1	<5.0	<0.20	0.0054	<0.00070	0.0031
Honey		1	<7.0	<0.20	0.0031	0.00090	0.0019
Potatoes		1	<5.0	<0.20	0.0056	<0.0010	0.0015
Rabbit		1	<5.0	<0.20	0.014	0.00080	0.0054
Wheat		1	<7.0	<0.20	0.0016	<0.00080	0.0018
Grass	Kestrel Meads	1[E]	<14	<1.2	0.73	<0.20	0.88
Grass	Industrial Estate	1[E]	<7.3	<2.0	<0.80	<0.40	<0.80
Grass	Location 3	1[E]	<16	<2.0	<0.30	<0.20	<0.30
Grass	Tadley	1[E]	<25	<1.1	<0.20	<0.20	<0.20
Soil		1[#]			5.8	0.21	5.6
Soil	Kestrel Meads	1[E]	<5.9	2.8	14	<3.0	15
Soil	Industrial Estate	1[E]	<9.9	3.3	11	<4.0	11
Soil	Location 3	1[E]	<8.0	7.9	13	1.2	16
Soil	Tadley	1[E]	<8.0	5.4	15	<0.80	15

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Terrestrial samples							
Milk		4	<0.00011	<0.00013	<0.00011		
Milk	max		<0.00013	<0.00015	<0.00013		
Blackberries		1	<0.00010	0.00010	0.00020		
Broad beans		1	<0.00010	<0.00030	0.00020		
Cabbage		1	<0.00010	<0.00080	0.00090		
Carrots		1	<0.00010	<0.00020	0.00050		
Honey		1	<0.00010	<0.00010	0.00020		
Potatoes		1	<0.00010	<0.00020	0.00020		
Rabbit		1	<0.00010	<0.00020	<0.00020		
Wheat		1	<0.00010	<0.00020	0.00040		
Grass	Kestrel Meads	1[E]	<0.16	<0.078		15	170
Grass	Industrial Estate	1[E]	<0.29	<0.10		10	100
Grass	Location 3	1[E]	<0.20	<0.20		<3.0	160
Grass	Tadley	1[E]	0.32	0.65		<5.0	160
Soil	Kestrel Meads	1[E]	<0.50	<0.30		260	570
Soil	Industrial Estate	1[E]	<0.60	<0.50		280	430
Soil	Location 3	1[E]	<0.50	<0.60		240	460
Soil	Tadley	1[E]	<1.0	<1.0		310	740

* *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, 2010

Location	Ground type	No. of sampling observ-ations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass and mud	1	0.073
Pangbourne, riverbank	Grass	3	0.071
Mapledurham, riverbank	Mud	1	0.067
Mapledurham, riverbank	Grass and mud	3	0.068

Table 5.3(a). Concentrations of radionuclides in food and the environment near defence establishments, 2010

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	^{54}Mn	^{58}Co	^{60}Co	^{65}Zn	^{106}Ru	^{110m}Ag	^{125}Sb
Barrow												
Grass	Barrow	2[F]		<6.0								
Derby												
Parsnips		1[F]				<0.14	<0.28	<0.13	<0.35	<1.4	<0.24	<0.28
Sediment	River Derwent, upstream	1						<0.41				
Sediment	Station Road Bridge	1						<0.50				
Sediment	Fritchley Brook	1						<0.48				
Sediment	River Derwent, downstream	3						<0.94				
Water	River Derwent, upstream	1						<0.23				
Water	Station Road Bridge	1						<0.42				
Water[c]	Fritchley Brook	1		<2.9				<0.23				
Water	River Derwent, downstream	3						<0.34				
Devonport												
Ballan wrasse	Plymouth Sound	1[F]			36	<0.07	<0.13	<0.07	<0.20	<0.64	<0.13	<0.16
Corkwing wrasse	Plymouth Sound	1[F]			22	<0.06	<0.08	<0.07	<0.19	<0.56	<0.12	<0.13
Crabs	Plymouth Sound	2[F]			14	<0.08	<0.11	<0.08	<0.19	<0.83	<0.13	<0.19
Shrimps	Lynher Estuary	1[F]			35	<0.04	<0.06	<0.04	<0.12	<0.41	<0.08	<0.10
Cockles	Southdown	1[F]				<0.07	<0.11	<0.08	<0.17	<0.73	<0.12	<0.16
Pacific oysters	Southdown	1[F]				<0.03	<0.05	<0.03	<0.07	<0.29	<0.06	<0.08
Mussels	River Lynher	2[F]	<25	<25		<0.10	<0.16	<0.10	<0.23	<1.0	<0.17	<0.24
Seaweed[d]	Kinterbury	2						<0.58				
Sediment[e]	Kinterbury	2		<5.4				<0.97				
Sediment	Torpoint (South)	2		<5.0				<1.5				
Sediment	Lopwell	2		<6.5				<1.5				
Seawater	Torpoint (South)	2		<3.1	<7.2			<0.30				
Seawater	Millbrook Lake	2		<3.5	<5.0			<0.26				
Beetroot		1[F]		<4.0				<0.20		<1.4	<0.20	
Blackberries		1[F]		<5.0				<0.10		<1.3	<0.20	
Courgettes		1[F]		<5.0				<0.10		<1.5	<0.20	
Lettuce		1[F]		<4.0				<0.30		<1.5	<0.30	
Faslane												
Fucus vesiculosus	Rhu	1				<0.10	<0.22	<0.10	<0.29	<0.76	<0.12	<0.20
Mussel shells	Shandon	1				<0.11	<0.20	<0.10		<0.92	<0.11	<0.25
Mussels	Shandon	1				<0.10	<0.10	<0.10	<0.10	<0.14	<0.10	<0.10
Winkles	Garelochhead	1				<0.14	<0.31	<0.12	<0.39	<1.1	<0.14	<0.29
Sediment	Carnban boatyard	1				<0.10	<0.23	<0.10	<0.33	<0.78	<0.13	<0.22
Seawater	Carnban boatyard	2		<1.2		<0.10	<0.12	<0.10	<0.15	<0.42	<0.10	<0.14
Beef muscle	Faslane	1						<0.05		<0.29	<0.05	
Grass	Auchengaich	1						<0.05		<0.29	<0.05	
Soil	Auchengaich	1						<0.39		<4.5	<0.66	
Freshwater	Lochan Ghlas Laoigh	1		<1.2								
Freshwater	Helensburgh Reservoir	1		<1.2								
Freshwater	Loch Finlas	1		<1.2								
Freshwater	Auchengaich	1		<1.2								
Freshwater	Loch Eck	1		<1.2								
Freshwater	Loch Lomond	1		<1.2								
Holy Loch												
Sediment	Mid Loch	1				<0.10	<0.15	<0.10	<0.27	<0.58	<0.10	<0.14
Rosyth												
Crabs	East of dockyard	1				<0.10	<0.16	<0.10	<0.26	<0.87	<0.10	<0.24
Whelks	East of dockyard	1				<0.10	<0.16	<0.10	<0.16	<0.41	<0.10	<0.10
Fucus vesiculosus	East of dockyard	1				<0.10	<0.19	<0.10	<0.25	<0.68	<0.10	<0.18
Sediment	East of dockyard	1				<0.10	<0.11	<0.10	<0.22	<0.56	<0.10	<0.17
Sediment	Port Edgar	1				<0.10	<0.31	<0.12	<0.47	<1.1	<0.10	<0.30
Sediment	West of dockyard	1				<0.10	<0.10	<0.10	<0.20	<0.52	<0.10	<0.15
Sediment	East Ness Pier	1				<0.10	<0.10	<0.10	<0.20	<0.52	<0.10	<0.16
Sediment	Blackness Castle	1				<0.10	<0.16	<0.10	<0.25	<0.60	<0.10	<0.17
Sediment	Charlestown Pier	1				<0.10	<0.14	<0.10	<0.27	<0.67	<0.11	<0.19
Seawater	East of dockyard	2		<1.2		<0.10	<0.11	<0.10	<0.16	<0.54	<0.10	<0.16
Freshwater	Castlehill	1		<1.2								
Freshwater	Holl Reservoir	1		<1.2								
Freshwater	Gartmorn	1		<1.2								
Freshwater	Morton No. 2	1		<1.0								

Table 5.3(a). continued

Material	Location or selection[a]	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{131}I	^{134}Cs	^{137}Cs	^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Derby												
Parsnips		1[F]	*	<0.12	<0.11	<0.18				<0.09		
Sediment	River Derwent, upstream	1			2.8		19	<1.1	20		280	630
Sediment	Station Road Bridge	1			2.2		20	<2.0	20		370	710
Sediment	Fritchley Brook	1			0.91		15	<0.63	14		410	560
Sediment	River Derwent, downstream	3			3.0		41	<1.6	36		470	780
Grass		4[F]					0.096	0.0039	0.094			
Grass	max						0.17	0.0060	0.16			
Soil		4[F]					19	0.73	18			
Soil	max						21	0.87	21			
Water	River Derwent, upstream	1									<0.050	0.15
Water	Station Road Bridge	1									<0.040	0.16
Water[c]	Fritchley Brook	1			<0.19		0.019	<0.0050	0.014		<0.050	0.23
Water	River Derwent, downstream	3									<0.11	0.27
Devonport												
Ballan wrasse	Plymouth Sound	1[F]	*	<0.07	0.14	<0.16				<0.19		
Corkwing wrasse	Plymouth Sound	1[F]	*	<0.06	0.14	<0.10				<0.06		
Crabs	Plymouth Sound	2[F]	<0.66	<0.08	<0.09	<0.19				<0.17		
Shrimps	Lynher Estuary	1[F]	*	<0.04	<0.05	<0.08				<0.05		
Cockles	Southdown	1[F]	*	<0.08	<0.07	<0.12				<0.06		
Pacific oysters	Southdown	1[F]	*	<0.03	<0.03	<0.08				<0.08		
Mussels	River Lynher	2[F]	*	<0.10	<0.09	<0.19				<0.15		
Seaweed[d]	Kinterbury	2	20									
Sediment[e]	Kinterbury	2			3.6					<0.90		
Sediment	Torpoint (South)	2			3.1							
Sediment	Lopwell	2			7.8							
Beetroot		1[F]		<0.20	<0.20							
Blackberries		1[F]		<0.20	<0.20							
Courgettes		1[F]		<0.20	<0.20							
Lettuce		1[F]		<0.20	<0.30							
Faslane												
Fucus vesiculosus	Rhu	1		<0.10	0.69	<0.21				<0.13		
Mussel shells	Shandon	1		<0.10	<0.10	<0.23				<0.13		
Mussels	Shandon	1		<0.10	0.16	<0.10				<0.10		
Winkles	Garelochhead	1		<0.11	0.20	<0.22				<0.12		
Sediment	Carnban boatyard	1		<0.11	9.7	1.5				<0.26		
Seawater	Carnban boatyard	2		<0.10	<0.10	<0.14				<0.11		
Beef muscle	Faslane	1		<0.05	0.21					<0.09		
Grass	Auchengaich	1		<0.05	1.6					<0.08		
Soil	Auchengaich	1		<0.49	180					1.9		
Freshwater	Lochan Ghlas Laoigh	1			<0.01						<0.010	0.019
Freshwater	Helensburgh Reservoir	1			<0.01						<0.010	0.027
Freshwater	Loch Finlas	1			<0.01						<0.010	0.035
Freshwater	Auchengaich	1			<0.01						<0.010	0.032
Freshwater	Loch Eck	1			<0.01						<0.010	0.017
Freshwater	Loch Lomond	1			<0.01						<0.010	0.033
Holy Loch												
Sediment	Mid Loch	1		<0.10	6.8	0.78				0.69		
Rosyth												
Crabs	East of dockyard	1		<0.10	<0.10	<0.21				<0.12		
Whelks	East of dockyard	1		<0.10	<0.10	<0.11				<0.10		
Fucus vesiculosus	East of dockyard	1		<0.10	0.13	<0.19				<0.13		
Sediment	East of dockyard	1		<0.10	3.2	0.61				<0.28		
Sediment	Port Edgar	1		<0.14	11	1.2				<0.36		
Sediment	West of dockyard	1		<0.10	1.7	<0.18				<0.21		
Sediment	East Ness Pier	1		<0.10	6.5	<0.23				<0.19		
Sediment	Blackness Castle	1		<0.10	1.7	0.34				<0.22		
Sediment	Charlestown Pier	1		<0.10	1.0	<0.25				<0.25		
Seawater	East of dockyard	2		<0.10	<0.10	<0.16				<0.10		
Freshwater	Castlehill	1			<0.01						<0.010	0.024
Freshwater	Holl Reservoir	1			<0.01						<0.010	0.035
Freshwater	Gartmorn	1			<0.01						<0.010	0.13
Freshwater	Morton No. 2	1			<0.01						<0.012	0.068

* *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 <0.0050, 0.0060 and <0.0050 Bq l^{-1}*

[d] *The concentration of ^{99}Tc was 3.6 Bq kg^{-1}*

[e] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were <0.70 and 1.2 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, 2010

Establishment	Location	Ground type	No. of sampling observ-ations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Devonport	Torpoint South	Mud and stones	1	0.11
Devonport	Torpoint South	Rock and stones	1	0.10
Devonport	Kinterbury Access Gate	Mud and stones	1	0.088
Devonport	Kinterbury Access Gate	Rock and stones	1	0.097
Devonport	Lopwell	Mud	1	0.099
Devonport	Lopwell	Mud and salt marsh	1	0.092
Faslane	Gareloch Head	Mud, sand and stones	2	<0.047
Faslane	Gulley Bridge Pier	Sand and stones	2	0.051
Faslane	Rhu	Gravel	2	0.051
Faslane	Helensburgh	Sand	2	0.054
Faslane	Carnban boatyard	Gravel	2	0.066
Holy Loch	North Sandbank	Mud and sand	1	0.059
Holy Loch	Kilmun Pier	Sand and stones	1	0.072
Holy Loch	Mid-Loch	Sand	1	0.060
Rosyth	Blackness Castle	Mud and sand	2	0.056
Rosyth	Charlestown Pier	Sand	2	<0.047
Rosyth	East Ness Pier	Sand	2	0.050
Rosyth	East of Dockyard	Sand	2	0.050
Rosyth	Port Edgar	Mud	2	0.059
Rosyth	West of Dockyard	Mud and rock	2	<0.050

6. Radiochemical production

Key points

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire

- Public radiation doses from all sources were less than 22 per cent of the dose limit. The highest dose was due to direct radiation from the site
- Gaseous discharges of radon-222 decreased to the lowest value in recent years
- Concentrations of radioactivity in terrestrial and aquatic samples, and gamma dose rates, were low and similar to those in 2009

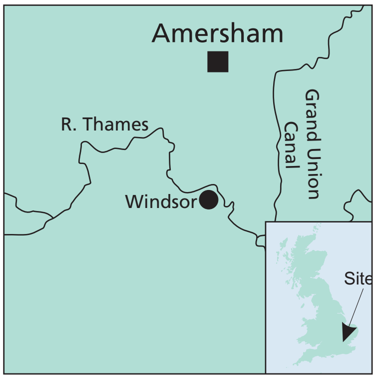
GE Healthcare Limited, Maynard Centre, Cardiff, South Glamorgan

- Public radiation doses from all sources were less than 1 per cent of the dose limit. The highest exposure was due to external radiation emitted from radionuclides in the sediment
- Quotient Bioresearch was issued with a permit to discharge radioactive wastes in April 2010
- Gaseous discharges of tritium, carbon-14 and phosphorous-32/33 decreased, and liquid discharges of tritium and carbon-14 decreased
- Tritium concentrations in fish and shellfish continued their long-term decline, with flounder concentrations below 1 kBq l^{-1}; carbon-14 concentrations also decreased

This section considers the results of monitoring by the Environment Agency and Food Standards Agency at two sites associated with the radiopharmaceutical industry. The sites, at Amersham and Cardiff, are operated by GE Healthcare. This is a health science company functioning in world-wide commercial healthcare and life science markets. GE Healthcare also administers an additional facility on the Harwell campus, and the environmental effects of these operations are covered by general monitoring of the Harwell site (Section 3).

Permits have been issued by the Environment Agency to each of the sites allowing the discharge of gaseous and liquid radioactive wastes (Appendix 2). Independent monitoring of the environment around the Amersham and Cardiff sites is conducted by the Food Standards Agency and the Environment Agency. The medium-term trends in discharges, environmental concentrations and dose at Amersham and Cardiff were considered in a recent summary report (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b).

6.1 Grove Centre, Amersham, Buckinghamshire



GE Healthcare's principal establishment is located in Amersham, Buckinghamshire. It consists of a wide range of plants for manufacturing diagnostic imaging products, using short half-life radionuclides such as fluorine-18 and technetium-99m, for use in medicine and research. The routine monitoring programme consists of analysis of fish, milk, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 3.1. The most recent habits survey was undertaken in 2009 (Clyne *et al*., 2010b).

Doses to the public

The *total dose* from all pathways and sources of radiation was assessed to have been 0.22 mSv, or 22 per cent of the dose limit (Table 6.1), and unchanged from 2009. This dose was primarily due to the relatively high level of direct radiation to local adult inhabitants at the site perimeter. Exposure from direct radiation varies around the boundary of the Grove Centre and therefore the *total dose* is determined as a cautious upper value. The trend in *total dose* over the period 2004 – 2010 is given in Figure 1.1. *Total doses* remained broadly similar with time and were dominated by direct radiation.

Source specific assessments of exposures for high-rate consumers of locally grown foods, for anglers, and for workers at Maple Lodges, were less than the *total dose* in 2010 (Table 6.1). The dose for high rate consumers of locally grown foods which includes a contribution from the gaseous plume related pathways was 0.012 mSv, or approximately 1 per cent of the dose limit to members of the public of 1 mSv. The decrease in dose, from 0.016 mSv in 2009, was primarily due to the reduction in atmospheric discharges of radon-222, although 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 2009 habits survey at Amersham did not directly identify any consumers of fish, shellfish or freshwater plants. As in previous surveys, however, there was anecdotal evidence of fish consumption, albeit occasional and at low rates. To allow for this, a consumption rate of 1 kg per year for fish has been included in the dose assessment for anglers.

The Grove Centre discharges liquid waste to Maple Lodge sewage treatment works, and the prolonged proximity to raw sewage and sludge experienced by sewage treatment workers is a common exposure pathway (National Dose Assessment Working Group, 2004). The dose received by these workers in 2009 was modelled using the methods described in Appendix 1. The dose from a combination of external exposure to contaminated raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides was less than 0.005 mSv.

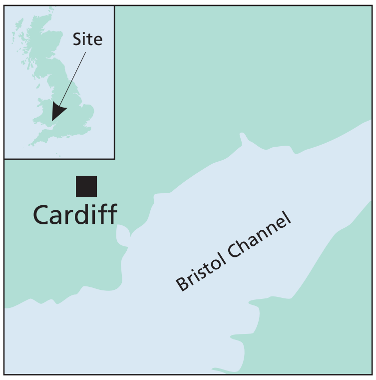
Gaseous discharges and terrestrial monitoring

The Amersham facility is permitted to discharge gaseous radioactive wastes via stacks on the site. In 2010, radon-222 discharges were reduced to the lowest value in recent years; other gaseous discharges were very similar to those in 2009. Activity concentrations in terrestrial samples were generally below the limits of detection (Table 6.2). Sulphur-35 was positively detected at low concentrations in some crop and grass samples in 2010. Caesium-137 activities were again detected in soil near the site, and this is likely to be due to global fallout from testing of weapons or from the Chernobyl accident.

Liquid waste discharges and aquatic monitoring

Radioactive liquid wastes are discharged to sewers serving the Maple Lodge sewage treatment works (STW); treated effluent subsequently enters the Grand Union Canal and the River Colne. The results of the aquatic monitoring programme are given in Table 6.2. Activity concentrations in freshwater, and effluent and sludge from Maple Lodge STW, were below, or near, the limits of detection. The sludge samples contained very low concentrations of iodine-131 in 2010, 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 sewage treatment works outfall is likely to be derived from weapons test fallout or the Chernobyl accident. Gross alpha and beta activities in water were below the WHO screening levels for drinking water. Gamma dose rates (given in footnote, Table 6.2) above the banks of the canal remained low, and are very similar to levels expected due to background radiation.

6.2 Maynard Centre, Cardiff



GE Healthcare operates a second establishment, on the Forest Farm industrial estate near Whitchurch, Cardiff. GE Healthcare ceased manufacturing a range of radiolabelled products containing tritium in late 2009 and products containing carbon-14 in April 2010. The site will be decommissioned and the bulk of the site will be de-licensed, leaving a small licensed area for storage of historic radioactive wastes. GE Healthcare's custom radiolabelling division has been acquired by Quotient Bioresearch, (a division of Quotient Bioscience) who will operate from different premises in Cardiff (purpose-built laboratory at Trident Park). Quotient Bioresearch was issued with a permit by the Environment Agency to discharge radioactive wastes, effective from 16 April 2010.

The Food Standards Agency and the Environment Agency conduct a routine monitoring programme on behalf of the Welsh Government. This includes sampling of locally produced food, fish and shellfish, and external dose rate measurements over muddy, intertidal areas (Figure 6.1). These are supported by analyses of intertidal sediment. Environmental materials including seawater, freshwater, seaweed, soil and grass provide additional information. The most recent habits survey was undertaken in 2003 (McTaggart *et al*., 2004).

Past monitoring data from Cardiff has been reviewed in order to compare the apparent enhancement of tritium concentrations on uptake by marine biota with bioaccumulation at other UK sites (Hunt *et al*., 2010). The observed enhancement factor at Cardiff remains at least an order of magnitude greater than at the other sites studied, although the organically bound fractions were uniformly high. Various earlier monitoring and research efforts have targeted organically bound tritium (OBT) in foodstuffs (Food Standards Agency, 2001b; Swift, 2001; Williams *et al*., 2001; Leonard *et al*., 2001 and McCubbin *et al*., 2001).

Doses to the public

In 2010, the *total dose* from all pathways and sources was assessed to have been 0.006 mSv (Table 6.1), or approximately 0.5 per cent of the dose limit. This dose estimates take into account the increased dose coefficients for OBT derived for discharges from the Maynard Centre and includes consideration of prenatal children. The dominant contribution to this exposure was the low levels of external radiation emitted from radionuclides in the sediment and mostly due to radioactive sources other than from the GE Healthcare site in Cardiff. The prenatal children of adults who spend time over intertidal sediments were the most exposed people. Tritium in fish contributed approximately 0.001 mSv to the *total dose*. Trends in *total doses* in the Severn Estuary (and areas of the south coast) are shown in Figure 6.5. 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. Most recently, the *total doses* have continued to decrease over time, and were low.

Source specific assessments of exposures for consumers of locally grown foods (that consumed crops grown in soil treated with sludge pellets), for recreational users of the River Taff, and for workers at Cardiff East Waste Water Treatment Works, were less than 0.006 mSv in 2010 (Table 6.1). The dose to consumers of locally grown foods and seafood, at high-rates, were 0.005 and 0.010 mSv, respectively. The dose from terrestrial food in 2009 was 0.008 mSv and the decrease was mostly due to lower carbon-14 concentrations in milk in 2010. The dose to seafood consumers in 2009 was 0.009 mSv, and the increase in 2010 resulted from an increase from gamma dose exposure.

The dose coefficients for OBT differ from those for tritiated water (see Appendix 1) and the estimates of dose to members of the public account for this. For ingestion of seafood caught near Cardiff, an area taken to be equivalent to the Bristol Channel, a dose coefficient based on a site-specific study of the consumption of fish caught in Cardiff Bay is used. A recent experimental study by Hunt *et al*. (2009) suggests that this raised dose coefficient is conservative, but it is retained for 2010 dose assessments on the advice of the HPA. For ingestion of other food, the ICRP dose coefficient for OBT is applied.

Gaseous discharges and terrestrial monitoring

The Maynard Centre discharges radioactivity to the atmosphere via stacks on the site. This is predominantly tritium and carbon-14, with smaller levels of phosphorus-32/33 and iodine-125 also released. Following the significant decrease of tritium discharges in 2009 (from 2008), further reductions in releases of tritium (mostly insoluble tritium) occurred in 2010. This resulted from the reduced commercial operations, in relation to the site's planned shutdown. Carbon-14 and phosphorous-32/33 discharges were also lower in 2010, compared to those in 2009.

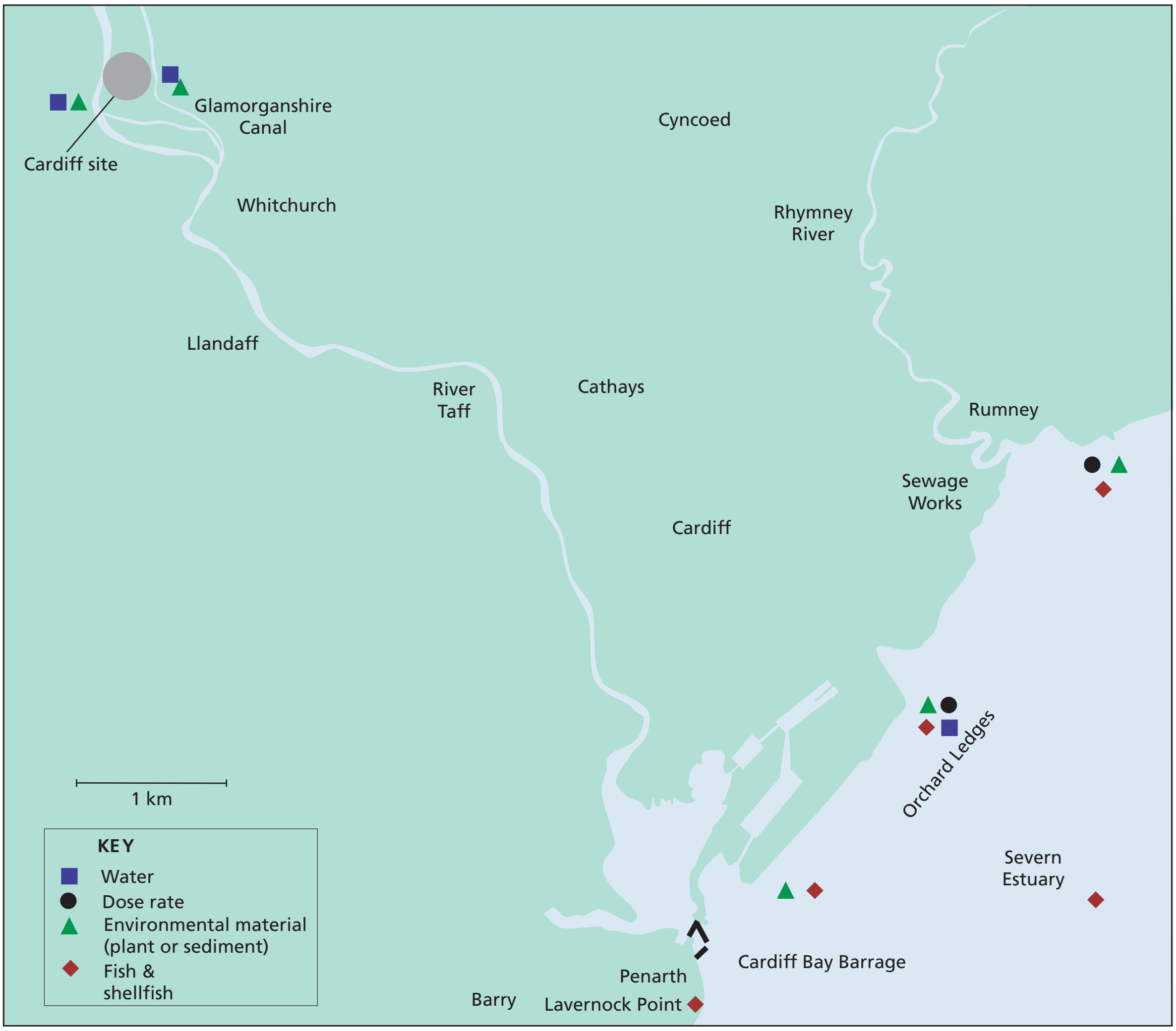


Figure 6.1. Monitoring locations at Cardiff, 2010 (not including farms)

The main focus of the terrestrial sampling was for the content of tritium, carbon-14 and sulphur-35 in milk, crops, freshwater, soil and grass. The Environment Agency also analysed samples of sewage products from the Cardiff East Waste Water Treatment Works (WWTW) for tritium and carbon-14. This enabled an assessment of exposure from eating crops grown on land fertilised with sludge pellets to be undertaken. The constraints of the Sludge (Use in Agriculture) Regulations (United Kingdom – Parliament, 1989) (commonly referred to as the Safe Sludge Matrix) require that crops cannot be harvested within 10 months of the application of sludge pellets. A recent Food Standards Agency research project (Ham *et al*., 2007) investigated the transfer of tritium from treated soil to crops, under the Safe Sludge Matrix conditions, and concluded that the transfer of tritium to each of the crops considered was small.

Enhanced tritium concentrations continued to be detected in terrestrial food samples (Table 6.3(a)), however, levels in 2010 were generally lower (where comparisons can be made), consistent with lower discharges in recent years. Similarly, and for the same reason, carbon-14 concentrations declined in some foodstuffs and in grass samples this year. Low concentrations of sulphur-35 and caesium-137 were detected in foods (similar to those in 2009); both these nuclides are not discharged by the site. Phosphorus-32 and iodine-125 were below the limits of detection in all terrestrial samples.

Samples of raw and treated sewage and associated products from Cardiff East WWTW were analysed for tritium and carbon-14 in 2010. The results (Table 6.3(a)) show enhanced concentrations of tritium in sludge pellets.

Relatively low levels of tritium continue to be detected in sediment and freshwater from the Glamorganshire Canal; however, this is not used as a source of water for the public water supply. The recent trend in sediment concentrations from the marine and freshwater environments are shown in Figure 6.4. The overall decline echoes that of tritium discharges, although the decline in marine levels (east/west of the pipeline) is less pronounced than in the canal sediments over the whole time period. In 2010, tritium was also detected at low concentrations from site run-off water into the River Taff.

Liquid waste discharges and aquatic monitoring

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

The bulk of the radioactivity discharged to the YP sewer is tritium and carbon-14. The amount of tritium released to the sewer in 2010 was decreased in comparison to discharges in 2009. Over the longer term the discharge rate of this nuclide has decreased substantially (Figure 6.2). Carbon-14 discharges also decreased in 2010, continuing its recent and long-term downward trend (Figure 6.3).

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 2010 are given in Tables 6.3(a) and (b). The effects of liquid discharges remain evident in enhanced tritium and carbon-14 concentrations in fish samples. Further analysis of these samples shows that a high proportion of the tritium was still associated with organic matter, a situation that has been observed since the late 1990s (McCubbin *et al*., 2001; Leonard *et al*., 2001; Williams *et al*., 2001). The tritium is strongly bound to organic matter and has the potential to transfer through the marine food chain from small organisms to accumulate in fish. In 2010, tritium concentrations in flounder, mullet and dogfish decreased significantly, whilst other fish species were generally similar, as compared with levels of their respective species in 2009. Moreover, the tritium concentrations reported in flounder were the lowest values in over a decade and below the 1 kBq l^{-1} level for the first time over this period. The continued overall decline in tritium concentrations in fish from the Cardiff area is likely to be a direct response to the decreasing inputs from the Maynard Centre, as well as a shift in the composition of this discharge away from organically bound compounds. However, the annual uncertainty and variation in certain species suggests that complex indirect uptake mechanisms continue to affect tritium concentrations in the region.

No mussel samples were collected from Cardiff in 2010 due to the scarcity of the available species, leaving limpets as the only mollusc sample. Figure 6.2 indicates that the overall tritium concentrations in mollusc samples have decreased significantly over the last decade. Tritium was also detected in marine sediment samples at similar levels to those in 2009. The mean concentration of carbon-14 in both fish and molluscs showed a decrease consistent with the reduction in discharges in 2009. The longer term trend in concentrations and the relationship to discharges is shown in Figure 6.3. Concentrations of caesium-137 in marine samples remain low and can largely be explained by other sources such as Chernobyl, weapon test fallout and discharges from other establishments such as the Hinkley Point, Berkeley and Oldbury nuclear sites. Where directly comparable, gamma dose rates over sediment were slightly higher than 2009 levels, and are not in the main attributable to discharges from the Maynard Centre.

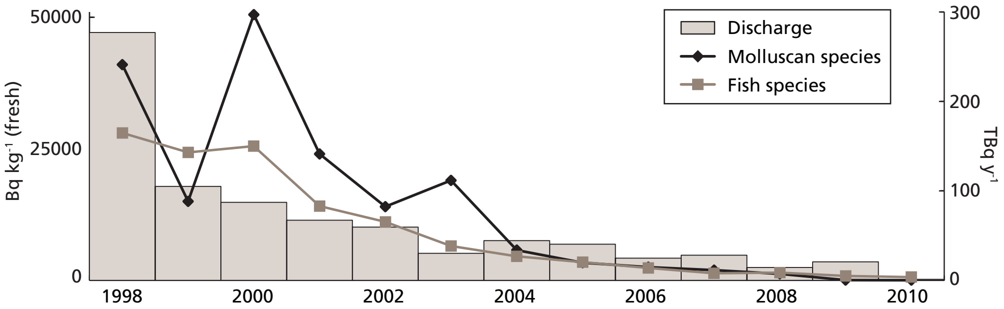


Figure 6.2. Tritium liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2010 (species include all those reported in RIFE for the given year)

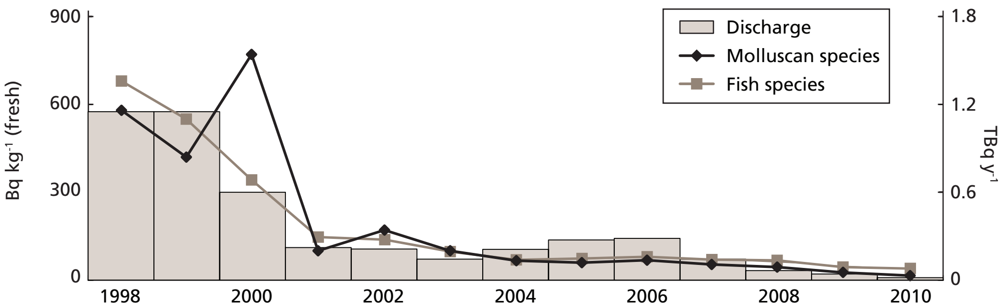


Figure 6.3. Carbon-14 liquid discharge from Cardiff and mean concentrations in fish and molluscs near Cardiff, 1998-2010 (species include all those reported in RIFE for the given year)

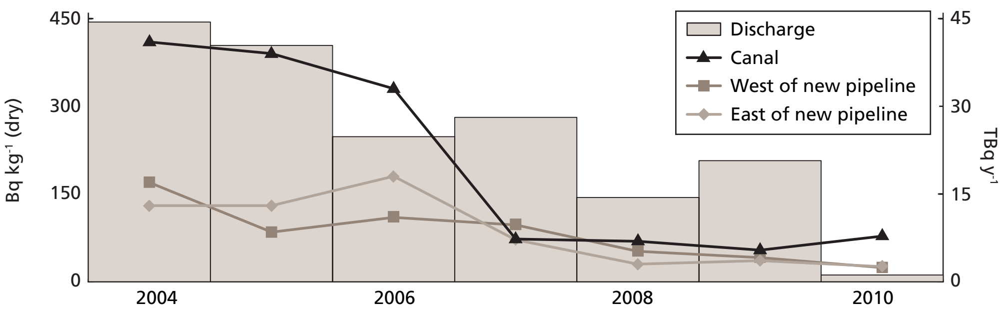


Figure 6.4. Tritium liquid discharge from Cardiff and mean concentrations in sediment near Cardiff, 2004-2010

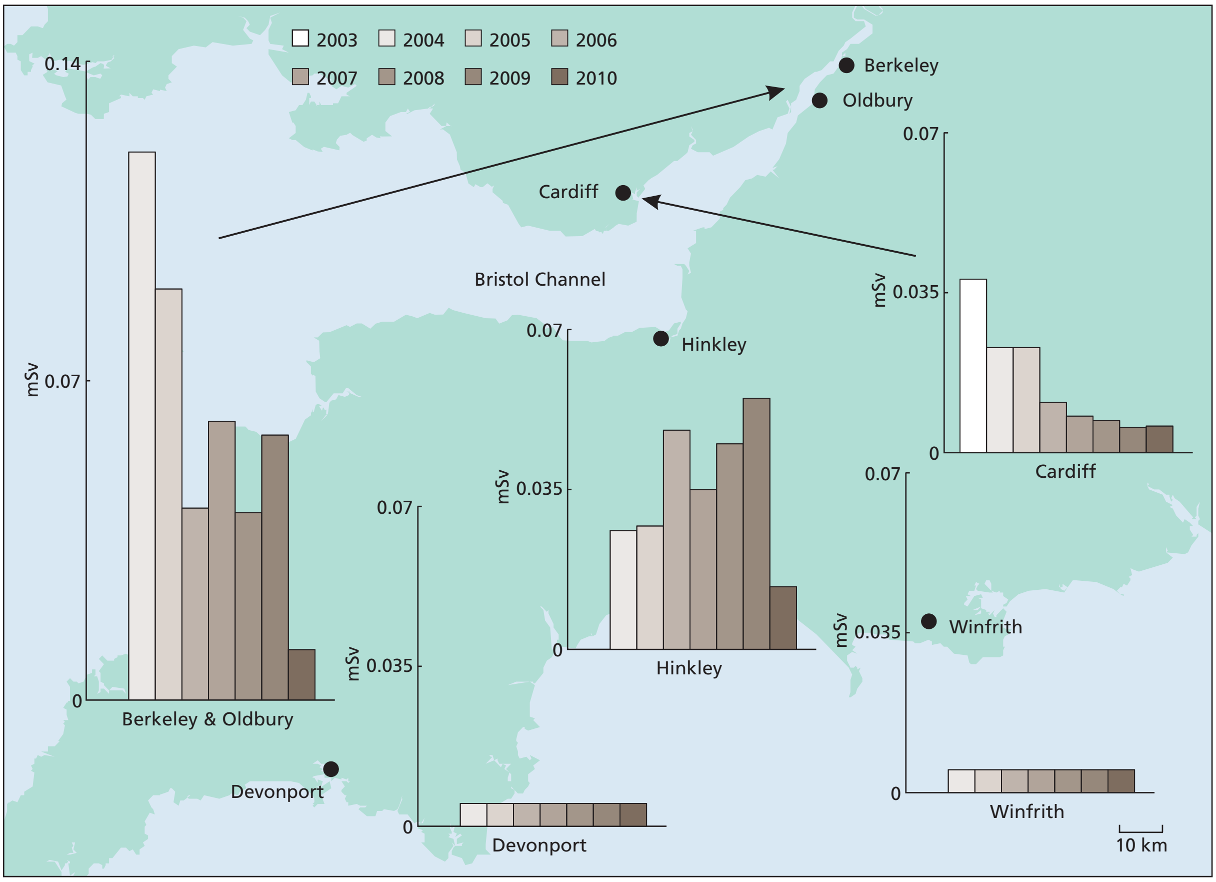


Figure 6.5. *Total dose* for major sites in the Severn Estuary and south coast, 2003-2010

Table 6.1. Individual radiation exposures - radiochemical sites, 2010

Site	Exposed population[a]	Exposure, mSv per year						
		Total	Fish and Shellfish	Other local food	External radiation from intertidal areas or river banks	Intakes of sediment or water	Gaseous plume related pathways	Direct radiation from site
Amersham								
***Total dose* - all sources**	**Local adult inhabitants (0 - 0.25km)**	**0.22**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.22**
Source specific doses	Anglers	<0.005	<0.005	-	<0.005	-	-	-
	Consumers of locally grown food[b]	0.012	-	<0.005	-	-	0.010	-
	Workers at Maple Lodge STW	<0.005	-	-	<0.005[c]	<0.005[d]	-	-
Cardiff								
***Total dose* - all sources**	**Prenatal children of occupants over sediment**	**0.006**	**<0.005**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Prenatal children of seafood consumers	0.010	<0.005	-	0.007	-	-	-
	Recreational users of River Taff	<0.005	-	-	<0.005	<0.005	-	-
	Consumers of locally grown food[b]	0.005	-	0.005	-	-	<0.005	-
	Workers at Cardiff East WWTW	<0.005	-	-	<0.005[c]	<0.005[d]	-	-
	Prenatal children of consumers of crops grown in soil treated with sludge pellets	<0.005	-	<0.005	-	-	-	-

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

[b] *Children aged 1y*

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

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

Table 6.2. Concentrations of radionuclides in food and the environment near Amersham, 2010[g]

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{32}P	^{35}S	^{57}Co	^{65}Zn	^{125}I
Freshwater samples								
Flounder	Beckton	1	<25			<0.02	<0.11	
Sediment	River Colne (Grand Union Canal)	2[E]				<0.42	<2.5	<25
Sediment	Outfall (Grand Union Canal)	2[E]				<0.54	<3.2	<24
Freshwater	Maple Cross	2[E]	<2.9			<0.16	<0.77	<3.8
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<2.9			<0.16	<0.75	<3.9
Freshwater	River Chess	1[E]	<2.9			<0.15	<0.92	<3.1
Freshwater	River Misbourne - upstream	1[E]	<2.9			<0.13	<0.51	<2.6
Freshwater	River Misbourne - downstream	1[E]	<2.9			<0.12	<0.58	<3.8
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]	<17	<1.3	<0.81	<0.14	<0.65	<2.3
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	<12	<1.5	<1.1	<0.13	<0.61	<2.5
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]	<9.1	<1.6	<0.81	<0.12	<0.54	<2.6

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{131}I	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Freshwater samples							
Flounder	Beckton	1	<0.84	0.09	<0.04		
Sediment	River Colne (Grand Union Canal)	2[E]	<16	3.3		<110	450
Sediment	Outfall (Grand Union Canal)	2[E]	<18	8.7		210	390
Freshwater	Maple Cross	2[E]	<7.3	<0.26		<0.085	0.42
Freshwater	Upstream of outfall (Grand Union Canal)	2[E]	<8.8	<0.28		<0.045	0.17
Freshwater	River Chess	1[E]	<0.47	<0.33		<0.040	<0.10
Freshwater	River Misbourne - upstream	1[E]	<0.32	<0.20		<0.060	<0.10
Freshwater	River Misbourne - downstream	1[E]	<0.39	<0.27		<0.040	<0.10
Crude effluent[d]	Maple Lodge Sewage Treatment Works	4[E]		<0.26	<0.36	<0.080	0.45
Digested sludge[e]	Maple Lodge Sewage Treatment Works	4[E]	1.2	<0.26	<0.33	<3.0	<4.1
Final effluent[f]	Maple Lodge Sewage Treatment Works	4[E]		<0.22	<0.32	<0.063	0.63

Table 6.2. continued

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{35}S	^{57}Co	^{65}Zn	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples											
Milk		2	<4.4	<0.23			<0.016	<0.0031	<0.20		
Milk	max		<4.5				<0.017				
Apples		1	<4.0	<0.20			<0.033		<0.20		
Beetroot		1	<5.0	<0.20			<0.039		<0.20		
Blackberries		1	<4.0	<0.20			<0.049		<0.20		
Broad beans		1	<6.0	<0.20			<0.045		<0.20		
Carrots		1	<5.0	<0.10			<0.059		<0.20		
Peas		1	<6.0	0.30			<0.046		<0.20		
Spinach		1	<5.0	0.40			<0.038		<0.20		
Wheat		1	<8.0	0.90			<0.081		<0.20		
Grass	Next to site	1[E]		5.8	<0.71	<3.3	<14	<1.8	<1.3	<5.0	290
Grass	Orchard next to site	1[E]		3.1	<0.49	<2.3	<9.3	<1.3	<0.86	<5.0	240
Grass	Water Meadows (River Chess)	1[E]		8.0	<0.58	<2.9	<12	<1.6	<1.1	<2.0	340
Soil	Next to site	1[E]			<0.20	<1.1	<6.6	<0.51	9.4	340	960
Soil	Orchard next to site	1[E]			<0.22	<1.5	<6.8	<0.61	3.3	430	890
Soil	Water Meadows (River Chess)	1[E]			<0.17	<0.72	<5.1	<0.45	9.9	104	440

[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 <3.7 Bq l^{-1}*

[e] *The concentration of ^{3}H as tritiated water was <3.8 Bq l^{-1}*

[f] *The concentration of ^{3}H as tritiated water was <3.8 Bq l^{-1}*

[g] *The gamma dose rates in air at 1m over grass and grass and mud on the bank of the Grand Union Canal were 0.060 and 0.063 µGy h^{-1} respectively*

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

Table 6.3(a). Concentrations of radionuclides in food and the environment near Cardiff, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{125}I	^{131}I	^{134}Cs	^{137}Cs
Marine samples										
Cod	East of new pipeline	1		190		23		*	<0.04	0.36
Flounder	East of new pipeline	4	920	990		38		<0.71	<0.10	0.40
Sole	East of new pipeline	2		1700		60		<0.44	<0.04	0.22
Mullet	East of new pipeline	1		32		35		*	<0.05	0.45
Lesser spotted dogfish	Off Orchard Ledges	2	280	290		43		<0.65	<0.13	0.50
Skates/Rays	Off Orchard Ledges	2	470	570		37		<0.28	<0.07	0.71
Limpets	Lavernock Point	2	<29	<25		15		<0.45	<0.14	0.49
Seaweed[d]	Orchard Ledges	2[E]		<16	<4.5	11	<3.1			<1.5
Sediment	East of new pipeline	2[E]		26		<6.0	<21			18
Sediment	West of new pipeline	2[E]		24	<4.2	<6.6	<20			22
Seawater	Orchard Ledges	2[E]		<14	<3.5		<2.1			<0.24

Material	Location or selection[b]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			Organic ^{3}H[e]	^{3}H	^{3}H[f]	^{14}C	^{35}S	^{125}I	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples											
Milk[g]		6	<5.0	<5.2		14	<0.33	<0.017		<0.20		
Milk[g]	max		<5.9	<7.8		16	<0.40	<0.019				
Blackberries		1	3.0	33		18	<0.20	<0.050		<0.20		
Cabbage		1	<17	11		<3.0	0.80	<0.051		<0.20		
Honey		1		<8.0		56	0.40	<0.024		<0.20		
Leeks		1	3.0	7.0		<3.0	1.1	<0.043		<0.20		
Onions		1	<7.0	<5.0		<3.0	0.20	<0.048		<0.20		
Potatoes		1	<7.0	<5.0		13	<0.10	<0.065		<0.20		
Rape oil		1		<15		120	4.3	<0.053		<0.20		
Strawberries		1	<4.0	<4.0		4.0	0.50	<0.051		0.20		
Swede		1	1.0	5.0		6.0	0.80	<0.038		<0.20		
Wheat		1		<6.0		75	0.80	<0.051		<0.20		
Grass		5	<27	<32		43				<0.20		
Grass	max		<68	64		45				0.20		
Silage		2	<16	<19		50						
Silage	max		26	32		72						
Soil		3								5.5		
Soil	max									6.5		
Sediment	Canal	2[E]		78		23		<22		9.5		
Freshwater	River Taff upstream	2[E]		<12	<3.7	<5.0		<1.5	<1.9	<0.21	<0.055	0.29
Freshwater	Run off into River Taff	1[E]		35	26	<2.4		<0.30	<3.2	<0.21	<0.060	0.23
Freshwater	River Taff downstream	1[E]		<9.0	<3.0	<4.0		<2.6	<0.30	<0.21	<0.040	0.46
Freshwater	Canal	2[E]		<13	13	<4.2		<1.4	<1.8	<0.21	<0.12	<0.11
Crude effluent	Cardiff East WWTW	1[E]	26	28	<3.8	<5.2						
Final effluent	Cardiff East WWTW	1[E]	42	44	<3.8	<5.7						
Sludge pellets	Cardiff East WWTW	1[E]		1100		88						

* *Not detected by the method used*

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

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

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

[d] *The concentration of ^{99}Tc was 6.9 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 <0.36 (max <0.39) 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, 2010

Location	Ground type	No. of sampling observ-ations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
East of Pipeline	Mud and sand	1	0.069
East of Pipeline	Mud and rock	1	0.085
West of Pipeline	Mud and sand	1	0.097
West of Pipeline	Mud and stones	1	0.11
Peterstone Wentlooge	Salt marsh	2	0.083

7. Industrial and landfill sites

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

7.1 Low Level Waste Repository near Drigg, Cumbria

The Low Level Waste Repository (LLWR) is the UK's national low level waste disposal facility and is located on the West Cumbrian coast, approximately 7 km south east of Sellafield. The main function of LLWR is to receive low-level solid radioactive wastes from all UK nuclear sites (except Dounreay) and many non-nuclear sites. Where possible the waste is compacted, and then most waste is grouted within containers before disposal. Wastes are now disposed of in engineered concrete vaults on land, whereas prior to the early 1990s waste was disposed of in open clay lined trenches. The site is operated by LLW Repository Limited on behalf of the NDA. From 1 April 2008, a consortium, UK Nuclear Waste Management Ltd (UKNWM), took over as the Parent Body Organisation for LLW Repository Limited.

A report published by the Environment Agency provides new data on radionuclides in a variety of wildlife species (including small mammals and reptiles) collected in the Drigg sand dunes. The wildlife is contaminated indirectly by permitted discharges from the Sellafield site. The monitoring results indicate that there is likely to be no adverse impact on wildlife in the sand dunes (Beresford *et al.*, 2008).

The disposal permit allows for the discharge of leachate from the site through a marine pipeline. These discharges are small compared with those discharged from the nearby Sellafield site (Appendix 2). Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme, described in Section 2. The contribution to exposures due to LLWR discharges is negligible compared with that attributable to Sellafield and any effects of LLWR discharges in the marine environment could not, in 2010, be distinguished from those due to Sellafield. In 2010, the total transfers of solid waste to the LLWR for disposal were generally less than those in 2009.

Key points

LLWR, near Drigg

- Total transfers of solid radioactive waste to the LLWR site near Drigg for disposal were generally less in 2010
- Concentrations and dose rates at LLWR were similar to those in 2009
- Doses near Drigg were dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven

Other sites

- Tritium found in leachate from other landfill sites. Probably due to disposal of Gaseous Tritium Light Devices. Doses were less than 0.5 per cent of dose limit
- The Studsvik Metals Recycling Facility commenced operations as a new nuclear site in September 2009, with its first full year of operation during 2010. Discharges were all low and within permitted limits.
- Enhancement in natural radionuclides at Whitehaven from phosphate processing now very difficult to detect, however the radiation dose from the enhancement was estimated to be 18 per cent of the dose limit
- Radium-226 contamination requires further investigation near Dalgety Bay, Fife
- Discharges from other non-nuclear sites (hospitals, universities etc.) were all within limits set in regulations

During 2010, the LLWR near Drigg reported some negative figures for the disposal of solid low level waste by burial on the site (Appendix 2). These negative figures reflect an exercise undertaken in February 2010 in which a number of waste containers were transferred from a disposal vault to a storage vault, or to positions within a vault currently identified as for storage only. Insufficient further waste was disposed of in the disposal vault, during the remainder of 2010, to restore the total radioactivity of some groups of radionuclides within this vault to positive disposal figures. This resulted in negative overall disposal figures during the year for the site. These transfers were undertaken to optimise the limited remaining disposal capacity for the receipt of 'overweight' containers in the disposal vault. There remains the possibility that, should a permit for further disposal not be granted, the stored containers (not currently permitted for disposal) will be moved elsewhere for storage or disposal. Such future movement of containers could be problematic if 'overweight'. Hence, the movement of a number of containers has been, as far as possible, to a location in the disposal vault where the need for their relocation is much less likely.

Although the permit for disposal to the Drigg Stream has been revoked, reassurance monitoring of samples of water and sediment has continued. The results are given in Table 7.2. The gross alpha and beta concentrations were below or close to the WHO screening levels for drinking water from the Drigg stream. Although the stream is not known to be used as a source of drinking water, it is possible that occasional use could occur, for example by campers. If the stream was used as a drinking water supply for three weeks, the dose would be less than 0.005 mSv. Concentrations of radionuclides in sediment from the Drigg stream were similar to those for 2009. They reflect the legacy of direct discharges of leachate from the disposal site into the stream (BNFL, 2002). This practice stopped in 1991.

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

The monitoring programme of terrestrial foodstuffs at the site is primarily directed at the potential migration of radionuclides from the waste burial site via groundwater. Results for 2010 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 2010, as it was in 2009. In general, concentrations of radionuclides detected were similar to or lower than those found near Sellafield (Section 2). The *total dose* from all pathways and sources, including a component due to Chernobyl and weapon test fallout, was 0.18 mSv, or 18 per cent of the dose limit for members of the public of 1 mSv (Table 7.1). This is dominated by the effects of the legacy of discharges into the sea at Sellafield and Whitehaven, which are near to the LLWR site. If these effects were to be excluded, and the sources of exposure from the LLWR are considered, the people most exposed are represented by adults spending time near the site. Their *total dose* in 2010 was 0.038 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 0.012 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. 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 2010 is shown in Figure 7.1 and the results are presented in Tables 7.3 and 7.4. The programme in England and Wales reduced significantly in 2007 because the data from the previous, larger programme, collected over many years, showed that any enhancements in concentrations were predictable and gave rise to doses of very low significance. The remaining programme in England and Wales constitutes continued monitoring in relation to sites near Springfields where solid LLW has been disposed of, and at a few other landfill sites where disposals of radioactive waste are ongoing.

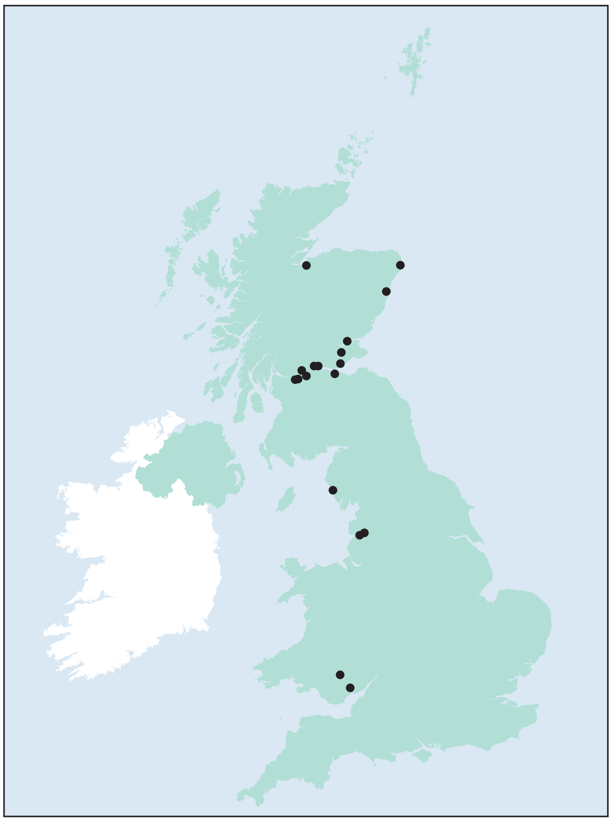


Figure 7.1. Landfill sites monitored in 2010

The results, in common with previous years, show very low concentrations of caesium-137 in leachate and evidence for migration of tritium from some of the discharge sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices (Mobbs *et al.*, 1998). Inadvertent ingestion of leachate (2.5 l per year) from the site with the highest observed concentration of tritium would result in a dose of less than 0.005 mSv or less than 0.5 per cent of the dose limit for members of the public of 1 mSv (Table 7.1).

7.3 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, and discharges during 2010 were well below the limits (Appendix 2). Transfer of LLW to the LLWR and VLLW to landfills, along with normal refuse for the

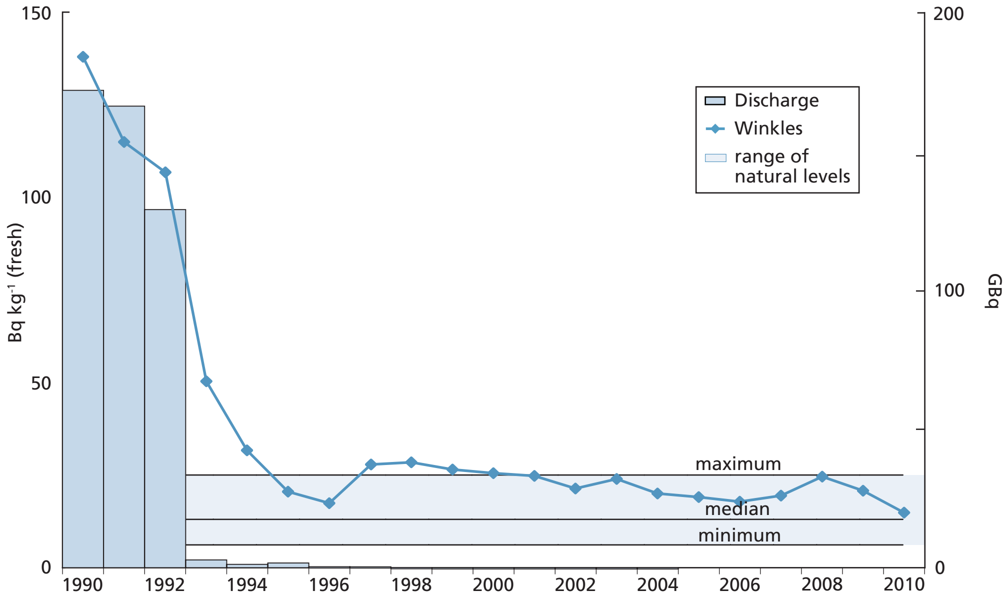


Figure 7.2. Polonium-210 discharge from Whitehaven and concentration in winkles at Parton, 1990-2010

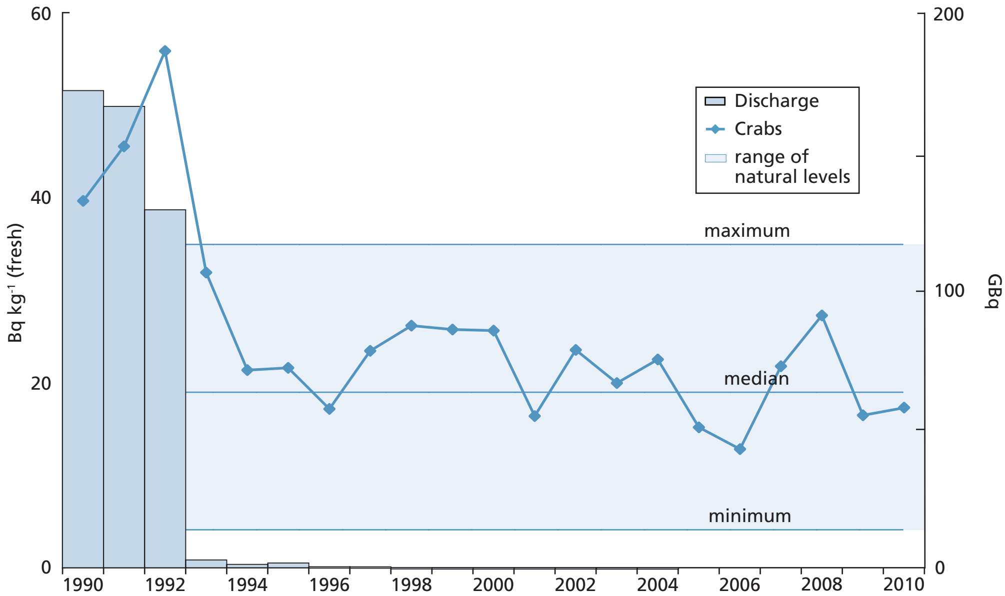


Figure 7.3. Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990-2010

purposes of disposal, is also allowed by the permit. No transfers were made during 2010. The permit includes conditions requiring Studsvik UK Ltd to monitor discharges and undertake environmental monitoring.

7.4 Phosphate processing, Whitehaven, Cumbria

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

The results of routine monitoring for naturally-occurring radioactivity near the site in 2010 are shown in Table 7.5. Analytical effort has focused on lead-210 and polonium-210, which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. Concentrations of polonium-210 and other naturally-occurring radionuclides are slightly enhanced near Whitehaven but quickly reduce to background levels further away. Figures 7.2 and 7.3 show how concentrations of polonium-210 in winkles and crabs have decreased since 1998. Concentrations in the early 1990s were in excess of 100 Bq kg^{-1} (fresh weight). There were small decreases in concentrations of polonium-210 in local samples in 2010 compared with 2009. However, the changes were small and taking into account the ranges of values observed, it is now difficult to distinguish between the total naturally-occurring radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. These are shown in Figures 7.2 and 7.3 and in Appendix 1 (Annex 4). There were small enhancements for some samples above the expected natural background median levels for marine species, but the majority were within the ranges observed in the undisturbed marine environment. It is nevertheless considered prudent to continue to estimate doses based on the difference between observed concentrations and median levels indicative of natural background.

The critical radiation exposure pathway is internal irradiation, due to the ingestion of naturally-occurring radioactivity in local fish and shellfish. Centred on the Sellafield site to the south of Whitehaven, the group includes people with habits relating to the immediate area around Whitehaven, including Saltom Bay and Parton. It is identical to the group used to assess the impact of the Sellafield site (Section 2). An additional, smaller group limited to the immediate area around Saltom Bay is no longer assessed separately because the larger group provides adequate protection and a more robust assessment. The estimated contribution due to background median concentrations of naturally-occurring radionuclides has been subtracted. Consumption rates for people who eat at high-rates were reviewed and revised in 2010. The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

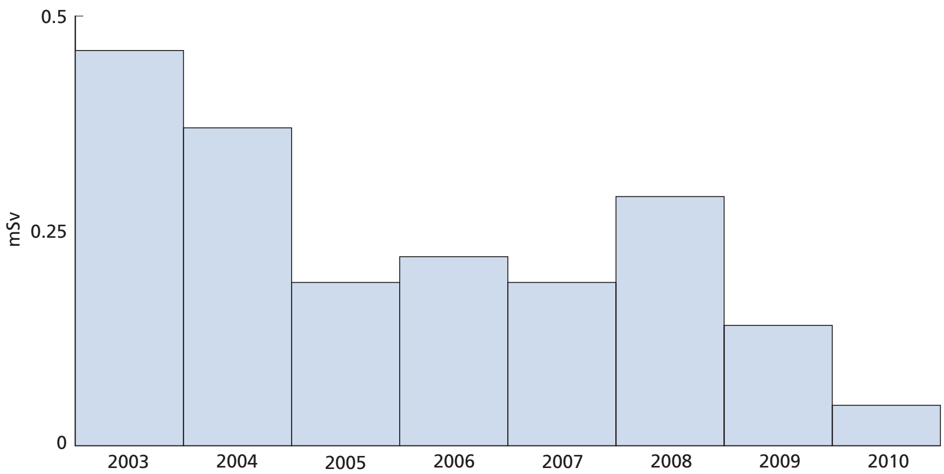


Figure 7.4. Trend in *total dose* to seafood consumers from naturally-occurring radionuclides near Whitehaven, 2003-2010

The *total dose* to local high rate consumers of molluscs was 0.18 mSv in 2010 (Table 7.1), below the dose limit for members of the public of 1 mSv and a decrease from the estimate for 2009 of 0.28 mSv. The decrease was largely due to small decreases in concentrations of polonium-210 in seafood though changes in consumption rates also had an effect. The dose includes the effects of all sources near the site, enhanced naturally-occurring radionuclides from the non-nuclear industrial activity (i.e. TNORM), and Sellafield operations. The source specific assessment of dose, targeted directly at high-rate seafood consumers confirmed the *total dose* assessment and gave a similar result, 0.26 mSv. The contribution to the *total dose* from enhanced natural radionuclides was 0.047 mSv in 2010, compared with 0.14 mSv in 2009. The change was largely due to the reductions in concentrations of polonium-210 in seafood.

7.5 Aberdeen

Enhancement of naturally-occurring radionuclides in the marine environment may also result from operations conducted by Scotoil in Aberdeen. The company operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. Prior to these operations, a fertiliser manufacturing process was operated on the site, which made discharges to sea. Scotoil is authorised by SEPA to discharge small amounts of radioactive waste to the sea near Aberdeen Harbour. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring. The primary discharge is of radium-226 and radium-228, with lead-210 and polonium-210 in smaller quantities. Following a review of the authorisation held by Scotoil, SEPA issued a variation notice requiring a range of improvements. The variation notice which required use of the discharge pipeline to cease by December 2008 was appealed by Scotoil in 2007.

Following a public inquiry in March and April 2008 to consider the appeal made by Scotoil, Scottish Ministers announced their decision, based on the Reporter's recommendations, in October 2008. The main outcome of the decision is that the discharge of solid radioactive waste into the sea must cease by October 2011.

Scotoil is currently developing a waste treatment facility for the solidification of radioactive waste prior to the cessation of their discharges into the sea.

7.6 Dalgety Bay, Fife

Radioactive items containing radium-226 and associated daughter products have been detected in Dalgety Bay in Fife since at least 1990. Contamination is likely to be due to past military operations at the Royal Naval Air Station (RNAS) Donibristle, which closed in 1959. The air station played a role as an aircraft repair, refitting and salvage yard. It is believed that waste was incinerated and the resultant ash and clinker was disposed of in an area of ground that, as a result of erosion, is now exposed and adjacent to the foreshore. Some of the incinerated material contained items which had been painted with luminous paint containing radium-226.

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

The data from a monitoring exercise, conducted during March 2006, was used to undertake a screening risk assessment. The monitoring survey report and screening risk assessment have been published (RWE Nukem, 2006; Scottish Environment Protection Agency, 2006). The screening risk assessment considered the range of activities of radium-226 in samples removed from the beach, the likelihood of encountering such items and various modes of exposure - ingestion, inhalation and external exposure.

More recently, further studies have been undertaken by the MoD (Male and Jones, 2008). Their study included sampling, measurement and assessment in parts of the beach and residential area. The results were compared to the 3 mSv per year criterion recommended for use in relation to radioactively contaminated land (Department for Environment, Food and Rural Affairs, 2006b). The results showed that contamination at two residential properties could lead to exposures in excess of 3 mSv per year.

In 2010, SEPA conducted further work on the potential solubility and doses which could be received from a source present on the beach at Dalgety Bay should it be ingested, together with work on the potential doses which could occur from skin contact. Both reports will be available at: http://www.sepa.org.uk/radioactive_substances/publications/dalgety_bay_reports.aspx

This study reports that there is low potential of a skin burn being received following exposure to a source, although if a source were to be ingested it could result in a dose in excess of 100 mSv to young infants.

The scheduled monitoring programme undertaken by Defence Estates (now the Defence Infrastructure Organisation (DIO)) came to a conclusion in 2010 and SEPA considered in the absence of such a programme whether further actions were needed to protect the public from the radioactive sources present on the beach. As sources which could give significant doses to members of the public were still being recovered from the beach, SEPA concluded that a further programme of monitoring and retrieval was needed coupled with the continued presence of signs to provide information to the public on the hazards present. Following discussions with SEPA, the DIO has agreed to undertake a further programme of monitoring and recovery. The DIO has also agreed to support the work of SEPA in attempting to determine the primary source of the contamination which continues to re-populate the beach; this work will be reported in the next RIFE report.

7.7 Other non-nuclear sites

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

A summary of the most recent data for the quantities discharged under regulation is given in Tables 7.6 and 7.7. The data are grouped according to the main industries giving rise to such wastes in the UK and exclude information for other industries considered in other sections of this report, principally the nuclear sector. The main industries are:

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

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

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

Monitoring of the effects of the non-nuclear sector is not undertaken routinely because of the relatively low impact of the discharges. However, ad hoc programmes are carried out to confirm that impacts are low and, when these occur, they are described in this report.

In 2010, SEPA undertook a small-scale survey (as part of the annual programme) of the effects of discharges from non-nuclear operators by taking and analysing samples of mussels and other materials in the River Clyde. The results in marine samples show the expected effects of Sellafield discharges at this distance (Table 7.8). The results were similar to those in 2009. An assessment of the dose to a hypothetical group of high-rate mollusc consumers was undertaken. The dose was less than 0.005 mSv or less than 0.5 per cent of the dose limit.

In 2010, SEPA also responded to public concern over potential radium contamination at an intertidal area in the Firth of Forth. SEPA believed the reported "blue glow" to be a natural phenomenon of bioluminescence phytoplankton (Noctiluca scintillans). The algae could not be sampled due to the time delay in contacting SEPA; however a dose rate measurement and sediment sample confirmed that there was no significant radiological hazard present on the beach. The dose rate was 0.061 $\mu Gy\ h^{-1}$ and the concentrations of caesium-137, europium-155 and americium-241 were 24, 1.7 and 2.0 $Bq\ kg^{-1}$ (dry), respectively.

Table 7.1. Individual radiation exposures - industrial and landfill sites, 2010

Site	Exposed population[a,d]	Exposure, mSv per year					
		Total	Seafood (nuclear industry discharges)	Seafood (other discharges)	Other local food	External radiation from intertidal areas	Intakes of sediment and water
Total dose - all sources							
Sellafield, Whitehaven and LLWR	Adult mollusc consumers	0.18[c]	0.13	0.047	<0.005	0.009	-
Source specific - doses							
LLWR near Drigg	Consumers of locally grown food[b]	0.012	-	-	0.012	-	-
	Consumers of water from Drigg stream	<0.005	-	-	-	-	<0.005
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers[b]	<0.005	-	-	-	-	<0.005
Whitehaven (habits averaged 2006-10)	Seafood consumers[c]	0.26	0.15	0.082	-	0.031	-

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

[b] *Children aged 1y*

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

[d] *None of the people represented in this table were considered to receive direct radiation from the site*

Table 7.2. Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2010

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb
Milk		1	<4.5	13	<0.19	0.076	<0.32	<0.24	<0.0030	<1.1	<0.33
Blackberries		1	<4.0	14	<0.10	0.16	<0.30	<0.20		<1.1	<0.50
Cabbage		1	<5.0	<3.0	<0.20	0.52	<0.20	<0.20	<0.021	<0.60	<0.30
Deer muscle		1	<5.0	19	<0.20	0.019	<0.30	<0.20	<0.021	<0.60	<0.20
Eggs		1	6.0	42	<0.20	0.021	<0.40	<0.20		<1.2	<0.60
Pheasants		1	<6.0	29	<0.20	<0.0070	<0.30	<0.20	<0.029	<1.4	<0.20
Potatoes		1	<5.0	13	<0.10	0.023	<0.30	<0.20	<0.026	<1.4	<0.30
Sheep muscle		1	7.0	22	<0.20	0.029	<0.20	<0.10	<0.024	<1.1	<0.20
Sheep offal		1	<8.0	<10	<0.10	0.66	<0.30	<0.10	<0.020	<0.80	<0.40
Swede		1	6.0	7.0	<0.30	0.33	<0.40	<0.20		<1.8	<0.40
Grass		2							0.10		
Grass	max								0.19		
Sediment	Drigg Stream	4[E]			<1.6	<7.3	<1.6	<0.64		<7.5	<3.9
Freshwater	Drigg Stream	4[E]	<5.7		<0.31	<0.10					
Freshwater	Railway Drain	1[E]	13		<0.25	1.2					

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	<0.0075	<0.18	<0.18		<0.73				
Blackberries		1	<0.026			0.073	<0.80				
Cabbage		1	<0.020			0.15	<0.50				
Deer muscle		1	<0.041			2.4	<0.70				
Eggs		1	<0.030			0.15	<1.4				
Pheasants		1	<0.032			0.26	<0.50				
Potatoes		1	<0.027			0.43	<0.80				
Sheep muscle		1	<0.027			0.64	<0.70				
Sheep offal		1	<0.024			0.40	<0.50				
Swede		1	<0.026			0.52	<0.90				
Sediment	Drigg Stream	4[E]		<0.84	650		<4.0	19	20	21	16
Freshwater	Drigg Stream	4[E]		<0.29	<0.26			<0.016	<0.0093	<0.0050	<0.0043
Freshwater	Railway Drain	1[E]		<0.24	<0.21			<0.0060	<0.0050	<0.0060	<0.0050

Material	Location or selection[a]	No. of sampling observ-ations[c]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}								
			^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1				<0.00010	<0.00028	<0.026	0.00035		
Blackberries		1				<0.00010	0.00020	<0.052	0.0010		
Cabbage		1				<0.00010	<0.00020	<0.045	0.00070		
Deer muscle		1				<0.00010	<0.00020	<0.063	0.00020		
Eggs		1				<0.00010	<0.00010	<0.040	0.00020		
Pheasants		1				<0.00010	0.00020	<0.067	0.00010		
Potatoes		1				<0.00010	<0.00020	<0.049	0.00020		
Sheep muscle		1				<0.00020	0.0017	<0.077	0.0025		
Sheep offal		1				0.0078	0.043	0.24	0.059		
Swede		1				0.00010	<0.00020	<0.050	0.00050		
Grass		2	0.015	<0.00065	0.016						
Grass	max		0.022	<0.00070	0.022						
Soil		1	11	0.43	10						
Sediment	Drigg Stream	4[E]	110	<4.0	93	38	220	1400	340	980	2100
Freshwater	Drigg Stream	4[E]	<0.016	<0.0063	0.011	<0.0078	<0.0063	<0.55	<0.015	<0.053	0.63
Freshwater	Railway Drain	1[E]	0.024	<0.0050	0.022	<0.0070	0.0060	<0.20	<0.030	<0.20	5.7

[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 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, 2010

Area	Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness Tip	1	24	<15	<0.05	<0.05
City of Glasgow	Summerston Tip	1	230	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	490	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	22	<15	<0.05	<0.05
Dunbartonshire	Birdstone	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	14	<15	<0.05	<0.05
Edinburgh	Braehead	1	<2.5	<15	<0.05	<0.05
Fife	Balbarton	1	67	<15	<0.05	<0.05
Fife	Melville Wood	1	47	<15	<0.05	<0.05
Highland	Longman Tip	1	<2.5	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	100	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	220	<15	<0.05	<0.05

Table 7.4. Concentrations of radionuclides in water from landfill sites in England and Wales, 2010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1}						
			^{3}H	^{3}H[a]	^{14}C	^{40}K	^{60}Co	^{137}Cs	^{228}Th
Glamorgan									
Trecatti Landfill, Merthyr Tydfil	Raw Leachate	2	360	310	<3.8				
Trecatti Landfill, Merthyr Tydfil	Treated leachate	2	360	370	<4.2				
Lancashire									
Clifton Marsh	Borehole 6	2		9.3		<6.2	<0.29	<0.24	<0.010
Clifton Marsh	Borehole 19	2		<5.0		<8.3	<0.33	<0.27	<0.0070
Clifton Marsh	Borehole 40	2		<4.3		<5.3	<0.24	<0.20	<0.012
Clifton Marsh	Borehole 59	2		11		<5.3	<0.25	<0.20	<0.0060
Ulnes Walton	Pond	1		<2.8		<11	<0.45	<0.34	<0.0070
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2		23	<5.4	<6.3	<0.30	<0.24	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq kg^{-1}						
			^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Lancashire									
Clifton Marsh	Borehole 6	2	<0.0050	<0.0050	0.026	<0.0050	0.023	<0.25	5.3
Clifton Marsh	Borehole 19	2	<0.0050	<0.0050	0.047	<0.0065	0.041	<0.35	2.8
Clifton Marsh	Borehole 40	2	<0.0050	<0.0050	0.0085	<0.0050	0.0065	<0.085	1.4
Clifton Marsh	Borehole 59	2	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.25	2.3
Ulnes Walton	Pond	1	<0.0050	<0.0050	0.069	<0.0070	0.071	0.15	0.48
South Glamorgan									
Lamby Way Tip[b]	Borehole 1A	2						<1.1	1.7

[a] *As tritiated water*
[b] *The concentrations of ^{125}I and ^{131}I were <2.2 and <1.9 Bq l^{-1} respectively*

Table 7.5. Concentrations of naturally occurring radionuclides in the environment, 2010

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Phosphate processing, Whitehaven										
Winkles	Saltom Bay	4	12	0.91						
Winkles	Parton	4	15	1.4	0.63	0.82	0.38	1.6	0.054	1.4
Winkles	North Harrington	1	19							
Winkles	Nethertown	4	17							
Winkles	Drigg	1			1.1	1.1	0.81			
Winkles	Tarn Bay	1	11							
Mussels	Parton	4	39	1.1						
Mussels	Nethertown	4	34	2.9						
Limpets	St Bees	2	15							
Cockles	Ravenglass	2	24							
Crabs	Parton	4	17	0.12	0.097	0.019	0.0073	0.066	0.0021	0.059
Crabs	Sellafield coastal area	4	11	0.15						
Lobsters	Parton	4	6.8	0.12	0.040	0.0075	0.0035	0.043	0.0018	0.037
Lobsters	Sellafield coastal area	4	12	0.063						
Cod	Parton	2	0.62	0.23	0.021	0.0033	0.0013	0.0065	<0.00027	0.0052
Dab	Whitehaven	1	1.7							
Other samples										
Winkles	South Gare (Hartlepool)	2	8.6	0.78						
Winkles	Kirkcudbright	1	3.2							
Mussels	Ribble Estuary	2			0.23	0.58	0.11			
Cockles	Southern North Sea	1			0.56	0.26	0.42			
Cockles	Flookburgh	1	13							
Scallops	Kirkcudbright	1	1.9							
Crabs	Kirkcudbright	1	3.9							
Lobsters	Kirkcudbright	1	1.7							
Shrimps	Ribble Estuary	2			0.0056	0.0052	0.0011			
Wild fowl	Ribble Estuary	1			0.0048	0.0033	0.0014			
Seaweed	Isle of Man	1						1.8	<0.22	1.4
Sediment	Kirkcudbright	1						11	0.54	11

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

Table 7.6. Discharges of gaseous radioactive wastes from non-nuclear establishments in the United Kingdom, 2009[a]

	Discharges during 2009, GBq							
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)	
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland
^{3}H	1.1E-01						1.1E+03	
^{14}C	4.7E-03			5.3E-03			1.3E+03	9.2E-03
^{18}F	1.9E+02						3.4E+01	
^{35}S	2.3E-05						2.2E-01	
^{85}Kr							1.4E-01	
^{99m}Tc				1.4E+00				
^{125}I	2.7E-05			5.6E-02			2.6E-01	
^{129}I							3.6E-05	
^{131}I				5.4E-01			9.2E-02	
^{137}Cs							4.8E-09	
^{222}Rn							2.0E+00	
Plutonium Alpha							2.4E-07	
Uranium Alpha							1.2E-10	
^{241}Am							4.4E-07	
Other Alpha particulate							8.6E+01	
Other Beta/Gamma					3.1E+02			
Other Beta/Gamma Particulate	9.6E+02		3.1E+00	3.2E-01		2.0E+00	1.7E+04	

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland discharge data refers to 2010*

Table 7.7. Discharges of liquid radioactive waste from non-nuclear establishments in the United Kingdom, 2009[a]

	Discharges during 2009, TBq										
	Education (Universities and Colleges)			Hospitals			Other (Research, manufacturing and public sector)			Oil and gas (onshore)	Oil and gas (offshore)
	England and Wales	Northern Ireland	Scotland	England and Wales	Northern Ireland	Scotland	England and Wales	Scotland	Northern Ireland	Scotland	Scotland
^{3}H	3.7E-02	2.6E-05		5.4E-04	4.4E-04		2.5E-01				
^{14}C	5.0E-03	6.7E-06		1.3E-03		8.3E-04	5.5E-01	4.1E-03	5.7E-03		
^{18}F	5.2E-01		6.2E-02	1.7E+00	2.3E-01	2.5E-01	9.6E-01				
^{22}Na	3.7E-07			4.0E-09			8.6E-10				
^{32}P	2.3E-02	9.6E-05	3.3E-03	7.1E-03	2.8E-05	1.2E-03	1.0E-02	5.6E-04			
^{33}P	1.5E-03	4.0E-09	1.3E-02				6.0E-03	1.4E-02			
^{35}S	3.2E-02	3.0E-04	2.9E-03	3.0E-03			7.0E-03	4.3E-04			
^{51}Cr	7.3E-03		5.6E-05	4.5E-02	5.1E-04	3.2E-03	1.1E-03				
^{57}Co				3.2E-05			2.1E-09				
^{58}Co				1.3E-06			7.1E-07				
^{60}Co	2.1E-09						2.0E-07				
^{67}Ga				2.3E-02	2.2E-04	8.7E-04	1.7E-04				
^{75}Se	3.6E-05			8.0E-04		1.2E-05	6.8E-06				
^{89}Sr				2.0E-02		5.9E-03	1.4E-04				
^{90}Sr	4.0E-09						1.7E-07				
^{90}Y	3.3E-07			3.6E-01	4.0E-06						
^{99}Tc	7.8E-06			8.6E-01							
^{99m}Tc	1.6E-03			5.3E+01	1.5E+00	5.0E+00	5.8E-01				
^{106}Ru				1.9E-04			3.5E-08				
^{111}In	3.0E-03			3.1E-01	7.6E-03	3.4E-02	4.5E-03				
^{123}I				9.6E-01	5.8E-02	1.4E-01	1.1E-02				
^{125}Sb							3.8E-09				
^{125}I	3.0E-03	1.2E-04	6.2E-04	1.8E-03	3.2E-05		6.3E-02		5.0E-05		
^{129}I							1.3E-07				
^{131}I	4.6E-04		3.8E-03	8.9E+00	1.3E-02	1.1E+00	1.6E-01				
^{134}Cs							1.6E-07				
^{137}Cs	2.8E-05		1.8E-05				2.3E-05				
^{144}Ce							7.4E-11				
^{153}Sm				4.7E-02							
^{201}Tl				1.8E-01	3.2E-03	2.6E-02	3.5E-04				
^{232}Th							4.3E-03				
Plutonium Alpha	1.8E-05						2.2E-06				
Uranium Alpha	6.1E-07						7.9E-03				
^{237}Np							1.2E-07				
^{241}Am	5.0E-09						7.7E-07				
^{241}Pu							4.4E-06				
Total Alpha	2.4E-05			2.0E-03			2.9E-02			1.3E-02	7.8E-03
Total Beta/Gamma (Excl Tritium)	6.3E-01		8.9E-02	5.3E+01		6.6E+00	1.4E+00	5.4E-03		8.7E-03	3.7E-03
Other Alpha particulate	2.9E-10			1.7E-05			1.3E-04				
Other Beta/ Gamma[b]	1.2E-02		2.8E-05	4.0E-01	1.0E-07	9.0E-04	4.9E-02				
Other Beta/ Gamma particulate							9.3E-03				

[a] *Excludes nuclear power, defence and radiochemical manufacturing (Amersham and Cardiff) industries. Excludes discharges which are exempt from reporting. Northern Ireland discharge data refers to 2010*

[b] *Excluding specific radionuclides*

Table 7.8. Monitoring in the River Clyde, 2010[a]

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}				
			^{3}H	^{14}C	^{90}Sr	^{99}Tc	^{125}Sb
Between Finlaystone and Woodhall	Mussels	1		37		5.2	<0.27
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1				160	<0.10
14 km downstream of Dalmuir	Sediment	1		<15			0.64
Downstream of Dalmuir	Freshwater	4					<0.10
River Clyde	Freshwater	4	<1.1		<0.0050		

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}			
			^{137}Cs	^{155}Eu	^{241}Am	Gross beta
Between Finlaystone and Woodhall	Mussels	1	0.30	<0.24	<0.15	
Between Finlaystone and Woodhall	*Fucus vesiculosus*	1	1.8	0.10	<0.10	
14 km downstream of Dalmuir	Sediment	1	44	1.6	1.8	
Downstream of Dalmuir	Freshwater	4	<0.10	<0.10	<0.10	
River Clyde	Freshwater	4	<0.10			0.96

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

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

8. Chernobyl and regional monitoring

8.1 Chernobyl

25 years ago the Chernobyl accident occurred in April 1986, in the former USSR (now Ukraine). After the accident, radiocaesium was detected in sheep grazing certain upland areas in the UK, which were subjected to heavy rainfall in the days following the accident. Restrictions were put in place on the movement, sale and slaughter of sheep from the affected areas, in order to prevent animals from entering the food chain above the action level of 1,000 Bq kg^{-1} of radiocaesium, a level based on the recommendations of an EU expert committee in 1986.

A programme of monitoring live animals, known as the Mark and Release Scheme, ensures that food safety is protected, whilst allowing established sheep farming practices to continue. A farmer wishing to move sheep out of a restricted area must have them tested using an external radiation monitor held against the sheep. Any sheep assessed to have levels of radiocaesium exceeding the limit of 1,000 Bq kg^{-1} is marked on the back of the head with coloured paint. Painted sheep may be moved off restricted areas, but cannot be sold to slaughter nor returned to the restricted areas for a minimum of three months, which allows time for the radiocaesium to pass out of the body. Results of the Mark and Release monitoring programme for 2010 are given in Table 8.1.

The Food Standards Agency is reviewing these controls to assess whether these protective measures are still required to maintain food safety. The review will include an assessment of the risk to consumers and the potential radiation dose by looking at levels of radiocaesium and peoples' consumption patterns. Sheep monitoring surveys during the summers of 2010 and 2011 in England and Wales will provide data to inform this assessment.

There have been substantial reductions in the number of farms under restriction since 1986 (Figure 8.1). In January 2010, there remained a total of 340 farms or part farms (8 in England, 2 in Scotland and 330 in Wales) subject to restrictions. There are approximately 190,000 sheep within these restricted areas. This represents a reduction of over 95 per cent since 1986, when approximately 9,700 farms and 4,225,000 sheep were under restriction across the UK. All remaining restrictions in Northern Ireland were lifted in 2000. In Scotland, restrictions for the two remaining farms were lifted in 2010, although one farm has a conditional consent to ensure sheep are clean-grazed prior to sale or slaughter.

Sampling locations for freshwater fish affected by Chernobyl are now limited to Cumbria in England, which had areas of relatively high deposition of fallout from the accident. Samples from areas of low deposition in England were also obtained for comparison. Table 8.2 presents concentrations of caesium-134 and caesium-137 in fish. Other artificial radionuclides from the Chernobyl accident are no longer detectable. In 2010, the highest concentration of caesium-137 was 130 Bq kg^{-1} in perch from Devoke Water, up from 87 Bq kg^{-1} in 2009. This apparent change is based on observations of single samples and is most likely to be due to sample variability. Levels in fish from other locations were generally similar to those in recent years, and substantially less (by an order of magnitude) than the 1,000 Bq kg^{-1} level reached shortly after the accident. Caesium-134 concentrations were below detection limits in all samples. The long-term trend of radiocaesium in freshwater fish has been reviewed (Smith *et al.*, 2000) and the effective ecological half-life of radiocaesium during the late 1990s has been shown to be between six and 30 years. Monitoring results for Devoke Water for perch and trout, over the period 1986 – 2010, are shown in Figure 8.2.

Key points

- Contamination of sheep and fish with caesium-137 from Chernobyl remains evident but is decreasing. Concentrations in fish are now less than 10 per cent of those observed in the immediate aftermath of the accident
- Monitoring and assessment was increased in 2011 because of the Fukushima-Daiichi nuclear power station incident in Japan
- Sampling of marine biota from the Channel Islands continued to monitor possible effects from French nuclear facilities discharging radioactivity into the English Channel. Doses were less than 1 per cent of the limit
- Monitoring in Northern Ireland and the Isle of Man showed low concentrations of man-made radionuclides from Sellafield and other UK nuclear facilities. Doses were approximately 1 per cent of the dose limit
- Samples from the UK food supply, air, rain and drinking water were analysed. Natural radionuclides dominated the doses due to consumption of general diet and drinking water
- Surveys of seas around the UK supported international assessments for the OSPAR Treaty and showed the extent of tritium and caesium-137 contamination. In the North Sea, caesium-137 concentrations showed a decrease over concentrations reported in 2008 from Chernobyl input

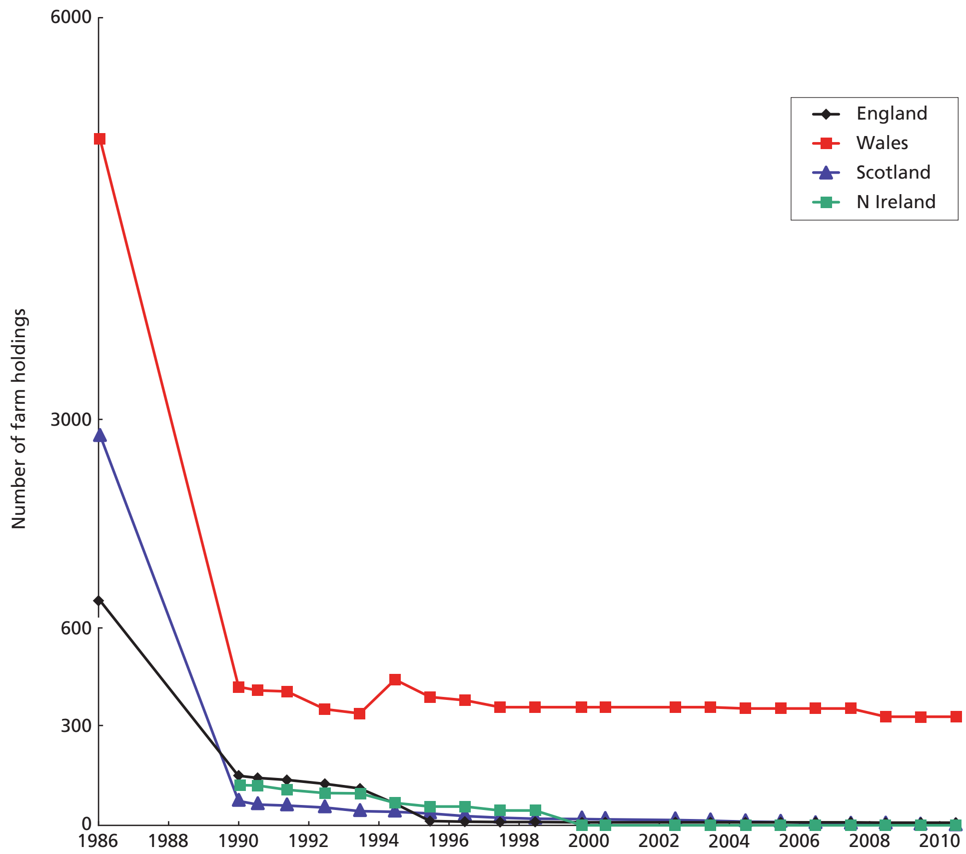


Figure 8.1. Numbers of farm holdings under restriction, 1986-2010

A cautious assessment has been made of the dose from consuming fish contaminated with radiocaesium following the Chernobyl accident. A consumption rate of 37 kg per year, sustained for one year, was taken to be an upper estimate for adults subject to the highest exposures. Actual exposures are likely to be much lower, not only because this consumption rate is higher than expected (Leonard *et al.*, 1990) but also because, in practice, hatchery-reared or farmed fish are likely to contribute most to the diet and have a much lower radiocaesium concentration. In 2010, estimated doses were less than 0.1 mSv.

8.2 Fukushima-Daiichi

On 11 March 2011, a serious nuclear accident occurred at the Fukushima-Daiichi site in north-eastern Japan, following the Tohuku earthquake and consequent tsunami. Large amounts of radioactivity were released to air and the sea. In terms of protection of UK citizens, the UK Government, together with the responsible agencies, reacted quickly, and made an assessment of risks and introduced several measures to help minimise risks to people.

These included advice to UK citizens in Japan:

- To stay away from a large area around the site
- Not to eat locally produced food
- On keeping and disposing of contaminated items

and also actions taken in the UK:

- Introduction of controls on importation of food into the UK
- Increased monitoring following positive detection of radionuclides in air across the UK, with measurements of air, rain, grass and food in the UK to check for the effects of atmospheric transport and deposition from Japan

The results of increased monitoring in Scotland have been published on the SEPA website (http://www.sepa.org.uk/radioactive_substances/publications/other_reports.aspx). Related monitoring results for the UK will be published in RIFE next year. Small amounts of iodine-131 from the Fukushima-Daiichi nuclear power station were detected in air, rain and food. The concentrations measured meant there was no risk to public health from contamination detected in the UK and the monitoring returned to routine frequency in July 2011. No contamination of food at points of entry into the UK had been detected by the time of writing this report (July 2011).

8.3 Channel Islands

Samples of marine environmental materials provided by the Channel Island States have been analysed for levels of radioactivity. The programme monitors the effects of radioactive discharges from the French reprocessing plant at Cap de la Hague and the power station at Flamanville; it also serves to monitor any effects of historical disposals of radioactive waste in the Hurd Deep, a natural trough in the western English Channel. Fish and shellfish are monitored in order to determine

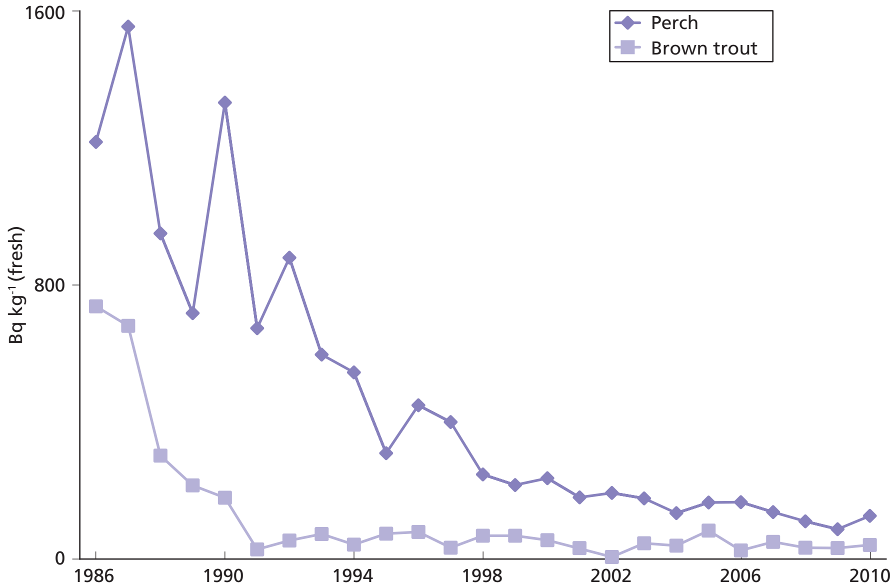


Figure 8.2. Caesium-137 concentrations in freshwater fish from Devoke Water, Cumbria

exposure from the internal irradiation pathway; sediment is analysed with relevance to external exposures. Seawater and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers.

Analysis results for 2010 are given in Table 8.3. There was evidence of routine releases from the nuclear industry in some samples (cobalt-60 and technetium-99); however, activity concentrations in fish and shellfish were low and similar to those in previous years. Apportionment to different sources, including weapon test fallout, is difficult in view of the low levels detected. No evidence for significant releases of activity from the Hurd Deep site was found.

An assessment of the dose to people who consume high-rates of fish and shellfish was undertaken, and in 2010 they were estimated to receive less than 0.005 mSv, which is 0.5 per cent of the dose limit for members of the public. The assessment included a contribution from external exposure. The concentrations of artificial radionuclides in the marine environment of the Channel Islands and the effects of discharges from local sources, therefore, continued to be of negligible radiological significance.

Milk and crop samples from the Channel Islands were also analysed. The results are included in Tables 8.7 and 8.8, respectively, and form part of the programmes considered in Sections 8.7 and 8.8.

8.4 Isle of Man

The Food Standards Agency carries out an on-going programme of radioactivity monitoring on behalf of the Department of Environment, Food and Agriculture on the Isle of Man for a range of terrestrial foodstuffs (Table 8.4). The results complement the Isle of Man Government's own independent radiation monitoring programme (www.gov.im/dlge/enviro/govlabs) and provide a comprehensive assessment of environmental radioactivity levels on the Isle of Man. Results of aquatic monitoring are presented in Section 2 because of their significance in relation to Sellafield, but are also included here for completeness (Table 8.4).

Radioactivity monitoring on the island serves two purposes: first to monitor the continuing effects of radiocaesium deposition resulting from the Chernobyl accident in 1986; and second to respond to public concern over the effects of the nuclear industry. The potential sources of exposure from the UK nuclear industry are: (i) liquid discharges into the Irish Sea and sea-to-land transfer; and (ii) gaseous discharges of tritium, carbon-14 and sulphur-35 and atmospheric transport.

Many of the analyses conducted showed that levels of radionuclides were below the limit of detection of the method used. Carbon-14 concentrations were similar to those expected from natural background, and concentrations of sulphur-35, strontium-90, radiocaesium, plutonium isotopes and americium-241 detected in local milk and crops were all similar to the values observed in the regional networks of UK dairies and crop sampling locations remote from nuclear sites. The results demonstrate that there was no significant impact on Manx foodstuffs from operation of mainland nuclear installations in 2010.

Radiation doses to people on the Isle of Man from different exposure pathways are given in Table 2.18. The dose to local people from high-rate consumption of the terrestrial foodstuffs monitored in 2010 was 0.009 mSv (0.008 mSv in 2009), which is less than 1 per cent of the dose limit for members of the public of 1 mSv. The effects of liquid discharges from Sellafield into the Irish Sea are discussed fully in Section 2. The dose to people consuming large quantities of Manx fish and shellfish was less than 0.005 mSv in 2010, which is unchanged from the 2009 dose, and residents spending a typical amount of time on sandy beaches were assessed to receive 0.010 mSv from external exposure to radionuclides entrained on the sand.

8.5 Northern Ireland

The Northern Ireland Environment Agency undertakes monitoring of the far field effects of liquid discharges into the Irish Sea from Sellafield. The programme is made up of sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 8.3). The external exposure pathway is studied by monitoring of gamma dose rates over intertidal areas. The results are presented in Tables 8.5(a) and (b).

In 2010, the main effect of discharges from Sellafield was evident as concentrations of technetium-99 in shellfish and seaweed samples. These were somewhat lower than in 2009, reflecting the considerably decreased inputs to the Irish Sea in recent years. Caesium-137 concentrations were low and similar to 2009 levels, and trace amounts of transuranic nuclides were detected. Observed concentrations were less than those found nearer to Sellafield. The radiation dose rates over intertidal areas were similar to those in previous years.

Habits representative of high-rate fish and shellfish consumers have been established by a survey of consumption and occupancy in coastal regions of Northern Ireland (Smith *et al*., 2002). The dose to the most exposed people on the basis of monitoring results from the marine environment in 2010 was 0.010 mSv, which is 1 per cent of the dose limit for members of the public.

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

8.6 General diet

As part of the Government's general responsibility for food safety, concentrations of radioactivity are determined in diets of the regions. These data (and those on other dietary components in Sections 8.7 and 8.8) form the basis of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with those from other EU Member States (e.g. Joint Research Centre, 2009). Concentrations of radioactivity in the general diet are reported to the EC by the Food Standards Agency (for England, Northern Ireland and Wales), and by SEPA (for Scotland) under a sampling programme run by the Food Standards Agency.

In 2010, the concentrations found in a survey of radioactivity in canteen meals collected across the UK (Table 8.6) were similar to the mean concentrations found in UK diet in 2009 with some higher potassium-40* levels apparent, particularly in Northern Ireland and Wales.

8.7 Milk

The programme of milk sampling across dairies in the UK continued in 2010. The aim is to collect and analyse samples for their radionuclide content on a monthly basis. The programme, together with that for crops presented in the following section, provides useful information with which to compare data from farms close to nuclear sites and other establishments that may enhance concentrations above background levels. Milk data are reported by the Food Standards Agency (for England, Northern Ireland and Wales) and SEPA (for Scotland) as part of the UK submission to the EC under Article 36 of the Euratom Treaty (e.g. Joint Research Centre, 2009).

The results are summarised in Table 8.7. 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 their limits of detection. The mean concentration of strontium-90 detected was about 0.04 Bq l^{-1}. In the past, the concentrations of radiocaesium in dairy milk were highest from regions that received the greatest amounts of Chernobyl fallout. However, the concentrations are now very low and it is less easy to distinguish this trend. The highest concentrations of caesium-137 were found in Northern Ireland.

Radiation dose from the consumption of milk at average rates was assessed for various age groups. In 2010 the maximum dose was to one-year-old infants. For the range of radionuclides analysed, the dose was less than 0.005 mSv. Previous surveys (e.g. Food Standards Agency and Scottish Environment Protection Agency, 2002) have shown that if a full range of nuclides are analysed and assessed the dose is dominated by naturally-occurring lead-210 and polonium-210 whereas man-made radionuclides contribute less than 10 per cent.

8.8 Crops

The nationwide programme of monitoring naturally-occurring and man-made radionuclides in crops continued in 2010 (Table 8.8). Tritium activity was below the LoD in most samples. Carbon-14 was generally detected at levels close to those expected to occur through natural processes. Levels of other naturally-occurring radionuclides varied from region to region. Plutonium isotopes and americium-241 were detected at trace levels in some samples. However, within the variability observed, the concentrations of all radionuclides in crops were similar to those observed in 2009.

In 2010, screening instruments for radioactivity were triggered at Dover Docks by the presence of caesium-137 in a consignment of food being imported into the UK. A sample

**The potassium content of the body is under strict homeostatic control. It remains constant in the body. The dose does not vary with the levels in the environment and is often treated separately from doses due to other naturally occurring radionuclides*

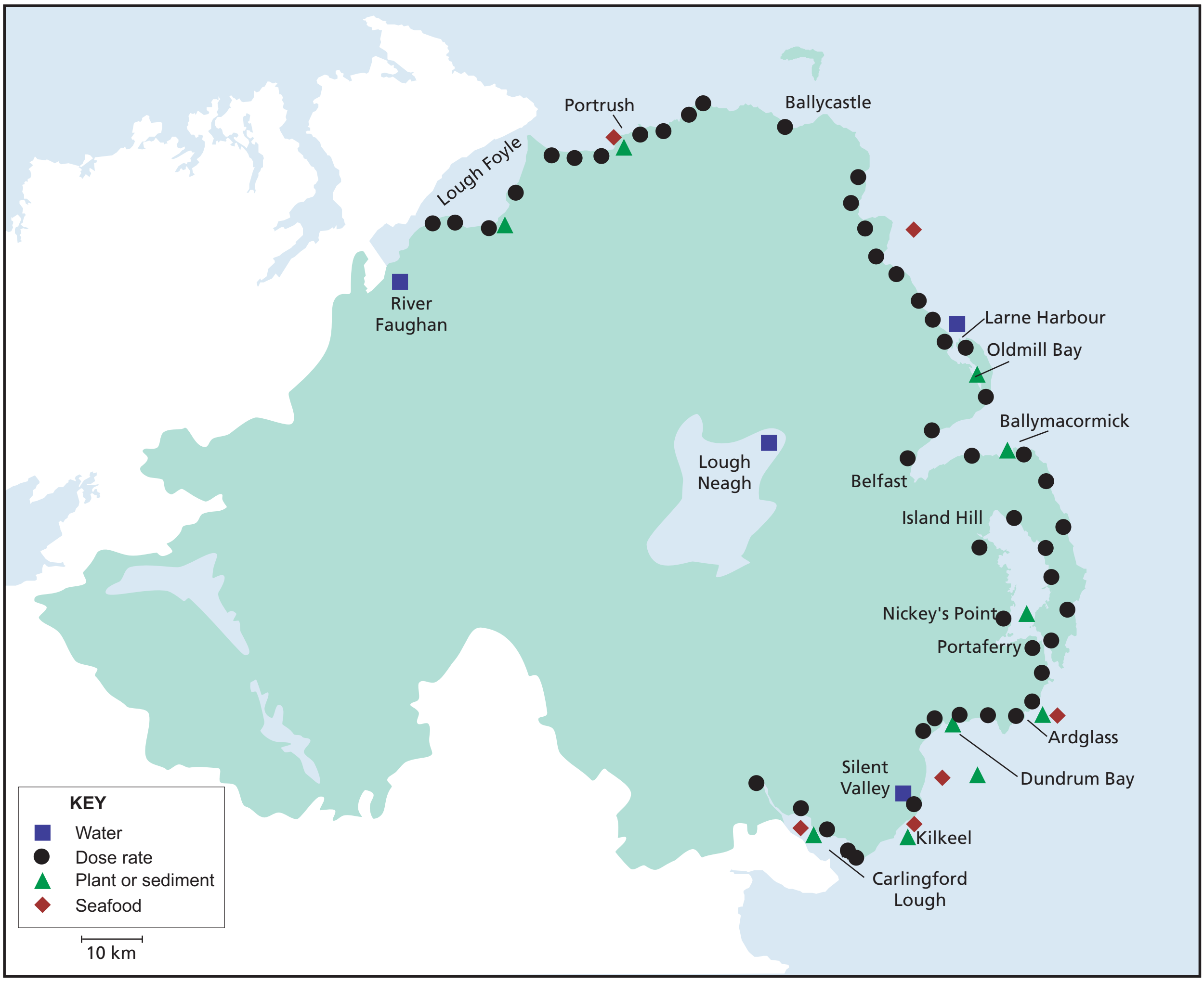


Figure 8.3. Monitoring locations in Northern Ireland, 2010

was analysed and the results are given in Table 8.9. The activity concentration was 110 Bq kg^{-1}. This was below the maximum level permissible under EC regulations, which is 600 Bq kg^{-1}, and so no action on food restrictions was necessary.

8.9 Airborne particulate, rain, freshwater, groundwater and sediments

Monitoring of radioactivity in rainwater and air took place at several UK locations as part of a monitoring programme of background sampling. These data are reported by HPA (for England, Northern Ireland and Wales) and SEPA (for Scotland) on behalf of DECC, NIEA and the Scottish Government, as part of the UK submission to the EC under Article 36 of the Euratom Treaty (e.g. Joint Research Centre, 2009). The results are given in Table 8.10. The routine programme comprised two components (i) regular sampling and analysis on a quarterly basis and (ii) supplementary analysis on an ad hoc basis by gamma-ray spectrometry. Caesium-137 concentrations were all below the limits of detection. These levels in air, typical of recent years, remain less than 0.01 per cent of those observed in 1986, the year of the Chernobyl reactor accident.

Concentrations of beryllium-7, a naturally-occurring radionuclide formed by cosmic ray reactions in the upper atmosphere were detected at similar levels at all sampling locations. Peak air concentrations of this radionuclide tend to occur during spring and early summer as a result of seasonal variations in the mixing of stratospheric and tropospheric air (Environment Agency, 2002a). Tritium concentrations in rainwater were similar to those in 2009. Concentrations in air and rainwater are very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2010 (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 (e.g. Joint Research Centre, 2009). Sampling is designed to be representative of the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples are representative of natural waters before treatment and supply to the public water system. The results in Tables 8.11, 8.12 and 8.13 show that concentrations of tritium are all substantially below the EU indicator limit for tritium of 100 Bq l^{-1}. The highest value in Scotland was found at Gullielands Burn which is near to the Chapelcross nuclear site. The origin of the local source is being investigated (see Section 4). Concentrations of gross alpha and gross beta were all below the WHO screening levels for drinking water of 0.5 and 1.0 Bq l^{-1}, respectively.

The mean annual dose from consumption of drinking water in the UK was assessed as 0.027 mSv in 2010 (Table 8.14). 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 also estimated to be 0.027 mSv (above the mean annual dose value, but rounded to two significant figures) due to radionuclides in a source of drinking water from Matlock in Derbyshire.

Separately, in 2010, SEPA took a series of groundwater samples from across Scotland with the aim of determining natural variability. Samples were taken in summer and winter to assess seasonal effects which may be caused by changes in ground water flow. The mean results are displayed in Table 8.15. All samples contained levels of tritium and caesium-137 below the limit of detection, and so in this respect the seasonal and geographical variability was low. The relatively high result for total beta activity in Ayrshire in the table is not high in the context of other measurements made for water (Tables 8.11 – 8.13).

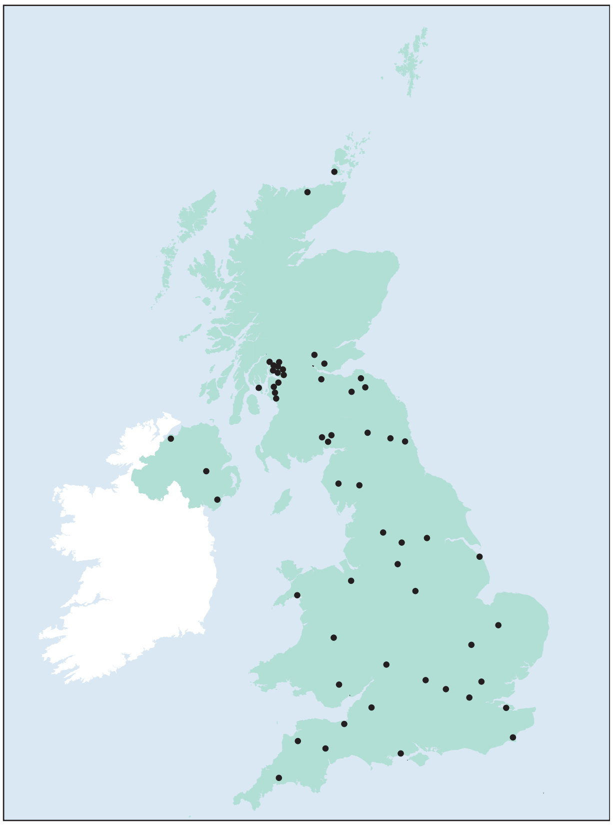


Figure 8.4. Drinking water sampling locations, 2010

8.10 Seawater surveys

The UK Government is committed to preventing pollution of the marine environment from ionising radiation, with the ultimate aim of reducing concentrations in the environment to near background values for naturally-occurring radioactive substances, and close to zero for artificial radioactive substances (Department of Energy and Climate Change, Department of the Environment, Northern Ireland, The Scottish Government and Welsh Assembly Government, 2009). Therefore a programme of surveillance into the distribution of key radionuclides is maintained using research vessels and other means of sampling.

The seawater surveys reported here also support international studies concerned with the quality status of coastal seas (e.g. OSPAR, 2010b). In 2006, OSPAR adopted the Periodic Evaluation of the Progress in Implementing the OSPAR Radioactive Substances Strategy (concerning progressive and substantial reductions in discharges of radioactive substances, as compared with the agreed baseline) (OSPAR, 2009d). The programme of radiological surveillance work provides the source data and therefore the means to monitor and make an assessment of progress in line with the UK's commitments towards OSPAR's 1998 Strategy for Radioactive Substances target for 2020. The surveys also provide information that can be used to distinguish different sources of man-made radioactivity (e.g. Kershaw and Baxter, 1995). Data have been used to examine the long distance transport of activity to the Arctic (Leonard *et al*., 1998; Kershaw *et al*., 1999) and to derive dispersion factors for nuclear sites (Baxter and Camplin, 1994). In addition, the distribution of radioactivity in seawater around the British Isles is a significant factor in determining the variation in individual exposures at coastal sites, as seafood is a major contribution to food chain doses. Evidence to help gauge progress towards achievement of the Government's vision for radionuclides and other hazardous substances is set out in a recent report (Department for Environment, Food and Rural Affairs, 2010).

The research vessel programme on radionuclide distribution currently comprises annual surveys of the Bristol Channel/western English Channel and biennial surveys of the Irish Sea and the North Sea. The results obtained in 2010 are given in Figures 8.5 – 8.9. Shoreline sampling is also conducted around the UK, and the data are given in Table 8.16. Much of the shoreline sampling is directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, commentary is found in the relevant site section.

A survey of the North Sea was conducted in 2010. The caesium-137 data from this survey (Figure 8.5) show very low concentrations (0.01 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 over the last 5 years. However in 2010, unlike previous surveys, there was no evidence of input of Chernobyl-derived caesium-137 from the Baltic (via the Skaggerak) close to the Norwegian Coast. 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 1970s. Due to significantly decreasing discharges after 1978, remobilisation of caesium-137 from contaminated sediments in the Irish Sea is now the dominant source of water contamination for most of the North Sea (McCubbin *et al*., 2002).

Caesium-137 concentrations in the Irish Sea are only a small percentage of those prevailing in the late 1970s (typically up to 30 Bq l^{-1}; Baxter *et al*., 1992), when discharges were substantially higher. The 2009 seawater survey recorded concentrations of up to 0.1 Bq l^{-1} in the eastern Irish Sea, and concentrations elsewhere were generally below 0.05 Bq l^{-1}.

The predominant source of caesium-137 to the Irish Sea is now considered to be remobilisation into the water column from activity associated with seabed sediment. Discharges from Sellafield have decreased substantially since the commissioning of the SIXEP waste treatment process in the mid 1980s, and this has been reflected in a near exponential decrease in shoreline seawater concentrations at St Bees (Figure 8.10). Longer time series showing peak concentrations in the Irish Sea and, with an associated time-lag, the North Sea are also shown in Figure 8.10.

Concentrations of caesium-137 (< 0.002 Bq l^{-1}) in the western English Channel (Figure 8.6) were not distinguishable from the background levels of global fallout (within experimental error).

A full assessment of long-term trends of caesium-137 in surface waters of Northern European seas is provided elsewhere (Povinec *et al*., 2003).

Tritium concentrations in North Sea seawater, in 2010, are shown in Figure 8.7, and were generally lower than those observed in the Irish Sea in 2009 (Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a) due to the influence of discharges from Sellafield and other nuclear sites. As in previous North Sea surveys, the concentrations of tritium were elevated (but still very low) along, and close to, the coast-line of main-land Europe (South-east North Sea). The most probable source of this is from authorised discharges of tritium from French nuclear power plants located on the coast of the English Channel.

In the Bristol Channel, the combined effect of tritium discharges from Cardiff, Berkeley, Oldbury and Hinkley Point remains evident from sample points close to these installations (Figure 8.8). These few tritium concentrations were slightly elevated in comparison to corresponding data in 2009 and 2008, but are still low in contrast to the North-east Irish Sea. Overall, the general level in the Bristol Channel is low and many

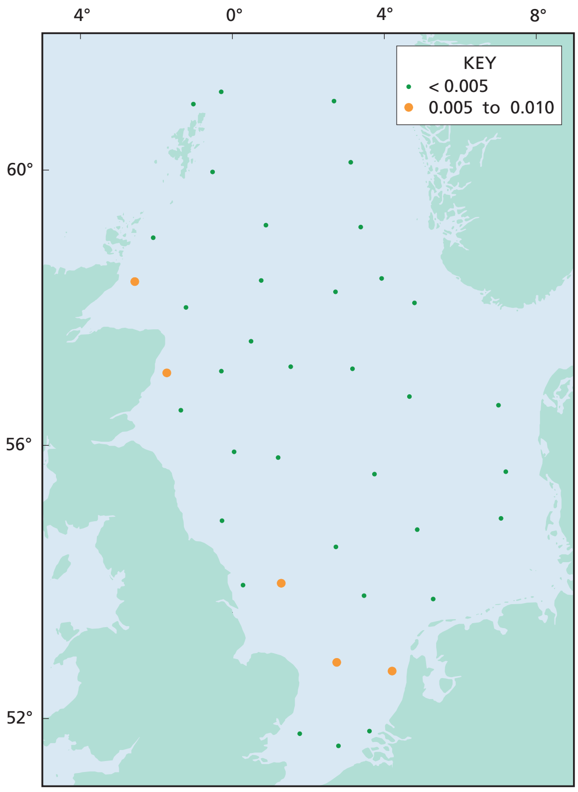


Figure 8.5. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the North Sea, August-September 2010

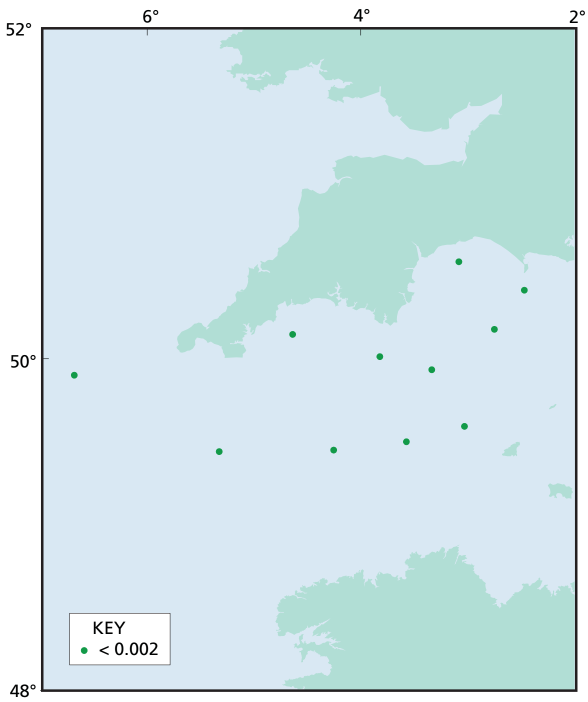


Figure 8.6. Concentrations (Bq l^{-1}) of caesium-137 in filtered surface water from the western English Channel, March 2010

samples were below the limits of detection. Tritium concentrations in the western English Channel were very low (Figure 8.9).

Technetium-99 concentrations in seawater are now decreasing following the substantial increases observed from 1994 to their most recent peak in 2003. The results of research cruises to study this radionuclide have been published by Leonard *et al*., (1997a, b; 2004) and McCubbin *et al*., (2002; 2008). Trends in plutonium and americium concentrations in seawater of the Irish Sea have been considered by Leonard *et al*. (1999). Full reviews of the quality status of the north Atlantic and a periodic evaluation of progress towards internationally agreed targets have been published by OSPAR (2000b; 2009d; 2010).

Samples of seawater were also collected as part of routine site and regional monitoring programmes. These are reported in the relevant sections of this report, and the analysis results are collated in Table 8.16. Most radionuclides are below limits of detection, and tritium and caesium-137 levels are consistent with those in Figures 8.5 – 8.9.

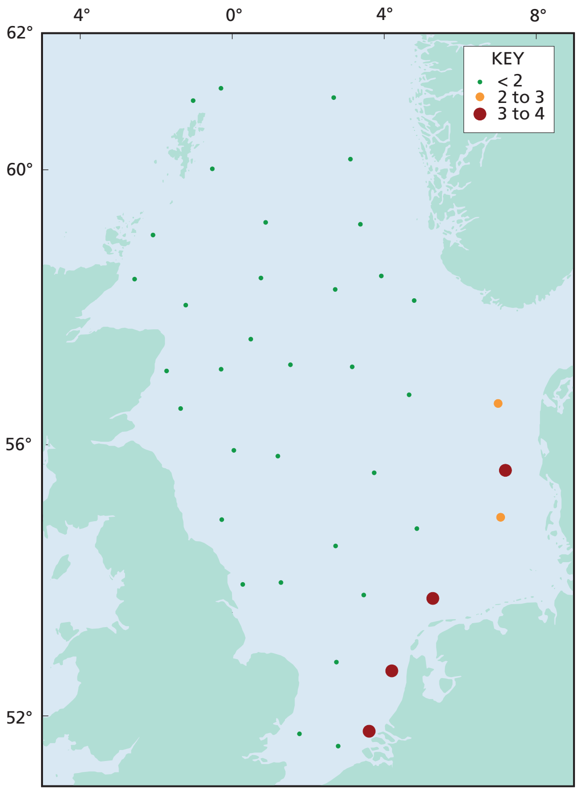


Figure 8.7. Concentrations (Bq l^{-1}) of tritium in surface water from the North Sea, August-September 2010

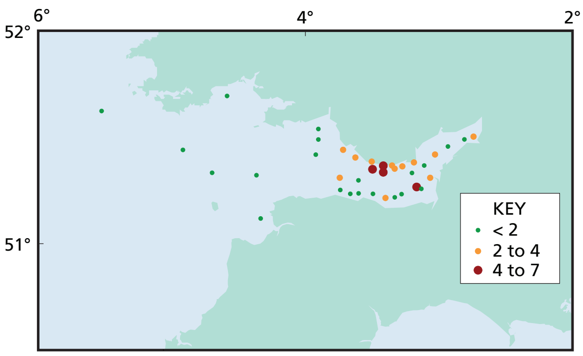


Figure 8.8. Concentrations (Bq l^{-1}) of tritium in surface water from the Bristol Channel, September 2010

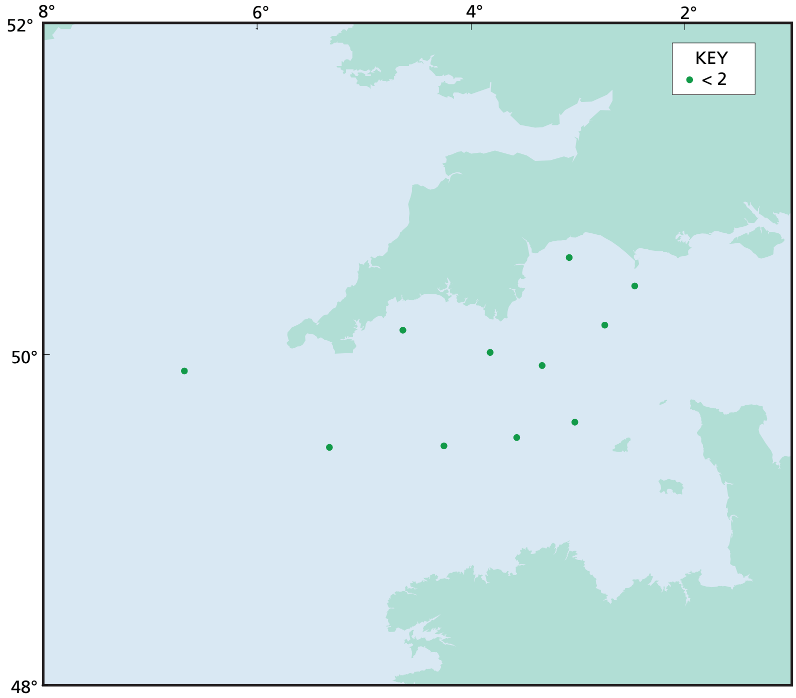


Figure 8.9. Concentrations (Bq l^{-1}) of tritium in surface water from the western English Channel, March 2010

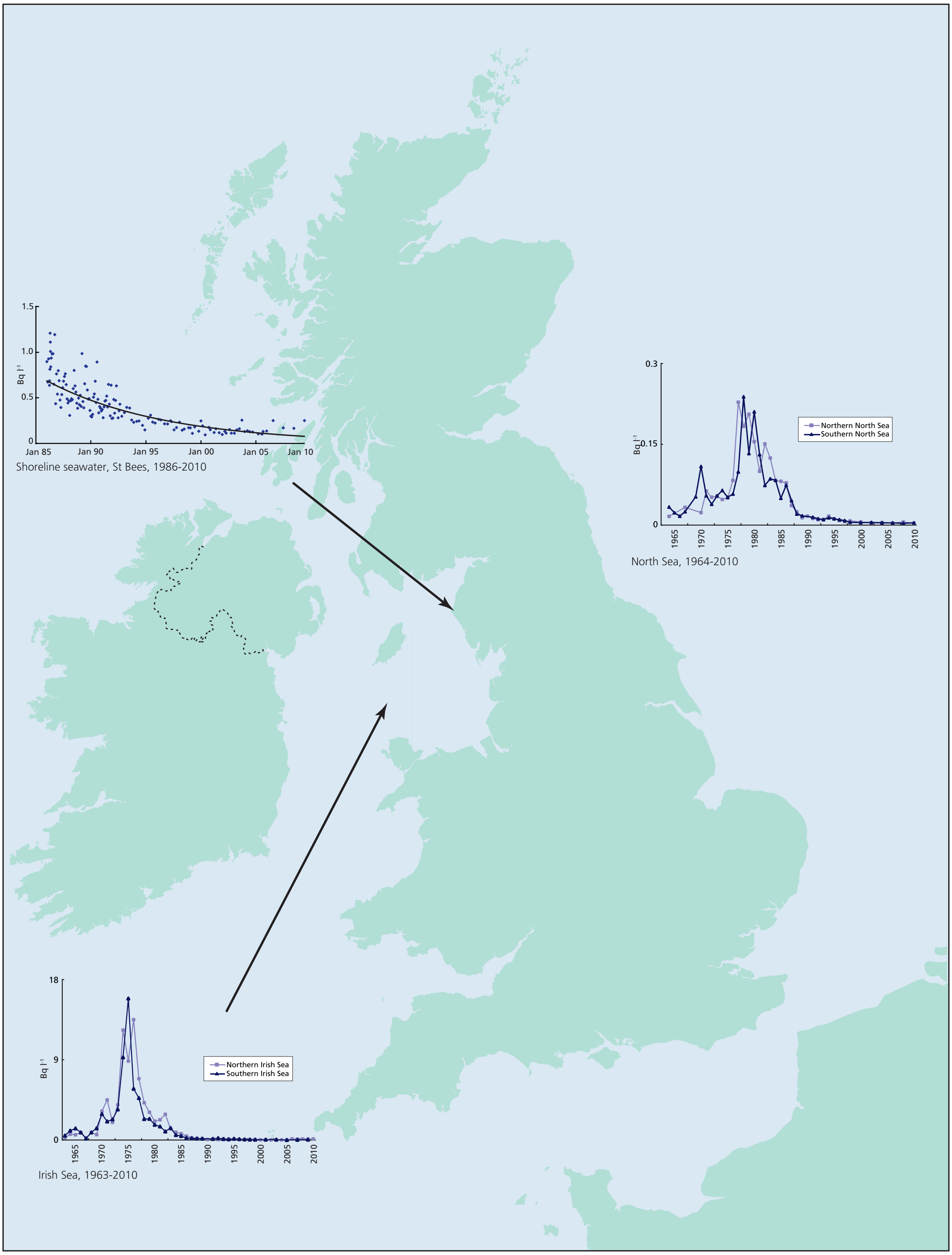


Figure 8.10. Concentration of caesium-137 in the Irish sea, North sea and in shoreline seawater close to Sellafield (at St. Bees)

Table 8.1. Mark and release monitoring of sheep in England, Wales and Scotland, 2010

	England	Wales	Scotland	United Kingdom
Number of sheep monitored	3978	71111	120[a]	75209
Number of sheep above action level	0	129	0	129
Percentage of sheep above action level	0	0.18	0	0.17
Number of farms under restriction	8	330	2	340
Approximate number of sheep	6000	180000	1200	187200
Approximate land area (ha)	12000	53000	2800	67800

[a] *Results provided monitor calibration data*

Table 8.2. Concentrations of radiocaesium in the freshwater environment, 2010

Location	Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}	
			^{134}Cs	^{137}Cs
England				
Borrowdale	Rainbow trout	1	<0.05	0.13
Cogra Moss	Rainbow trout	2	<0.06	<0.15
Narborough[a]	Rainbow trout	1	<0.08	0.19
Low Wath	Rainbow trout	1	<0.12	0.25
Devoke Water	Brown trout	1	<0.09	41
Devoke Water	Perch	1	<0.29	130
Gilcrux	Rainbow trout	1	<0.05	0.10

[a] *The concentrations of ^{14}C, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am were 41, 0.000091, 0.000070 and 0.00017 Bq kg^{-1} respectively*

Table 8.3. Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2010

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				<0.05			<0.51	
	Bass	1				<0.04			<0.44	
	Crabs	1				<0.05			<0.44	
	Lobsters	1				<0.05			<0.44	
	Limpets	1				<0.07			<0.61	
	Scallops	1				<0.06			<0.42	
	Ormers	1				<0.08			<0.66	
Fermain Bay	*Porphyra*	2				<0.10			<1.1	
Fermain Bay	*Fucus serratus*	2				<0.10	<0.080	3.4	<0.91	
St. Sampson's Harbour	Mud	1				<0.17			<1.9	
	Seawater	2								
Jersey										
	Mackerel	1				<0.04			<0.37	
	Pollack	2				<0.07			<0.60	
	Bass	1				<0.08			<0.65	
	Crabs	1				<0.06			<0.49	
	Spiny spider crabs	1				<0.09			<0.74	
	Lobsters	1				<0.04		0.77	<0.32	
La Rocque	Oysters	1				<0.02			<0.21	
La Rozel	Limpets	1				<0.04			<0.26	
	Scallops	2				<0.09			<0.39	
Plemont Bay	*Porphyra*	2				<0.06			<0.48	
La Rozel	*Fucus vesiculosus*	4				<0.07	<0.092	8.7	<0.36	
Verclut	*Fucus vesiculosus*	1				0.05			<0.48	
Verclut	*Fucus serratus*	1				0.10			<0.50	
Verclut	*Laminaria digitata*	2				<0.05			<0.37	
St Helier	Mud	1				1.8			<2.0	
Alderney										
	Crabs	2	<25	<25	40	<0.05		<0.30	<0.37	
	Spiny spider crabs	1				0.45			<0.57	
	Lobsters	1				<0.06			<0.47	
	Toothed winkles	1	27	<25	37	0.23	<0.11		<1.5	
	Fucus vesiculosus	2								0.49
Quenard Point	*Fucus serratus*	4				<0.06	<0.039	7.1	<0.42	
Quenard Point	*Laminaria digitata*	4				<0.07			<0.70	
Little Crabbe Harbour	Mud and sand	1				0.93			<2.3	
	Seawater	3		<4.7						

Table 8.3. 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	0.21	<0.15	0.00061	0.00032	0.0013	*	*	120
	Bass	1	0.26	<0.13	0.000029	0.000095	0.00022	*	*	140
	Crabs	1	<0.04	<0.08	0.00035	0.0012	0.0033	0.000078	0.00045	85
	Lobsters	1	0.06	<0.12			<0.12			75
	Limpets	1	<0.06	<0.16			<0.19			87
	Scallops	1	<0.04	<0.07	0.00047	0.0018	0.0013	*	0.00014	140
	Ormers	1	<0.07	<0.18			<0.20			82
Fermain Bay	*Porphyra*	2	<0.09	<0.14	0.0012	0.0041	0.0049	*	0.00052	64
Fermain Bay	*Fucus serratus*	2	<0.07	<0.12	0.0027	0.011	0.0052	*	0.00037	170
St. Sampson's Harbour	Mud	1	0.55	<0.40	0.034	0.13	0.15	*	0.025	500
	Seawater	2	0.002							
Jersey										
	Mackerel	1	0.11	<0.08	<0.000011	0.000033	0.000082	*	*	
	Pollack	2	0.23	<0.16			<0.19			160
	Bass	1	0.16	<0.12			<0.07			120
	Crabs	1	<0.05	<0.08	0.00030	0.0010	0.0030	*	0.00048	100
	Spiny spider crabs	1	<0.07	<0.18			<0.21			110
	Lobsters	1	0.07	<0.07	0.00019	0.00069	0.0054	*	0.00050	79
La Rocque	Oysters	1	<0.02	<0.04	0.0016	0.0051	0.0055	*	0.00053	70
La Rozel	Limpets	1	<0.03	<0.04	0.0028	0.013	0.012	*	0.0011	80
	Scallops	2	<0.06	<0.09	0.014	0.038	0.057	0.0013	0.0057	120
Plemont Bay	*Porphyra*	2	<0.05	<0.08			<0.05			96
La Rozel	*Fucus vesiculosus*	4	<0.04	<0.10	0.0089	0.026	0.011	*	0.00089	150
Verclut	*Fucus vesiculosus*	1	<0.05	<0.13			<0.16			150
Verclut	*Fucus serratus*	1	0.09	<0.10			<0.07			190
Verclut	*Laminaria digitata*	2	<0.04	<0.09			<0.09			160
St Helier	Mud	1	1.6	1.4	0.28	0.82	1.6	0.0023	0.12	720
St Catherine's Bay	Seawater	1	0.001							
Alderney										
	Crabs	2	<0.04	<0.07	0.00017	0.00056	0.0027	*	0.00030	100
	Spiny spider crabs	1	<0.05	<0.10	0.0014	0.0045	0.0057	*	0.00057	130
	Lobsters	1	<0.05	<0.07	0.00045	0.0022	0.0061	*	0.00039	99
	Toothed winkles	1	<0.14	<0.34	0.0059	0.016	0.020	0.000098	0.0025	67
	Fucus vesiculosus	2								
Quenard Point	*Fucus serratus*	4	<0.04	<0.12	0.0050	0.020	0.0067	0.000096	0.00078	190
Quenard Point	*Laminaria digitata*	4	<0.06	<0.12			<0.10			240
Little Crabbe Harbour	Mud and sand	1	1.7	<0.57			1.1			710
	Seawater	3	0.002							

* *Not detected by the method used*

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

Table 8.4. Concentrations of radionuclides in food and the environment from the Isle of Man, 2010[a]

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{60}Co	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs
Aquatic samples									
Cod	4	<0.06	<0.13	<0.10		<0.52	<0.13	<0.06	1.4
Mackerel	2	<0.08	<0.16	<0.12		<0.72	<0.20	<0.08	0.67
Herring	2	<0.10	<0.30	<0.32		<0.86	<0.20	<0.09	0.53
Lobsters	4	<0.05	<0.09	<0.07	19	<0.41	<0.10	<0.05	0.27
Scallops	4	<0.05	<0.10	<0.08		<0.40	<0.10	<0.05	0.25
Seaweed[c]	4[E]	<0.74	<0.96	<0.52	180	<4.5	<2.6	<0.61	<0.57
Sediment	1[E]	<1.0	<2.6	<0.71		<6.9	<3.7	<0.92	7.5

Material	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
		^{144}Ce	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Aquatic samples									
Cod	4	<0.23	0.000071	0.00045	0.00083	*	*		
Mackerel	2	<0.39	0.00011	0.00093	0.0019	*	*		
Herring	2	<0.40			<0.19				
Lobsters	4	<0.18			<0.08				130
Scallops	4	<0.17	0.029	0.16	0.046	*	*		
Seaweed[c]	4[E]	<2.1			<0.72				
Sediment	1[E]	<3.7			<1.4			180	500

Material or selection[d]		No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru
Terrestrial samples									
Milk		2	<4.4	15	<0.33	<0.16	0.033	<0.0040	<1.0
Milk	max		<4.5		<0.38	<0.18	0.034		<1.2
Cabbage		1	<4.0	10	<0.30	<0.20	0.092	<0.021	<1.3
Potatoes		1	<5.0	15	0.30	<0.20	0.055	<0.028	<1.5
Rhubarb		1	<5.0	4.0	0.20	<0.30	0.068		<2.4

Material or selection[d]		No. of sampling observ-ations[e]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{125}Sb	^{129}I	Total Cs	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Terrestrial samples									
Milk		2	<0.38	<0.0080	0.059	<0.00010	0.00010	<0.020	0.00010
Milk	max				0.069				
Cabbage		1	<0.40	<0.025	0.074	<0.00010	<0.00040	<0.052	0.00030
Potatoes		1	<0.20	<0.021	0.057	0.00020	<0.00030	<0.053	<0.00020
Rhubarb		1	<0.50		0.087				

* *Not detected by the method used*

[a] *The gamma dose rate in air at 1m over sand and stones at Ramsey[E] was 0.091 µGy h^{-1}*

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

[c] *The concentrations of ^{234}U, ^{235}U and ^{238}U were 1.8, <0.22 and 1.4 Bq kg^{-1} respectively*

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

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

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

Table 8.5(a). Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2010[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	49	<0.06		<0.14	<0.06	2.1
Plaice	Kilkeel	4		<0.13		<0.29	<0.13	1.0
Haddock	Kilkeel	4		<0.09		<0.21	<0.10	0.83
Herring	Ardglass	2		<0.10		<0.20	<0.10	0.59
Spurdog	North coast	1		<0.12		<0.26	<0.13	2.3
Skates / rays	North coast	3		<0.16		<0.33	<0.15	1.3
Skates / rays	Kilkeel	4		<0.19		<0.39	<0.19	0.99
Crabs	Kilkeel	4		<0.10		<0.22	<0.10	0.24
Lobsters	Ballycastle	2		<0.09	19	<0.22	<0.09	0.16
Lobsters	Kilkeel	4		<0.10	25	<0.23	<0.10	0.27
Nephrops	Kilkeel	4		<0.14	7.8	<0.29	<0.14	0.58
Winkles	Minerstown	2		<0.05		<0.11	<0.05	0.36
Mussels	Carlingford Lough	2		<0.12	13	<0.30	<0.13	0.32
Scallops	Co. Down	2		<0.07		<0.13	<0.06	0.30
Ascophyllum nodosum	Ardglass	1		<0.15		<0.37	<0.16	0.55
Ascophyllum nodosum	Carlingford Lough	1		<0.11		<0.25	<0.12	0.41
Fucus spp.	Carlingford Lough	3		<0.07	56	<0.15	<0.08	0.51
Fucus spp.	Portrush	4		<0.05		<0.09	<0.04	0.07
Fucus vesiculosus	Ardglass	3		<0.08	80	<0.16	<0.09	0.32
Rhodymenia spp.	Portaferry	4		<0.12	5.3	<0.25	<0.12	0.34
Mud	Carlingford Lough	2		<0.84		<2.2	<1.1	52
Mud	Dundrum Bay	1		<0.94		<2.6	<1.3	31
Mud	Oldmill Bay	2		<0.76		<2.1	<1.0	30
Mud	Strangford Lough-Nicky's point	2		<0.79		<2.0	<1.0	27
Mud	Ballymacormick	1		<0.63		<1.6	<0.73	13
Mud	Carrichue	1		<0.48		<1.3	<0.64	1.1
Mud and sand	Carrichue	1		<0.78		<1.7	<0.81	1.5
Mud and sand	Ballymacormick	1		<0.86		<2.2	<0.96	11
Mud and sand	Dundrum Bay	1		<0.81		<1.7	<0.92	5.5
Sand	Portrush	2		<0.42		<1.0	<0.47	<0.46
Seawater	North of Larne	12			0.0022		*	0.01

Table 8.5(a). continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cod	Kilkeel	4	<0.13			<0.14		
Plaice	Kilkeel	4	<0.22			<0.15		
Haddock	Kilkeel	4	<0.17			<0.16		
Herring	Ardglass	2	<0.17			<0.10		
Spurdog	North coast	1	<0.20			<0.10		
Skates / rays	North coast	3	<0.26			<0.18		
Skates / rays	Kilkeel	4	<0.28			<0.17		
Crabs	Kilkeel	4	<0.16			<0.10		
Lobsters	Ballycastle	2	<0.21			<0.21		
Lobsters	Kilkeel	4	<0.20			<0.17		
Nephrops	Kilkeel	4	<0.20	0.0022	0.015	0.035	*	*
Winkles	Minerstown	2	<0.10	0.051	0.31	0.21	*	*
Mussels	Carlingford Lough	2	<0.28			<0.25		
Scallops	Co. Down	2	<0.12			<0.18		
Ascophyllum nodosum	Ardglass	1	<0.34			<0.33		
Ascophyllum nodosum	Carlingford Lough	1	<0.26			<0.31		
Fucus spp.	Carlingford Lough	3	<0.18			<0.08		
Fucus spp.	Portrush	4	<0.07			<0.10		
Fucus vesiculosus	Ardglass	3	<0.15			<0.16		
Rhodymenia spp.	Portaferry	4	<0.17	0.042	0.24	0.43	0.00092	0.00027
Mud	Carlingford Lough	2	<2.1	2.2	13	8.6	*	*
Mud	Dundrum Bay	1	<3.0			<4.5		
Mud	Oldmill Bay	2	<1.9			15		
Mud	Strangford Lough- Nicky's point	2	<1.9			11		
Mud	Ballymacormick	1	<1.4			12		
Mud	Carrichue	1	<1.2	0.055	0.38	0.63	*	0.0035
Mud and sand	Carrichue	1	<1.1			0.98		
Mud and sand	Ballymacormick	1	<2.0			15		
Mud and sand	Dundrum Bay	1	<1.3			1.3		
Sand	Portrush	2	<1.1			<1.2		

* *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 8.5(b). Monitoring of radiation dose rates in Northern Ireland, 2010[a]

Location	Ground type	No. of sampling observa-tions	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lishally	Mud	1	0.061
Eglington	Shingle	1	0.050
Carrichue	Mud	1	0.069
Bellerena	Mud	1	0.061
Benone	Sand	1	0.057
Castlerock	Sand	1	0.066
Portstewart	Sand	1	0.056
Portrush, Blue Pool	Sand	1	0.056
Portrush, White Rocks	Sand	1	0.056
Portballintrae	Sand	1	0.057
Giant's Causeway	Sand	1	0.055
Ballycastle	Sand	1	0.054
Cushendun	Sand	1	0.064
Cushendall	Sand and stones	1	0.058
Red Bay	Sand	1	0.066
Carnlough	Sand	1	0.061
Glenarm	Sand	1	0.053
Half Way House	Sand	1	0.053
Ballygally	Sand	1	0.056
Drains Bay	Sand	1	0.056
Larne	Sand	1	0.057
Whitehead	Sand	1	0.062
Carrickfergus	Sand	1	0.061
Jordanstown	Sand	1	0.061
Helen's Bay	Sand	1	0.059
Groomsport	Sand	1	0.058
Millisle	Sand	1	0.068
Ballywalter	Sand	1	0.066
Ballyhalbert	Sand	1	0.064
Cloghy	Sand	1	0.068
Portaferry	Shingle and stones	1	0.087
Kircubbin	Sand	1	0.070
Greyabbey	Sand	1	0.082
Ards Maltings	Mud	1	0.080
Island Hill	Mud	1	0.070
Nicky's Point	Mud	1	0.077
Strangford	Shingle and stones	1	0.089
Kilclief	Sand	1	0.069
Ardglass	Mud	1	0.086
Killough	Mud	1	0.083
Rocky Beach	Sand	1	0.072
Tyrella	Sand	1	0.074
Dundrum	Sand	1	0.082
Newcastle	Sand	1	0.11
Annalong	Sand	1	0.11
Cranfield Bay	Sand	1	0.078
Mill Bay	Sand	1	0.10
Greencastle	Sand	1	0.078
Rostrevor	Sand	1	0.11
Narrow Water	Mud	1	0.088

[a] *All measurements are made on behalf of the Northern Ireland Environment Agency*

Table 8.6. Concentrations of radionuclides in canteen meals, 2010[a]

Region	No. of sampling observ-ations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
England	8	31	96	<0.074	<0.06
Northern Ireland	5	36	100	0.11	<0.05
Scotland	12[S]	30		<0.037	<0.04
Scotland	2	31	95	0.050	0.06
Wales	5	38	120	0.074	<0.05

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

[S] *Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency*

Table 8.7. Concentrations of radionuclides in milk remote from nuclear sites, 2010

Location	Selection[a]	No. of farms/dairies[b]	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{14}C	^{90}Sr	Total Cs
Co. Antrim		1	<4.5	13	0.019	0.13
Co. Armagh		2	<2.6	16	0.023	0.098
Co. Armagh	max		<4.0		0.024	0.11
Cambridgeshire		1	<3.0	14	0.017	0.067
Ceredigion		1	<4.0	15	0.034	0.082
Cheshire		1	<4.0	14	0.018	0.12
Clwyd		1	<2.3	15	0.024	0.068
Cornwall		1	<4.5	16	0.029	0.064
Devon		1	<4.0	14	0.031	0.065
Dorset		1	<4.0	15	0.019	0.084
Co. Down		1	<4.5	12	0.025	0.13
Dumfriesshire		1	<5.0	<14	<0.10	<0.05[c]
Essex		1	<4.5	9.5	0.016	0.063
Co. Fermanagh		1	<4.0	14	0.024	0.094
Gloucestershire		1	<4.0	15	0.021	0.062
Guernsey		1	<2.3	12	0.020	0.076
Gwynedd		1	<4.0	9.5	0.029	0.070
Hampshire		1	<4.0	11	0.024	0.066
Humberside		1	<4.5	11	0.020	0.072
Kent		1	<4.0	14	0.023	0.079
Lanarkshire		1			<0.028	0.03[c]
Lancashire		1	<4.0	13	0.022	0.083
Leicestershire		1	<4.0	14	0.019	0.064
Middlesex		1	<4.0	15	0.018	0.065
Midlothian		1	<5.0	<15	<0.11	<0.05[c]
Nairnshire		1	<5.0	<15	<0.10	<0.05[c]
Norfolk		1	<4.5	13	0.020	0.074
North Yorkshire		1	<4.0	12	0.018	0.079
Renfrewshire		1	<5.0	<14	<0.10	<0.05[c]
Co. Tyrone		1	<4.0	15	0.019	0.096
Mean Values						
Channel Islands			<2.3	12	0.020	0.076
England			<4.1	13	0.021	0.073
Northern Ireland			<3.9	14	0.022	0.11
Wales			<3.4	13	0.029	0.073
Scotland			<5.0	<15	<0.088	<0.05[c]
United Kingdom			<4.1	<14	<0.040	<0.085

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

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

[c] *^{137}Cs only*

Table 8.8. Concentrations of radionuclides in animals and crops remote from nuclear sites, 2010[a]

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{3}H	^{14}C	^{90}Sr	Total Cs	^{210}Pb	^{210}Po	^{226}Ra
Ceredigion									
Aberystwyth	Lettuce	1	<4.0	7.0	0.031	0.052	0.10	0.048	0.0080
	Potatoes	1	<4.0	20	0.13	0.090	<0.022	0.0050	0.0040
Channel Islands									
Guernsey	Blackberries	1	<4.0	17	0.047	0.017	0.020	0.016	0.022
	Lettuce	1	<4.0	6.0	0.053	0.028	0.066	0.013	0.0090
Jersey	Potatoes	1	6.0	12	<0.0070	0.038			
	Strawberries	1	<5.0	7.0	0.048	0.045			
Cornwall									
Liskeard	Kale	1	<4.0	6.0	1.4	0.32	2.5	0.88	0.032
	Potatoes	1	<5.0	13	0.071	0.15	<0.022	0.0049	0.0090
Cumbria									
Carlisle	Cabbage	1	<5.0	<3.0	0.089	0.046	<0.037	0.011	<0.0040
	Gooseberries	1	<4.0	11	0.23	0.076	0.16	0.074	0.010
Devon									
Exeter	Blackberries	1	<4.0	19	0.045	0.042	0.034	0.021	0.010
	Lettuce	1	<4.0	4.0	0.31	0.073	0.13	0.071	0.0080
Dumfriesshire									
Dumfries	Mixed diet	4			<0.10	<0.05[b]			
East Lothian									
North Berwick	Mixed diet	4			<0.10	<0.05[b]			
Gloucestershire									
Cheltenham	Strawberries	1	<5.0	11	0.019	0.21	0.039	0.0083	0.0030
Wotton-under-Edge	Cabbage	1	<4.0	<3.0	0.097	0.070	<0.036	0.0070	0.011
Kent									
Chillenden	Cabbage	1	<5.0	<3.0	0.059	0.039	<0.018	0.0098	<0.0030
	Strawberries	1	<4.0	3.0	<0.0070	0.084	<0.017	0.0071	0.014
Lincolnshire									
Spilsby	Lettuce	1	<5.0	<3.0	0.13	0.042	0.17	0.092	0.045
Skegness	Strawberries	1	<5.0	8.0	0.022	0.14	<0.033	0.0037	0.0020
Norfolk									
Norwich	Cabbage	1	<4.0	8.0	0.059	<0.012	<0.032	0.0039	0.0030
	Strawberries	1	<4.0	7.0	0.0090	0.021	<0.030	0.0073	0.0040
Northamptonshire									
Northampton	Potatoes	1	<5.0	14	0.046	0.039	0.36	0.14	0.019
Wellingborough	Spinach	1	<4.0	<3.0	0.37	0.055	<0.032	0.0041	0.32
North Yorkshire									
Thirsk	Lettuce	1	<4.0	<3.0	0.16	0.065	0.078	0.066	0.015
	Strawberries	1	<4.0	10	0.091	<0.014	0.052	0.016	0.025
Northumberland									
Otterburn	Cabbage	1	<4.0	7.0	0.12	0.031	<0.027	0.0064	0.030
	Potatoes	1	<5.0	18	0.013	0.057	<0.035	0.0054	0.0050
North Humberside									
Cottingham	Cabbage	1	<4.0	<3.0	0.36	0.076	0.12	0.054	0.013
	Potatoes	1	<5.0	20	0.041	0.037	0.031	0.0050	0.0020
Renfrewshire									
Paisley	Mixed diet	4			<0.10	<0.05[b]			
Ross-shire									
Dingwall	Mixed diet	4			<0.10	<0.05[b]			
Somerset									
Chew Magna	Chard	1	<4.0	12	0.26	0.10	0.41	0.18	0.11
	Potatoes	1	<4.0	17	0.013	0.088	<0.024	0.015	0.015
Staffordshire									
Lichfield	Cabbage	1	<5.0	6.0	0.12	0.058	0.043	0.015	0.015
	Strawberries	1	<4.0	11	0.031	0.041	<0.019	0.0019	0.027
Suffolk									
Bury St Edmunds	Lettuce	1	<4.0	3.0	0.12	0.11	<0.030	0.031	0.0070
	Potatoes	1	<5.0	19	0.025	0.10	<0.041	0.0056	0.0090
Surrey									
Guildford	Cabbage	1	<5.0	<3.0	0.30	0.48	<0.028	0.0075	0.011
	Potatoes	1	<5.0	12	0.016	0.054	<0.032	0.0084	0.012
Weybridge	Beef Kidney	1	<8.0	49	0.047	0.27			
	Beef Liver	1	<8.0	20	0.25	0.34			
	Beef Muscle	1	<5.0	26	0.012	0.21			
	Sheep Kidney/Liver	1	8.0	43	0.12	0.37			
	Sheep Muscle	1	<6.0	38	<0.0080	0.17			
Wiltshire									
Chippenham	Kale	1	<4.0	<3.0	0.43	0.045	0.075	0.032	0.070
	Strawberries	1	5.0	10	0.10	0.097	0.034	0.012	<0.0020
Mean Values[c]									
Channel Islands			<4.8	11	<0.039	0.032	0.043	0.015	0.016
England			<4.8	<13	<0.15	<0.12	<0.16	0.060	<0.018
Wales			<4.0	14	0.081	0.071	<0.061	0.027	0.0060
Scotland					<0.10	<0.05[b]			
Great Britain			<4.4	<13	<0.11	<0.079	<0.11	0.043	<0.012

Table 8.8. continued

Location	Material	No. of samples	Mean radioactivity concentration (fresh), Bq kg^{-1}						
			^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Ceredigion									
Aberystwyth	Lettuce	1	0.0028						
	Potatoes	1	<0.00050	0.0010	<0.00060	0.0013			
Channel Islands									
Guernsey	Blackberries	1	0.0012	0.0021	<0.00060	0.0012	<0.00010	<0.00020	0.00010
	Lettuce	1	<0.00070				<0.00010	<0.00020	<0.00010
Jersey	Potatoes	1					<0.00010	<0.00010	<0.00010
	Strawberries	1					0.00010	<0.00020	0.00030
Cornwall									
Liskeard	Kale	1	0.0061						
	Potatoes	1	0.0021	0.0038	0.0012	0.0032			
Cumbria									
Carlisle	Cabbage	1	<0.0010						
	Gooseberries	1	<0.00080	0.0022	<0.00060	0.0027			
Devon									
Exeter	Blackberries	1	0.0014						
	Lettuce	1	0.0068						
Gloucestershire									
Cheltenham	Strawberries	1	0.0017						
Wotton-under-Edge	Cabbage	1	0.0020	0.0056	0.00070	0.0029			
Kent									
Chillenden	Cabbage	1	<0.0010						
	Strawberries	1	0.0010						
Lincolnshire									
Spilsby	Lettuce	1	0.021						
Skegness	Strawberries	1	<0.0012						
Norfolk									
Norwich	Cabbage	1	<0.0010	0.0044	0.00060	0.0024			
	Strawberries	1	<0.00080						
Northamptonshire									
Northampton	Potatoes	1	0.0011						
Wellingborough	Spinach	1	0.012	0.0075	0.0010	0.0069			
North Yorkshire									
Thirsk	Lettuce	1	0.014						
	Strawberries	1	0.00090						
Northumberland									
Otterburn	Cabbage	1	0.0027						
	Potatoes	1	0.0015						
North Humberside									
Cottingham	Cabbage	1	0.0019						
	Potatoes	1	0.0020	0.0049	<0.00060	0.0033			
Somerset									
Chew Magna	Chard	1	0.010	0.0063	<0.00040	0.0062			
	Potatoes	1	0.013						
Staffordshire									
Lichfield	Cabbage	1	0.0015						
	Strawberries	1	<0.00060	0.0042	0.00060	<0.00090			
Suffolk									
Bury St Edmunds	Lettuce	1	<0.0014						
	Potatoes	1	0.0045						
Surrey									
Guildford	Cabbage	1	0.0028						
	Potatoes	1	0.0019	0.0042	0.00090	0.0031			
Weybridge	Beef Kidney	1		0.0052	<0.00090	0.0037	<0.00010	<0.00030	0.00030
	Beef Liver	1					<0.00010	<0.00020	0.00020
	Beef Muscle	1					<0.00010	<0.00020	0.00020
	Sheep Kidney/Liver	1					<0.00010	<0.00030	0.00050
	Sheep Muscle	1					<0.00010	<0.00020	<0.00020
Wiltshire									
Chippenham	Kale	1	0.0018						
	Strawberries	1	0.00080						
Mean Values[c]									
Channel Islands			<0.0010	0.0021	<0.00060	<0.0012	<0.00010	<0.00018	<0.00015
England			<0.0036	0.0044	<0.00073	<0.0032	<0.00010	<0.00024	<0.00028
Wales			<0.0017	0.0010	<0.00060	0.0013			
Scotland									
Great Britain			<0.0026	0.0027	<0.00066	<0.0022	<0.00010	<0.00024	<0.00028

[a] *Results are available for other artificial nuclides detected by gamma spectroscopy. All such results are less than the limit of detection*

[b] *^{137}Cs only*

[c] *Great Britain mean excludes Channel Islands. Mean values include crops and animals*

Table 8.9. Concentrations of caesium-137 in imported foods monitored at ports, 2010

Port	Country of origin	Foodstuff	No. of sampling observations	Mean radioactivity concentration, Bq kg^{-1} (fresh) ^{137}Cs	Dilution factor
Dover					
	Ukraine	Blueberries	1	110	Nil

Table 8.10. Concentrations of radionuclides in rainwater and air 2010

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a] ^{3}H	^{7}Be	^{7}Be[d]	^{90}Sr[b]	^{137}Cs
Ceredigion								
	Aberporth	Rainwater	4	<1.2	1.5			<0.014
		Air	4		0.0016			$<7.2\ 10^{-7}$
Co. Down								
	Conlig	Rainwater	4		1.3			<0.019
		Air	4		$7.9\ 10^{-4}$			$<7.6\ 10^{-7}$
Dumfries and Galloway								
	Eskdalemuir	Rainwater	4	<1.2	1.5			<0.018
		Air	4		0.0012			$<7.1\ 10^{-7}$
Glasgow								
	Glasgow	Air	6					<0.010
North Yorkshire								
	Dishforth	Rainwater	4		2.2			<0.017
		Air	4		0.0010			$<8.8\ 10^{-7}$
Oxfordshire								
	Chilton	Rainwater	4		0.98	1.8	0.0010	<0.017
		Air	12		0.0014			$<2.7\ 10^{-7}$
Shetland								
	Lerwick	Rainwater	4		1.4			<0.019
		Air	4		0.0012			$<8.4\ 10^{-7}$
Suffolk								
	Orfordness	Rainwater	4	<1.3	2.7			<0.022
		Air	4		0.0015			$<9.4\ 10^{-7}$

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a] ^{137}Cs[d]	$^{239}Pu+^{240}Pu$[c]	^{241}Am[c]	Gross alpha[d]	Gross beta[d]
Ceredigion								
	Aberporth	Rainwater	4		$5.7\ 10^{-6}$	$5.2\ 10^{-6}$		
		Air	4		$4.6\ 10^{-10}$	$<3.0\ 10^{-10}$		
Glasgow								
	Glasgow	Air	6					<0.0020
Oxfordshire								
	Chilton	Rainwater	4	$<6.3\ 10^{-4}$			0.043	0.037

[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 8.11. Concentrations of radionuclides in sources of drinking water in Scotland, 2010

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	<1.2	<0.0052	<0.01	<0.010	0.027
Argyll and Bute	Auchengaich	1	<1.2		<0.01	<0.010	0.032
Argyll and Bute	Helensburgh Reservoir	1	<1.2		<0.01	<0.010	0.027
Argyll and Bute	Loch Ascog	1	<1.2		<0.01	<0.011	0.10
Argyll and Bute	Loch Eck	1	<1.2		<0.01	<0.010	0.017
Argyll and Bute	Lochan Ghlas Laoigh	1	<1.2		<0.01	<0.010	0.019
Argyll and Bute	Loch Finlas	1	<1.2		<0.01	<0.010	0.035
Clackmannanshire	Gartmorn	1	<1.2		<0.01	<0.010	0.13
Dumfries and Galloway	Black Esk	1	<1.1		<0.01	<0.010	0.015
Dumfries and Galloway	Gullielands Burn	1	31		<0.01	<0.014	0.36
Dumfries and Galloway	Purdomstone	1	<1.2		<0.01	<0.010	0.063
Dumfries and Galloway	Winterhope	1	<1.1		<0.01	<0.010	0.042
East Lothian	Hopes Reservoir	1	<1.2		<0.01	<0.010	<0.014
East Lothian	Thorters Reservoir	1	<1.2		<0.01	<0.010	<0.014
East Lothian	Whiteadder	1	<1.2		<0.01	<0.010	<0.014
East Lothian	Thornton Loch Burn	1	<1.0		<0.01	<0.011	0.15
Fife	Holl Reservoir	1	<1.2		<0.01	<0.010	0.035
Highland	Loch Baligill	1	<1.1		<0.01	<0.010	0.018
Highland	Loch Calder	1	<1.1		<0.01	<0.010	0.015
Highland	Loch Glass	4	<1.1	<0.0050	<0.01	<0.010	0.025
Highland	Loch Shurrerey	1	<1.1		<0.01	<0.010	0.017
North Ayrshire	Camphill	1	<1.2		<0.01	<0.010	0.022
North Ayrshire	Knockendon Reservoir	1	<1.0		<0.01	<0.010	0.038
North Ayrshire	Munnoch Reservoir	1	<1.2		<0.01	<0.012	0.069
North Ayrshire	Outerwards	1	<1.2		<0.01	<0.010	0.019
Orkney Islands	Heldale Water	1	<1.1		<0.01	<0.010	0.016
Perth and Kinross	Castlehill	1	<1.2		<0.01	<0.010	0.024
Scottish Borders	Knowesdean	4	<1.1	<0.0050	<0.01	<0.033	<0.044
Stirling	Loch Katrine	12	<1.1	0.0033	<0.002	<0.010	<0.022
West Dunbartonshire	Loch Lomond (Ross Priory)	1	<1.2		<0.01	<0.010	0.033
West Lothian	Morton No 2	1	<1.0		<0.01	<0.012	0.068

Table 8.12. Concentrations of radionuclides in sources of drinking water in England and Wales, 2010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{40}K	^{90}Sr	^{125}I
England						
Buckinghamshire	Bourne End, Groundwater	4	<4.0	0.035	<0.0010	
Cambridgeshire	Grafham Water	4	<4.0	0.31	0.0016	
Cheshire	River Dee, Chester	2	<4.0	<0.040	0.0014	
Cornwall	River Fowey	4	<4.0	0.065	0.0016	<0.0037
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<4.0	0.053	0.0023	
County Durham	Honey Hill Water Treatment Works, Consett	4	<4.0	0.031	0.0033	
County Durham	River Tees, Darlington	4	<4.0	0.046	0.0018	<0.0021
Cumbria	Haweswater Reservoir	4	<4.0	<0.013	0.0016	
Cumbria	Ennerdale Lake	4	<4.0	<0.010	0.0016	
Derbyshire	Arnfield Water Treatment Plant	4	<4.0	<0.015	<0.0010	
Derbyshire	Matlock, Groundwater[a]	4	<4.0	0.033	<0.0010	
Devon	River Exe, Exeter	4	<4.0	<0.049	<0.0021	<0.0036
Gloucestershire	River Severn, Tewkesbury	3	<4.0	0.14	0.0012	<0.0026
Greater London	River Lee, Chingford	4	<4.0	0.28	<0.0010	<0.0021
Hampshire	River Avon, Christchurch	4	<4.0	0.054	<0.0010	<0.0038
Humberside	Littlecoates, Groundwater	4	<4.0	0.065	<0.0011	
Kent	Denge, Shallow Groundwater	4	<4.0	0.11	0.0018	
Kent	Chatham, Deep Groundwater	4	<4.0	0.043	<0.0010	
Lancashire	Corn Close, Groundwater	4	<4.0	0.056	<0.0010	
Norfolk	River Drove, Stoke Ferry	4	<4.0	0.10	<0.0013	<0.0022
Northumberland	Kielder Reservoir	4	<4.0	<0.059	<0.0016	
Oxfordshire	River Thames, Oxford	4	<4.0	0.17	<0.0010	<0.0022
Somerset	Ashford Reservoir, Bridgwater	4	<4.0	0.064	<0.0010	
Somerset	Chew Valley Lake Reservoir, Bristol	4	<4.0	0.12	0.0017	
Surrey	River Thames, Walton	4	<4.0	0.19	<0.0012	0.0016
Surrey	River Thames, Chertsey	4	<4.0	0.18	<0.0012	<0.0021
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	4	<4.0	0.066	<0.0013	
Yorkshire	Chellow Heights, Bradford	4	<4.0	<0.016	0.0032	

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England						
Buckinghamshire	Bourne End, Groundwater	4	<0.0010	<0.021	0.062	<0.049
Cambridgeshire	Grafham Water	4	<0.0010	0.025	0.44	0.27
Cheshire	River Dee, Chester	2	<0.0015			
Cornwall	River Fowey	4	<0.0010	0.049	0.12	0.072
Cornwall	Roadsford Reservoir, Dowrglann, St Austell	4	<0.0010	<0.020	0.086	0.054
County Durham	Honey Hill Water Treatment Works, Consett	4	0.0022	0.060	0.15	0.092
County Durham	River Tees, Darlington	4	<0.0010	<0.020	0.076	0.051
Cumbria	Haweswater Reservoir	4	<0.0010	<0.020	<0.050	<0.050
Cumbria	Ennerdale Lake	4	<0.0010	<0.020	<0.049	<0.050
Derbyshire	Arnfield Water Treatment Plant	4	<0.0010	<0.020	<0.051	<0.050
Derbyshire	Matlock, Groundwater[a]	4	<0.0010	0.10	0.10	0.062
Devon	River Exe, Exeter	4	<0.0023	<0.020	0.10	0.064
Gloucestershire	River Severn, Tewkesbury	3	<0.0010	0.042	0.24	0.15
Greater London	River Lee, Chingford	4	<0.0010	0.029	0.41	0.25
Hampshire	River Avon, Christchurch	4	<0.0011	<0.020	0.12	0.074
Humberside	Littlecoates, Groundwater	4	<0.0020	0.021	0.14	0.087
Kent	Denge, Shallow Groundwater	4	<0.0010	<0.020	0.16	0.10
Kent	Chatham, Deep Groundwater	4	<0.0010	<0.022	0.062	<0.049
Lancashire	Corn Close, Groundwater	4	<0.0010	<0.020	0.081	<0.061
Norfolk	River Drove, Stoke Ferry	4	<0.0010	0.030	0.16	0.10
Northumberland	Kielder Reservoir	4	<0.0022	0.020	0.048	<0.050
Oxfordshire	River Thames, Oxford	4	<0.0010	0.023	0.24	0.14
Somerset	Ashford Reservoir, Bridgwater	4	<0.0010	0.020	0.11	0.069
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.0010	0.023	0.18	0.11
Surrey	River Thames, Walton	4	<0.0010	0.020	0.32	0.20
Surrey	River Thames, Chertsey	4	<0.0010	0.023	0.29	0.18
Yorkshire	Eccup No. 1, Washburn Valley, Leeds	4	<0.0011	0.017	0.11	0.069
Yorkshire	Chellow Heights, Bradford	4	<0.0010	<0.019	0.050	<0.050

Table 8.12. continued

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}		
			^{3}H	^{40}K	^{90}Sr
Wales					
Gwynedd	Cwm Ystradllyn Treatment Works	4	<4.0	<0.015	0.0025
Mid-Glamorgan	Llwyn-on Reservoir	4	<4.0	<0.028	<0.0014
Powys	Elan Valley Reservoir	4	<4.0	<0.015	0.0019

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration , Bq l^{-1}			
			^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	0.0014	<0.020	<0.048	<0.050
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.0010	<0.019	<0.049	<0.050
Powys	Elan Valley Reservoir	4	<0.0010	<0.020	<0.051	<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 <0.0095, <0.010, 0.040, <0.010 and 0.021 Bq l^{-1} respectively*

Table 8.13. Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2010

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	<1.2	0.0031	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.020	0.12
Co. Antrim	Lough Neagh	4	<1.2	0.0024	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.030	0.38
Co. Down	Silent Valley	4	<1.2	0.0023	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010	0.16	0.21

Table 8.14. Estimates of radiation exposure from radionuclides in drinking water, 2010[a]

Region	Mean exposure, mSv per year			Maximum exposure, mSv per year	
	Man-made radionuclides[b,c]	Naturally occurring radionuclides[b]	All radionuclides	Location	All radionuclides
England	<0.001	0.027	0.027	Matlock, Groundwater, Derbyshire	0.027
Wales[d]	<0.001			Cwm Ystradllyn Treatment Works Gwynedd	<0.001[d]
Northern Ireland	<0.001	0.026	0.027	R Faughan, Co. Londonderry	0.027
Scotland[d]	<0.001			Loch Lee, Angus	<0.001[d]
UK	<0.001	0.027	0.027	Matlock, Groundwater, Derbyshire	0.027

[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 8.15. Analysis of groundwater in Scotland, 2010

Location	Sample source	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{137}Cs	Gross alpha	Gross beta
Aberdeenshire	Turriff, Borehole	2	<1.9	<0.01	<0.072	<0.057
Angus	Forfar, Borehole	2	<3.1	<0.01	0.037	0.059
Ayrshire	Kilmarnock, Borehole	1	<5.0	<0.01	0.026	0.21
Dumfriesshire	Dumfries, Deep borehole	2	<3.1	<0.01	0.026	0.063
Dumfriesshire	Moffat, Deep borehole	1	<1.2	<0.01	0.014	0.029
East Lothian	Dunbar, Borehole	1	<5.0	<0.01	0.015	0.080
Highlands	Fort William, Borehole	2	<1.9	<0.01	<0.018	0.042
Highlands	Tomatin, Borehole	2	<1.9	<0.01	<0.011	0.045
Moray	Fochabers, Borehole	2	<1.9	<0.01	<0.011	0.096
Perth and Kinross	Kinross, Deep borehole	2	<3.1	<0.01	<0.012	0.078

Table 8.16. Concentrations of radionuclides in seawater, 2010

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}						
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag
Dounreay (Sandside Bay)	4	<1.1		<0.10			<0.54	<0.10
Dounreay (Brims Ness)	4	<1.1		<0.10			<0.46	<0.10
Rosyth	2	<1.2		<0.10			<0.54	<0.10
Torness	2	<4.1		<0.10			<0.32	<0.10
Hartlepool (North Gare)	2	<4.8		<0.25			<1.9	<0.28
Sizewell	2	<2.9		<0.24			<1.8	<0.25
Bradwell	2			<0.25			<1.8	<0.26
Dungeness south	2	<15		<0.25			<1.9	<0.27
Winfrith (Lulworth Cove)	1			<0.31			<2.4	<0.40
Alderney	3[F]	<4.7						
Devonport (Millbrook Lake)	2	<3.5	<5.0	<0.26				
Devonport (Tor Point South)	2	<3.1	<7.2	<0.30				
Hinkley	2			<0.33	<0.045		<2.4	<0.33
Berkeley and Oldbury	2			<0.25			<1.8	<0.26
Cardiff (Orchard Ledges)[a]	2	<14	<3.8	<0.30				
Holyhead	4[C]	<1.5						
Wylfa (Cemaes Bay)	2	<2.9		<0.34			<2.5	<0.34
Wylfa (Cemlyn Bay West)	2			<0.25			<1.8	<0.27
Heysham (inlet)	2	<7.3		<0.33			<2.4	<0.32
Seascale (Particulate)	2			<0.05	<0.050		<0.38	<0.06
Seascale (Filtrate)	2			<0.38	<0.050	<0.25	<2.7	<0.42
St. Bees	4	<8.3				<0.29		
St. Bees (Particulate)	2			<0.06	<0.020		<0.49	<0.06
St. Bees (Filtrate)	2	<13		<0.25	<0.040	<0.27	<1.9	<0.22
Seafield	4	<1.6		<0.10			<0.54	<0.11
Southerness[b]	4	<6.2		<0.10			<0.56	<0.10
Auchencairn	4	3.2		<0.10			<0.54	<0.10
Knock Bay	4	<1.1		<0.10			<0.64	<0.10
Knock Bay	4[C]	<2.1						
Hunterston	2	2.8		<0.10			<0.46	<0.10
Hunterston (South of pipeline)	2	2.3		<0.10			<0.41	<0.10
North of Larne	12[N]					0.0022		
Faslane (Carnban)	2	<1.2		<0.10			<0.42	<0.10

Table 8.16. continued

Location	No. of sampling observ-ations	Mean radioactivity concentration, Bq l^{-1}					
		^{134}Cs	^{137}Cs	^{144}Ce	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	4	<0.10	<0.10	<0.32	<0.11		
Dounreay (Brims Ness)	4	<0.10	<0.10	<0.29	<0.10		
Rosyth	2	<0.10	<0.10	<0.37	<0.10		
Torness	2	<0.10	<0.10	<0.21	<0.10		
Hartlepool (North Gare)	2	<0.23	<0.20	<1.0	<0.30	<5.5	15
Sizewell	2	<0.23	<0.20	<0.96	<0.31	<3.0	17
Bradwell	2	<0.24	<0.21	<1.1	<0.35	<3.5	12
Dungeness south	2	<0.24	<0.22	<1.1	<0.34	<4.0	15
Winfrith (Lulworth Cove)	1	<0.28	<0.26	<0.98	<0.31	<0.90	4
Alderney	3[F]	*	0.002				
Jersey	1[F]	*	0.001				
Guernsey	3[F]	*	0.002				
Hinkley	2	<0.31	<0.27	<1.1	<0.33	<2.5	14
Berkeley and Oldbury	2	<0.23	<0.21	<1.1	<0.34	<3.4	10
Cardiff (Orchard Ledges)[a]	2		<0.24				
Holyhead	4[C]	*	0.01				
Wylfa (Cemaes Bay)	2	<0.31	<0.28	<1.3	<0.38	<2.0	9.8
Wylfa (Cemlyn Bay West)	2	<0.24	<0.20	<1.0	<0.31	<4.0	19
Llandudno	1[C]	*	0.02				
Prestatyn	1[C]	*	0.03				
New Brighton	1[C]	*	0.04				
Ainsdale	1[C]	*	0.06				
Rossall	1[C]	*	0.04				
Heysham (inlet)	2	<0.30	<0.27	<1.1	<0.33	<3.5	11
Half Moon Bay	1[C]	*	0.09				
Silecroft	1[C]	*	0.05				
Seascale (Particulate)	2	<0.05	<0.08	<0.16	<0.19	0.48	0.18
Seascale (Filtrate)	2	<0.36	<0.30	<1.3	<0.42	<2.5	14
St. Bees	4	<0.27	<0.25				
St. Bees (Particulate)	2	<0.06	<0.06	<0.20	0.12	<0.15	0.45
St. Bees (Filtrate)	2	<0.24	<0.22	<1.0	<0.31	<2.0	15
Whitehaven	1[C]	*	0.05				
Maryport	1[C]	*	0.08				
Silloth	1[C]	*	0.08				
Seafield	4	<0.10	<0.17	<0.37	<0.11		
Southerness[b]	4	<0.10	<0.13	<0.38	<0.0035		
Auchencairn	4	<0.10	<0.10	<0.32	<0.10		
Ross Bay	1[C]	*	0.04				
Isle of Whithorn	1[C]	*	0.03				
Drummore	1[C]	*	0.03				
Knock Bay	4	<0.10	<0.10	<0.39	<0.11		
Knock Bay	4[C]	*	0.02				
Hunterston	2	<0.10	<0.10	<0.30	<0.12		
Hunterston (South of pipeline)	2	<0.10	<0.10	<0.24	<0.10		
North of Larne	12[N]	*	0.01				
Faslane (Carnban)	2	<0.10	<0.10	<0.30	<0.11		

* *Not detected by the method used*

[a] *The concentration of ^{3}H as tritiated water was <3.5 Bq l^{-1}, and the concentration of ^{125}I was <2.1 Bq l^{-1}*

[b] *The concentrations of ^{238}Pu and $^{239+240}Pu$ were <0.00055 and <0.0033 Bq l^{-1} respectively*

[C] *Measurements labelled "C" are made by Cefas on behalf of Defra*

[F] *Measurements labelled "F" are made on behalf of the Food Standards Agency and the Channel Island States*

[N] *Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency*

9. References

(Includes references from Appendix 1: CD supplement)

Allars, K, and McHugh, J., 2011. Generic Design Assessment Progress Report. Reporting Period 1 January 2011 – 31 March 2011. HSE and Environment Agency, Bristol and London.

Allott, R., 2005. Assessment of compliance with the public dose limit. Principles for the assessment of total retrospective public doses. NDAWG/2/2005. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Baxter, A.J. and Camplin, W.C., 1994. The use of caesium-137 to measure dispersion from discharge pipelines at nuclear sites in the UK. Proc. Instn. Civ. Engrs. Wat., Marit. And Energy, (106): 281 – 288.

Baxter, A.J., Camplin, W.C. and Steele, A.K., 1992. Radiocaesium in the seas of northern Europe: 1975 – 79. Fish. Res. Data Rep., MAFF Direct. Fish. Res., Lowestoft, (28): 1 – 166.

Beresford, N.A., Wood, M.D., Bescoby, M., Caborn, J.C., and Barnett, C.L., 2008. Sampling at Drigg sand dunes. SC070019. Environment Agency, Bristol and London.

BNFL, 2002. Discharges and monitoring of the environment in the UK. Annual Report 2001. BNFL, Warrington.

British Energy, 2009. Sizewell B Dry Fuel Store Environmental Scoping Report, T6730/SZB/R003/303075/PBor, September 2009, British Energy Group Plc.

Brenk, H.D., Onishi, Y., Simmonds, J.R. and Subbaratnam, T., (unpublished). A practical methodology for the assessment of individual and collective radiation doses from radionuclides in the environment. International Atomic Energy Authority draft working document no. 1987 – 05 – 06, Vienna.

Brown, J.E., Alfonso, B., Avila, R., Beresford, N.A., Copplestone, D., Pröhl, G., Ulanovsky A., 2008. The ERICA Tool. J. Environ. Rad., 99, 1371-1383.

Brown, J. and Etherington, G., 2011. Health Risks from Radioactive Objects on Beaches in the Vicinity of the Sellafield Site. HPA-CRCE-018, April 2011, HPA, Chilton.

Brown, J., Hammond, D., Wilding, D., Wilkins, B.T., and Gow, C., 2009. Transfer of radioactivity from seaweed to terrestrial foods and potential radiation exposures to members of the public: 2009. HPA-RPD-059. HPA, Chilton.

Byrom, J., Robinson, C.A., Simmonds, J.R., Walters, C.B. and Taylor, R.R., 1995. Food consumption rates for use in generalised radiological dose assessments. J. Rad. Prot., 15(4): 335 – 342.

Camplin, W.C. and Jenkinson, S., 2007. Use of measurements in determining retrospective dose assessments in RIFE. (NDAWG/11/03) 2007. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Camplin, W.C., Rollo, S. and Hunt, G.J., 2000. Surveillance related assessments of sea-to-land transfer. In Proceedings of the Second RADREM - TESC Workshop held in London 21 January 1999. Edited by Ould-Dada, Z. DETR/RADREM/00.001. DETR, London.

Camplin, W.C., Grzechnik, M. and Smedley, C.A., 2005. Methods for assessment of total dose in the Radioactivity in Food and the Environment report. NDAWG/3/2005. Environment Agency, Food Standards Agency, HPA, NII, Chilton.

Clyne, F.J., Gough, C., Edgar, A. and Smedley, C.A., 2008a. Radiological Habits Survey: Sellafield Beach Occupancy, 2007. Project C3015. RL 02/08. Cefas, Lowestoft

Clyne, F.J., Tipple, J.R., Garrod, C.J. and Smedley, C.A., 2008b. Radiological Habits Survey: Berkeley and Oldbury, 2007. Project C2848. RL 06/08. Cefas, Lowestoft.

Clyne, F.J., Tipple, J.R. Garrod, C.J., and Jeffs, T.M., 2009. Radiological Habits Survey: Sellafield 2008. Project C2448. RL 02/09. Cefas, Lowestoft.

Clyne, F.J., Gough, C., Edgar, A., Garrod, C.J. Elliott, J., 2010a. Radiological Habits Survey: Sellafield Beach Occupancy, 2009. Project C3635. RL 01/10. Cefas, Lowestoft

Clyne, F.J., Garrod, C.J. and Elliott, J., 2010b. Radiological Habits Survey: Amersham 2009. Project C2848. RL 04/10. Cefas, Lowestoft.

Clyne, F.J., Garrod, C.J., Tipple, J.R. and Jeffs, T.M., 2011a. Radiological Habits Survey: Dounreay 2008. Project C3635. RL 03/11. Cefas, Lowestoft.

Clyne, F.J., Garrod, C.J., Tipple, J.R. and Jeffs, T.M., 2011b. Radiological Habits Survey: Dumfries and Galloway Coast, 2007. Project C2448. RL 08/11. Cefas, Lowestoft.

Clyne, F.J., Elliott, J. and Garrod, C.J., 2011c. Radiological Habits Survey: Dunnet Bay Beach Occupancy, 2009. Project C3615. RL 10/11. Cefas, Lowestoft

Clyne, F.J., Garrod, C.J., Ly, V.E. and Rumney, P., 2011d. Radiological Habits Survey:

Dungeness, 2010. Project C2848. RL 11/11. Cefas, Lowestoft.

Clyne, F.J., Garrod, C.J., Rumney. P., Hughes, L.M. and Ly, V.E., 2011e. Radiological Habits Survey:

Hinkley Point, 2010. Project C2848. RL 01/11. Cefas, Lowestoft.

Clyne, F.J., Garrod, C.J., Rumney. P. and Ly, V.E., (in press). Radiological Habits Survey: Chapelcross, 2010.

Codex Alimentarius Commission, 2006. Codex Alimentarius Commission Report, Twenty-ninth session 3-7 July 2006. AL INORM 06/29/41. Codex, Rome.

Commission of the European Communities, 1989. Council regulation (Euratom) No 3954/87 laying down the maximum permitted levels of radioactive contamination of foodstuffs and feeding stuffs following a nuclear accident or any other case of radiological emergency. OJ 11(L371), amended by Council Regulation 2218/89 OJ 1(L211).

Commission of the European Communities, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. OJ L206: 7 – 50.

Commission of the European Communities, 1996. Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation. OJ 39(L159): 1 – 114.

Commission of the European Communities, 1998. Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. OJ L330: 32 – 54.

Commission of the European Communities, 1999a. Council Directive 1999/2/EC of the European Parliament and of the Council of 22 February 1999 on the approximation of the laws of Member States concerning foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 16.

Commission of the European Communities, 1999b. Council Directive 1999/3/EC of the European Parliament and of the Council of 22 February 1999 on the establishment of a Community list of foods and food ingredients treated with ionising radiation. OJ L 66, 13.3.99, 24.

Commission of the European Communities, 2000a. Commission recommendation on the application of Article 36 of the Euratom Treaty concerning the monitoring of the concentrations of radioactivity in the environment for the purpose of assessing the exposure of the population as a whole. OJ 27th July 2000. 2000/473/Euratom.

Commission of the European Communities, 2000b. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L327 22/12/2000 1 – 73.

Commission of the European Communities, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Directive). OJ L164.

Commission of the European Communities, 2010. Draft Euratom Basic Safety Standards Directive. Version 24 February 2010. CEC, Luxembourg.

Cooper, J. R., 2008. Review of risks from tritium – report of the AGIR – November 2007. Letter dated 17th April 2008. HPA, Chilton.

Copeland Borough Council et al., 1999. The radiological implications of contaminated feral pigeons found at Sellafield and Seascale. CBC, DH, Environment Agency, HSE, MAFF and NRPB, Penrith.

Copplestone, D., Bielby, S., Jones, S.R., Patton, D., Daniel P. and Gize, I., 2001. Impact assessment of ionising radiation on wildlife. R&D Publication 128. ISBN 1 85705590. Environment Agency, Bristol.

Dale, P., 2009. Dalgety Bay radium contamination. Scottish Environment Protection Agency, Stirling.

Dale, P., Robertson, I and Toner, M., 2008. Radioactive particles in dose assessments. J. Environ. Rad., 99: 1589-1595.

Department for Business, Enterprise and Regulatory Reform, 2008. Meeting the energy challenge. A White Paper on Nuclear Power. Cmnd.7296. HMSO, London.

Department for Environment, Food and Rural Affairs, 2002. UK strategy for radioactive discharges 2001 – 2020. Defra, London.

Department for Environment, Food and Rural Affairs, 2004a. National report on compliance with the obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Defra, London.

Department for Environment, Food and Rural Affairs, 2004b. Contribution of aerial radioactive discharges to radionuclide concentrations in the marine environment. DEFRA/RAS/04.002. Defra, London.

Department for Environment, Food and Rural Affairs, 2005a. 1: Marine Environment Quality. Report 1 of 5 contributing to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005b. 5: Integrated Regional Assessment. Report 5 of 5 contributing to Charting Progress: an Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, 2005c. The United Kingdom's second national report on compliance with the obligations of the joint convention on the safety of spent fuel management and on the safety of radioactive waste management. Defra, London.

Department for Environment, Food and Rural Affairs, 2005d. Water Environment Reports Submitted to the European Commission. News Release 142/05. Defra, London.

Department for Environment, Food and Rural Affairs, 2006a. Industry profile. Industrial activities which have used materials containing radioactivity. Defra, London.

Department for Environment, Food and Rural Affairs, 2006b. Environmental Protection Act 1990: Part 2a. Contaminated land. Circular 01/2006. Defra, London.

Department for Environment, Food and Rural Affairs, 2007a. Low level radioactive waste policy announced. News release 26 March 2007. Defra, London.

Department for Environment, Food and Rural Affairs, 2007b. Miliband announces radioactive waste disposal plan. News release 2006. Defra, London.

Department for Environment, Food and Rural Affairs, 2008. Summary of responses to the consultation on the standardised reporting of radioactive discharges, 22 August to 23 November 2007. Defra, London.

Department for Environment, Food and Rural Affairs, 2010. Charting Progress 2. Defra, London.

Department for Environment, Food and Rural Affairs, Scottish Executive and Welsh Assembly Government, 2002. Safeguarding our seas. A strategy for the conservation and sustainable development of our marine environment. Defra, London.

Department for Environment, Food and Rural Affairs, Department of the Environment, Northern Ireland, Scottish Executive, Welsh Assembly Government, 2005. Charting Progress. An Integrated Assessment of the State of UK Seas. Defra, London.

Department for Environment, Food and Rural Affairs, Department for Business, Enterprise and Regulatory Reform, National Assembly for Wales and Northern Ireland Assembly, 2008. Managing Radioactive Waste Safely: A framework for Implementing Geological Disposal, 2008. Cm7386. The Stationery Office, London.

Department of Energy and Climate Change, 2009a. Summary of responses to the consultation on the draft UK Strategy for radioactive discharges 2006-2030. DECC, London.

Department of Energy and Climate Change, 2009b. Draft national policy statement for nuclear power generation (EN-6). DECC, London.

Department of Energy and Climate Change, Department of the Environment, Northern Ireland, The Scottish Government and Welsh Assembly Government, 2009. UK Strategy for Radioactive Discharges. DECC, London.

Department of Energy and Climate Change, Department of the Environment (Northern Ireland), the Scottish Government and Welsh Assembly Government, 2010. Response of the UK Government and the Devolved Administrations of Northern Ireland, Scotland and Wales to the Committee on radioactive Waste Management' (CoRWM) report on "National Research and Development for Interim Storage and Geological Disposal of Higher Activity Radioactivity Wastes, and Management of Nuclear Materials." DECC, DoENI, The Scottish Government and Welsh Assembly Government, London, Belfast, Edinburgh and Cardiff.

Department of Energy and Climate Change and Nuclear Decommissioning Authority, 2011. The 2010 UK radioactive waste inventory. URN 10D/985. NDA/ST/STY(11)0004. DECC and Nuclear Decommissioning Authority, London and Moor Row, Cumbria.

Department of Energy and Climate Change and Welsh Assembly Government, 2009. Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment. DECC and WAG, London and Cardiff.

Department of the Environment Northern Ireland, 2010. A Northern Ireland Marine Bill – policy proposals. Consultation document. DoENI, Belfast.

Department of the Environment, Transport and the Regions, 2000. Radioactive Substances (Basic Safety Standards) (England and Wales) Direction 2000. DETR, London.

Dewar, A., Jenkinson, S. and Smedley, C., 2011. Parameter values used in coastal dispersion modelling for radiological assessments. SCO 6 0080/R3. Environment Agency, Bristol and London.

Dounreay Particle Advisory Group, 2008. 4th Report, November 2008. SEPA, Stirling.

DSTL Radiological Protection Services, 2009. Marine environmental radioactivity surveys at nuclear submarine berths 2007. The Stationery Office, London.

Elliott, J., Clyne F.J. and Garrod C.J. 2010. Radiological Habits Survey: Derby 2009. Project C2848. RL 05/10. Cefas, Lowestoft.

Environment Agency, 2002a. Radioactivity in the environment. Report for 2001. Environment Agency, Lancaster.

Environment Agency, 2002b. Radioactive Waste Regulation. Summary of Research 1996 – 2001. R&D Publication 129. Environment Agency, Bristol and London.

Environment Agency, 2005. Water Framework Directive - Characterisation of impacts from radioactive substances. Technical Report: MAPG/TR/2004/004. Environment Agency, Bristol and London.

Environment Agency, 2006a. Initial radiological assessment methodology – part 1 user report. SC030162/SR1. Environment Agency, Bristol and London.

Environment Agency, 2006b. Initial radiological assessment methodology – part 2 methods and input data. SC030162/SR2. Environment Agency, Bristol and London.

Environment Agency, 2007. New guidance coming on disposing of solid radioactive waste. Business and Industry, 29th May 2007. Environment Agency, Bristol and London.

Environment Agency, 2008a. Radioactive substances regulation. Environmental Principles. Public consultation. Environment Agency, Bristol and London.

Environment Agency, 2008b. Assessment of Best Available Techniques (BAT). Consultation draft. Environment Agency, Bristol and London.

Environment Agency, 2008c. Sellafield Radioactive Particles in the Environment – Programme of Work, February 2008. Environment Agency, Bristol and London.

Environment Agency, 2009a. Dealing with contaminated land in England and Wales. Environment Agency, Bristol and London.

Environment Agency, 2009b. Sellafield Radioactive Particles in the Environment – Review of Progress, June 2009. Environment Agency, Bristol and London.

Environment Agency, 2010a. Radiological impact of GDAs. Environment Agency, Bristol and London.

Environment Agency, 2010b. Briefing Note – Enhanced Beach Monitoring for Radioactive Particles near Sellafield site, March 2010. Environment Agency, Bristol and London.

Environment Agency, 2010c. Consultation Briefing Note – New nuclear power stations, June 2010. GEHO0610BSMO-E-P. Environment Agency, Bristol and London.

Environment Agency, 2011a. Generic design assessment of new nuclear power plant designs. Summary report of responses to the consultation on the detailed assessment of the submission by AREVA NP SAS and Electricité de France SA for their UK EPR design. Environment Agency, Bristol and London.

Environment Agency, 2011b. Generic design assessment of new nuclear power plant designs. Summary report of responses to the consultation on the detailed assessment of the submission by Westinghouse Electric Company LLC for its AP1000 design. Environment Agency, Bristol and London.

Environment Agency, 2011c. Briefing Note – Enhanced Beach Monitoring for Radioactive Particles near Sellafield site, April 2011. Environment Agency, Bristol and London.

Environment Agency, Environment and Heritage Service, Food Standards Agency and Scottish Environment Protection Agency, 2007. Radioactivity in Food and the Environment, 2006. RIFE-12. Environment Agency, Environment and Heritage Service, Food Standards Agency and SEPA. Bristol, Belfast, London and Stirling.

Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2008. Radioactivity in Food and the Environment, 2007. RIFE-13. Environment Agency, Food Standards Agency, NIEA and SEPA. Bristol, Belfast, London and Stirling.

Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2009. Radioactivity in Food and the Environment, 2008. RIFE 14. Environment Agency, Food Standards Agency, NIEA and SEPA, Bristol, Belfast, London and Stirling.

Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010a. Radioactivity in Food and the Environment, 2009. RIFE 15. Environment Agency, Food Standards Agency, NIEA and SEPA, Bristol, Belfast, London and Stirling.

Environment Agency, Food Standards Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2010b. Summary of Radioactivity in Food and the Environment 2004-2008. Environment Agency, Food Standards Agency, NIEA and SEPA, Bristol, Belfast, London and Stirling.

Environment Agency, Food Standards Agency and Scottish Environment Protection Agency, 2010. Environmental Radiological Monitoring. Radiological Monitoring Technical Guidance Note 2. Environment Agency, Food Standards Agency and Scottish Environment Protection Agency, Bristol, London and Stirling.

Environment Agency and Northern Ireland Environment Agency, 2009. Geological disposal facilities on land for solid radioactive wastes: guidance on requirements for authorisation. Environment Agency and NIEA, Bristol, London and Belfast.

Environment Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency, 2009. Near-surface disposal facilities on land for solid radioactive wastes: guidance on requirements for authorisation. Environment Agency, NIEA and SEPA, Bristol, London, Belfast and Stirling.

Food Standards Agency, 2001a. Consultative Exercise on Dose Assessment, 3 and 4 October 2000. FSA/0022/0501.500. Food Standards Agency, London.

Food Standards Agency, 2001b. Radiological survey of foodstuffs from the Cardiff area. Food Survey Information Sheet 18/01. www.food.gov.uk/science/surveillance/fsis-2001/radsurvcardiff.

Food Standards Agency, 2003. Analysis of farmed salmon for technetium-99 and other radionuclides. Food Survey Information Sheet Number 39/03. Food Standards Agency, London.

Food Standards Agency, 2004. Review of FSA research programmes on radiological protection. Research review report for the period 1998 – 2003. Food Standards Agency, London. http://www.food.gov.uk/science/research/researchinfo/radiologicalresearch/radioactivityenvironment/r01programme/radioprogsreview.

Food Standards Agency, 2009. Estimate of the Food Chain Risks to Inform an Assessment of the Need for and Extent of the Food and Environment Protection Act Area at Dounreay. Food Standards Agency, Aberdeen.

http://www.food.gov.uk/multimedia/pdfs/dounreayfepariskassessment.pdf

Food Standards Agency and Scottish Environment Protection Agency, 2002. Radioactivity in Food and the Environment, 2001. RIFE-7. Food Standards Agency and Scottish Environment Protection Agency, London and Stirling.

Garrod, C.J., Clyne, F.J., Tipple, J.R. and Edgar, A., 2008. Radiological Habits Survey: Harwell 2007. Project C2848. RL 07/08. Cefas, Lowestoft.

Garrod, C.J., Tipple, J.R., Clyne, F.J. and Jeffs, T.M., 2009. Radiological Habits Survey: Hartlepool 2008. Project C2848. RL 01/09. Cefas, Lowestoft.

Garrod, C.J., Clyne, F.J., Elliott, J.and Tipple, J.R., 2010. Radiological Habits Survey: Wylfa 2009. Project C2848. RL 03/10. Cefas, Lowestoft.

Garrod, C.J., Clyne, F.J., Rumney. P., Elliott, J., Smedley, C.A. and Ly, V.E. 2011. Radiological Habits Survey: Sizewell, 2010. Project C2848. RL 12/11. Cefas, Lowestoft.

Ham, G. J., Wilding, D. and Wilkins, B.T., 2007. Tritium concentrations in crops fertilised with contaminated sewage sludge. R01061. RPD-EA-15-2007. HPA, Chilton.

Harrison, J.D. and Phipps, A., 2001. Invited editorial: gut transfer and doses from environmental technetium. J. Radiol. Prot., 21: (9 – 11).

Harrison, J.D., Khursheed, A and Lambert, B.E., 2002. Uncertainties in dose coefficients for intakes of tritiated water and organically bound forms of tritium by members of the public. Radiation Protection Dosimetry, 98, 299 – 311.

Harvey, M., Oatway, W., Smith, J and Simmonds, J., 2008. Implied doses to the population of the EU arising from reported discharges for EU nuclear power stations and reprocessing sites in the years 1997 to 2004. Radiation Protection No. 153. CEC, Brussels.

Harvey, M., Smith, J. and Cabianca, T., 2010. Assessment of collective and per caput doses due to discharges of radionuclides from the oil and gas industry into the marine environment. RPD-EA-4-2010. HPA, Chilton.

Health Protection Agency, 2007. Review of the risks from tritium. Report of the Independent Advisory Group on Ionising Radiation. RCE-4. HPA, London.

Health Protection Agency, 2009. Application of the 2007 Recommendations of the ICRP to the UK. Advice from the Health Protection Agency. HPA, London.

Health and Safety Executive, 2007a. HSE grants consent for THORP re-start. Press releases E001:07 10 January 2007.

Health and Safety Executive, 2007b. HSE publishes THORP leak report. Press releases E006:07 23 February 2007.

Her Majesty's Inspectorate of Pollution, 1995. Routine measurement of gamma ray air kerma rate in the environment. Technical Guidance Note (Monitoring) M5. HMSO, London.

Hodgson, A., Scott, J.E., Fell, T.P., and Harrison, J.D., 2005. Radiation doses from the consumption of Cardiff Bay flounder containing organically bound tritium (OBT). Project SC020042/SR. Environment Agency, Bristol.

Hughes, J.S., Roberts, D, and Watson, S.J., 2006. Accidents and incidents involving the transport of radioactive materials in the UK. RPD-014. HPA, Chilton.

Hunt, G.J., 1984. Simple models for prediction of external radiation exposure from aquatic pathways. Radiat. Prot. Dosim., 8: 215 – 224.

Hunt, G.J., 1998. Transfer across the human gut of environmental plutonium, americium, cobalt, caesium and technetium: studies with cockles (Cerostoderma edule) from the Irish Sea. J. Radiol. Prot., 18(2): 101 – 109.

Hunt, G.J. and Allington, D.J., 1993. Absorption of environmental polonium-210 by the human gut. J. Radiol. Prot., 13(2):119 – 126.

Hunt, G.J. and Rumney, H.S., 2004. The human gut transfer of environmental polonium-210. Proc. Int. Conf. on widening the radiation protection world, 23 – 28 May 2004, Madrid. IRPA, Fontenay-aux-Roses.

Hunt, G.J and Rumney, H.S., 2005. The human alimentary tract transfer of environmental polonium-210. Proceedings of the Seventh International Symposium of the Society for Radiological Protection, 12th-17th June 2005, Cardiff. SRP, London.

Hunt, G.J. and Rumney, H.S., 2007. The human alimentary tract transfer and body retention of environmental polonium-210. J. Radiol. Prot., 27(4):405-26.

Hunt, J., Bailey, T. and Reese, A., 2009. The human body retention time of environmental organically bound tritium. J. Radiol. Prot., 29(1):23-36.

Hunt, G.J., Hewitt, C.J. and Shepherd, J.G., 1982. The identification of critical groups and its application to fish and shellfish consumers in the coastal area of the north-east Irish Sea. Health Physics 43 (6) 875 – 889.

Hunt, G.J., Leonard, D.R.P. and Lovett, M.B., 1986. Transfer of environmental plutonium and americium across the human gut. Sci. Total Environ., 53: 89 – 109.

Hunt, G.J., Leonard, D.R.P. and Lovett, M.B., 1990. Transfer of environmental plutonium and americium across the human gut. Sci. Total Environ., 90: 273 – 282.

Hunt, G.J., Young, A.K. and Bonfield, R.A., 2001. Transfer across the human gut of environmental technetium in lobsters (Homarus gammarus L.) from the Irish Sea. J. Radiol. Prot., 21: 21 – 29.

Hunt, G.J., Bailey, T.A., Jenkinson, S.B. and Leonard, K.S., 2010. Enhancement of tritium on uptake by marine biota: experience from UK coastal waters. J. Radiol. Prot., 30(1):73.

Hunt, G.J., Leonard, K.S., Gitzinger,C., Janssens, A., Godeanu-Metz, A. and Henrich, E., 2007. Article-35 of the Euratom Treaty: Overview of national radioactive discharge and environmental monitoring requirements in the European Union. Extended Synopsis in International Conference on Environmental Radioactivity, "From Measurement and Assessments in Regulations", 23-27 April 2007, Vienna.

International Atomic Energy Agency, 1996. International basic safety standards for protection against ionising radiation and for the safety of radiation sources. Saf. Ser. No. 115. IAEA Vienna.

International Atomic Energy Agency, 1997. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. INF CIRC/546. IAEA, Vienna.

International Atomic Energy Agency, 1999. Application of radiological exclusion and exemption principles to sea disposal. IAEA-TECDOC-1068. IAEA, Vienna.

International Atomic Energy Agency, 2003. Determining the suitability of materials for disposal at sea under the London Convention 1972: a radiological assessment procedure. IAEA-TECDOC-1375. IAEA, Vienna.

International Commission on Radiological Protection, 1991. 1990 Recommendations of the International Commission on Radiological Protection. Annal. ICRP 21(1 – 3). Pergamon Press, Oxford, 201pp. (ICRP Publ. (60)).

International Commission on Radiological Protection, 1994. Age-dependent doses to members of the public from intake of radionuclides: Part 2 Ingestion dose coefficients. Annal ICRP 23(3/4). Pergamon Press, Oxford, 167pp. (ICRP Publ. (67)).

International Commission on Radiological Protection, 1996a. Age-dependent doses to members of the public from intake of radionuclides: Part 5 Compilation of ingestion and inhalation dose coefficients. Annal. ICRP 26(1). Elsevier Science, Oxford, 91pp. (ICRP Publ. (72)).

International Commission on Radiological Protection, 1996b. Conversion coefficients for use in radiological protection against external radiation. Annal ICRP 26(3/4). Elsevier Science, Oxford (ICRP Publ. (74)).

International Commission on Radiological Protection, 2001. Doses to the embryo and fetus from intakes of radionuclides by the mother. Annal ICRP 31(1 – 3). Elsevier Science, Oxford. (ICRP Publ. (88)).

International Commission on Radiological Protection, 2007. The 2007 recommendations of the International Commission on Radiological Protection. Annal ICRP 37 (2-4). Elsevier Science, Oxford (ICRP Publ (103)).

International Commission on Radiological Protection, 2008. Environmental protection: the concept and use of reference animals and plants. Annal ICRP 38(4-6). Elsevier Science, Oxford, 242pp. (ICRP Publ(108)).

International Organisation for Standardisation, 2005. General requirements for the competence of testing and calibration laboratories. ISO 17025.

Jobling, S., Williams, R., Johnson, A., Taylor, A., Gross-Sorokin, M., Nolan, M., Tyler, C., van Aerle, R., Santos, E., and Brighty, G., 2006. Predicted exposures to steroid estrogens in UK rivers correlate with widespread sexual disruption in wild fish populations. Environmental Health Perspective, 114 (S-1), 32 – 39.

Joint Research Centre of the European Commission, 2009. Environmental Radioactivity in the European Community 2004 – 2006. Radiation Protection No. 161. CEC, Luxembourg.

Kelly, M. and Emptage, M.,1991. Radiological assessment of the estuary at Ravenglass: Distribution of radioactivity and its relationship to sedimentary processes. Department of Environment, London.

Kershaw, P.J. and Baxter, A.J., 1995. The transfer of reprocessing wastes from north-west Europe to the Arctic. Deep-Sea Res. II, 43(6): 1413 – 1448.

Kershaw, P.J., McCubbin, D. and Leonard, K.S., 1999. Continuing contamination of north Atlantic and Arctic waters by Sellafield radionuclides. Sci. Tot. Env., 237/238: 119 – 132.

Knowles, J.F., Smith, D.L. and Winpenny K., 1998. A comparative study of the uptake, clearance and metabolism of technetium in lobster (Homarus gammarus) and edible crab (Cancer pagurus). Radiat. Prot. Dosim., 75: 125 – 129.

Kocher, D.C. and Eckerman, K.F., 1987. Electron dose-rate conversion factors for external exposure of the skin from uniformly deposited activity on the body surface. Hlth. Phys., 53: 135 – 141.

Leonard, K. S. and Smedley, P. A., 2010a. Radiological assessment of dredging application for Watchet Habour (2010). RL 8/10. Cefas, Lowestoft.

Leonard, K. S. and Smedley, P. A., 2010b. Radiological assessment of dredging application for Oldbury Power Station (2010). RL 9/10. Cefas, Lowestoft.

Leonard, D.R.P., Camplin, W.C. and Tipple, J.R., 1990. The variability of radiocaesium concentrations in freshwater fish caught in the UK following the Chernobyl nuclear reactor accident: an assessment of potential doses to critical group consumers. pp. 247 – 256. In: 'Proc. Int. Symp. on Environmental Contamination Following a Major Nuclear Accident'. IAEA, Vienna, IAEA-SM-306/15.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997a. A summary report of the distribution of Technetium-99 in UK Coastal Waters. Radioprotection, 32: 109 – 114.

Leonard, K.S., McCubbin, D., Brown, J., Bonfield, R. and Brooks, T., 1997b. Distribution of technetium-99 in UK coastal waters. Mar. Pollut. Bull., 34(8): 628 – 636.

Leonard, K.S., McCubbin, D., McMahon, C.A., Mitchell, P.I. and Bonfield, R., 1998. 137Cs/90Sr ratios in the Irish Sea and adjacent waters: a source term for the Arctic. Radiat. Prot. Dosim., 75(1 – 4): 207 – 212.

Leonard, K.S., McCubbin, D., Blowers, P. and Taylor, B.R., 1999. Dissolved plutonium and americium in surface waters of the Irish Sea, 1973 – 96. J. Environ. Rad., 44: 129 – 158.

Leonard, K.S., McCubbin, D. and Bailey, T.A., 2001. Organic forms of tritium in food chains. Project R01023/C0814. RL 6/01. Cefas, Lowestoft.

Leonard, K.S., McCubbin, D., McDonald, P., Service, M., Bonfield, R. and Conney, S., 2004. Accumulation of technetium-99 in the Irish Sea. Sci. Tot. Env., 322: 255 – 270.

Leonard, K.S., Shaw, S., Wood, N., Rowe, J.E., Runacres, S.M., McCubbin, D. and Cogan, S.M., 2007. Independent radiological monitoring; results of a recent intercomparison exercise. 10th International Symposium on Environmental Radiochemical Analysis, 13-15 September 2006, Oxford. ERA III. Royal Society of Chemistry, London.

Male, N and Jones, J, 2008. Summary of Land quality assessment of former Donibristle Airfield, Dalgety Bay, Fife. Project 12920. Defence Estates, Sutton Coldfield.

Mayall, A., Cabianca, T., Attwood, C., Fayers, C.A., Smith, J.G., Penfold, J., Steadman, D., Martin, G., Morris, T.P. and Simmonds, J.R., 1997. PC-CREAM. Installing and using the PC system for assessing the radiological impact of routine releases. EUR 17791 EN. CEC, Luxembourg.

McCubbin, D., Leonard, K.S., Bailey, T.A., Williams, J. and Tossell, P., 2001. Incorporation of organic tritium (3H) by marine organisms and sediment in the Severn Estuary/Bristol Channel (UK). Mar. Pollut. Bull., 42 (10): 852 – 863.

McCubbin, D., Leonard, K.S., Brown, J., Kershaw, P.J., Bonfield, R.A. and Peak, T., 2002. Further studies of the distribution of 99Tc and 137Cs in UK and European coastal waters. Cont. Shelf. Res. 22/10: 1417 – 1445.

McCubbin, D. and Vivian, C., 2006. Dose assessments in relation to disposal at sea under the London Convention 1972: judging de minimis radioactivity. FSA Project R01062. RL5/06. Cefas, Lowestoft.

McCubbin, D., Jenkinson, S.B., Leonard, K.S., Bonfield, R.A. and McMeekan, I.T., 2008. An assessment of the availability of Tc-99 to marine foodstuffs from contaminated sediments. Project R01062 . RL09/08. Cefas, Lowestoft.

McKay, W.A., Barr H.M., Halliwell C.M., Spencer D., Adsley I. and Perks C.A., 1995. Site specific background dose rates in coastal areas. DoE/HMIP/RR/94/037. Her Majesty's Inspectorate of Pollution, London.

McTaggart, K., 2003. Habits survey notebook, Unpublished. Cefas, Lowestoft.

McTaggart, K., Tipple, J.R., Clyne, F.J. and Sherlock, M., 2007. Radiological Habits Survey: Heysham, 2006. Projects C1659, RB103 and C1666. RL 09/07. Cefas, Lowestoft.

McTaggart, K.A., Tipple, J.R., Clyne, F.J. and McMeekan, I.T., 2004. Radiological habits survey: Cardiff, 2003. RL 03/04. Cefas, Lowestoft.

Ministry of Agriculture, Fisheries and Food, 1994. The British Diet: Finding the facts. Food Surveillance Paper No. 40. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food, 1995. Terrestrial radioactivity monitoring programme (TRAMP) report for 1994. Radioactivity in food and agricultural products in England and Wales. MAFF, London, TRAMP/9, 223pp.

Ministry of Agriculture, Fisheries and Food, 1996. Pesticides Safety Directorate's Handbook. Appendix IC. MAFF, London.

Ministry of Agriculture, Fisheries and Food, 1998. National Food Survey 1997. The Stationery Office. London.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1998. Radioactivity in Food and the Environment, 1997. RIFE-3. MAFF and SEPA, London and Stirling.

Ministry of Agriculture, Fisheries and Food and Scottish Environment Protection Agency, 1999. Radioactivity in Food and the Environment, 1998. RIFE-4. MAFF and SEPA, London and Stirling.

Mobbs, S., Barraclough, I., Napier, I., Casey, A., Poynter, R. and Harvey, M., 1998. A review of the use and disposal of gaseous tritium light devices. Environment Agency, Lancaster.

National Radiological Protection Board, 1990. Gut transfer factors. Docs. NRPB 1(2). NRPB, Chilton, 26pp.

National Dose Assessment Working Group, 2004. Radiological Assessment Exposure Pathways Checklist (Common and Unusual). NDAWG/2/2004. Environment Agency, Food Standards Agency, NRPB, NII, Chilton.

National Radiological Protection Board, 2005. Guidance on the application of dose coefficients for the embryo and fetus from intakes of radionuclides by the mother. Docs NRPB 16(2). NRPB, Chilton, 41pp.

Northern Ireland Assembly, 2003. Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland).

Nuclear Decommissioning Authority, 2011a. Strategy effective from April 2011. NDA, Moor Row, Cumbria.

Nuclear Decommissioning Authority, 2011b. NDA Business Plan 2011/2014. NDA, Moor Row, Cumbria.

Organisation for Economic Co-operation and Development, Nuclear Energy Agency, 1985. Review of the continued suitability of the dumping site for radioactive waste in the North-East Atlantic. OECD, Paris, 448pp.

OSPAR, 1998. SINTRA Statement. Summary Record OSPAR 98/14/1, Annex 45. OSPAR, London.

OSPAR, 2000a. Convention for the protection of the marine environment of the North-East Atlantic. OSPAR, London.

OSPAR, 2000b. Quality Status Report 2000. OSPAR, London.

OSPAR, 2003. 2003 Strategies of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic. 2003-21. OSPAR, London.

OSPAR, 2006. Agreement on a monitoring programme for concentrations of radioactive substances in the marine environment. Annex 14, ref 9.8c, Malahide (Ireland): 27 June-1 July 2005. OSPAR, London.

OSPAR, 2009a. Liquid discharges from nuclear installations in 2007. OSPAR, London.

OSPAR, 2009b. Discharges of radioactive substances from the non-nuclear sectors in 2007. OSPAR, London.

OSPAR, 2009c. Implementation of PARCOM Recommendation 91/4 on liquid discharges. Report from the United Kingdom. OPSAR, London.

OSPAR, 2009d. Towards the Radioactive Substances Strategy Objectives. Third Periodic Evaluation, OSPAR, London.

OSPAR, 2010a. The North-East Atlantic Environment Strategy. Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010-2020. OSPAR Agreement 2010-3. OSPAR, London.

OSPAR, 2010b. Quality Status Report 2010. OSPAR, London.

OSPAR, 2011. Summary Record Meeting of the Radioactive Substances Committee (RSC), Monaco 22-24 February 2011. OSPAR, London.

Ould-Dada, Z., 2000. Sea-to-Land transfer of radionuclides. How much do we know. Proceedings of the second RADREM-TESC Workshop held in London on 21 January 1999. DETR/RADREM/00.001 DETR, London.

Povinec, P.P., Bailly Du Bois, P., Kershaw, P.J., Nies, H. and Scotto, P., 2003. Temporal and spatial trends in the distribution of 137Cs in surface waters of Northern European Seas - a record of 40 years of investigations. Deep Sea Res. II, 50: 2785 – 2801.

Povinec, P.P., Aarkrog, A., Buesseler, K.O., Delfanti, R., Hirose, K., Hong, G.H., Ito, T., Livingston, H.D., Nies, H., Noshkin, V. E., Shima, S., Togawa,O., 2005. 90Sr, 137Cs and 239,240Pu concentration surface water time series in the Pacific and Indian Oceans - WOMARS results. J. Environ. Rad, 81: 63 - 87.

Preston, A., Mitchell, N.T. and Jefferies, D.F., 1974. Experience gained in applying the ICRP Critical Group concept to the assessment of public radiation exposure in control of liquid waste disposal. Proc. Symp. IAEA Portoroz, IAEA-SM-184/10, 131 – 146.

Punt, A., Tyler, A., Saleh, S., Bradley, S and Copplestone, D., 2011. Measurement and assessment of external dose rates to people on houseboats and using riverbanks. Science Report: SC060080/SR. Environment Agency, Bristol and London.

Rollo, S.F.N., Camplin, W.C., Allington, D.J. and Young, A.K., 1992. Natural radionuclides in the UK marine environment. In: 'Proceedings of the Fifth International Symposium on Natural Radiation Environment, Salzburg, September 22 – 28, 1991'. Radiat. Prot. Dosim., 45(1/4): 203 – 210.

Rollo, S.F.N., Camplin, W.C., Duckett, L., Lovett, M.B. and Young, A.K., 1994. Airborne radioactivity in the Ribble Estuary. pp277 – 280. In: 'Proc. IRPA Regional Congress on Radiological Protection, 6 – 10 June 1994, Portsmouth, UK'. Nuclear Technology Publishing.

Rowe, J.E., Allott, R. and Morris, C., 2005. Response to questionnaire on the implementation of Article 35 of the Euratom Treaty - Environment Agency and Food Standards Agency Monitoring Programmes. MAPG/TR/2005/003. Environment Agency and Food Standards Agency, Bristol and London.

Rumney, P., Smedley, C.A., Garrod, C.J., Clyne, F.J., and Ly, V.E., (in press). Radiological Habits Survey: Rosyth, 2010.

RWE NUKEM, 2006. Investigation/hot spot removal at Dalgety Bay. TR/89191/001. RWE NUKEM, Rosyth.

Scotland - Parliament, 2010. Marine (Scotland) Act, 2010. OQPS, Edinburgh.

Scottish Environment Protection Agency, 2006. Radium contamination at Dalgety Bay, Fife. SEPA, Stirling.

Scottish Environment Protection Agency, 2007. Strategy for the Assessment of the potential impact of Sellafield Radioactive Particles on Southwest Scotland, December 2007. SEPA, Stirling.

Scottish Environment Protection Agency, 2009a. Decision Document on the Application by the Ministry of Defence to Dispose of Radioactive Waste (Solid, Liquid and Gaseous), August 2009. SEPA, Stirling.

Scottish Environment Protection Agency, 2009b. Report by the Scottish Environment Protection Agency for the Chapelcross Site Stakeholder Group on tritium levels in the local Chapelcross environment, 2009. SEPA, Stirling.

Scottish Environment Protection Agency, 2011. Decision Document - British Energy Generation Limited Torness Power Station, Dunbar, East Lothian, 2011. SEPA, Stirling.

Scottish Executive, 2000. Radioactive Substances (Basic Safety Standards) (Scotland) Direction 2000. Scottish Executive, Edinburgh.

Scottish Government, 2008. Environment Act 1995. The UK Strategy for Radioactive Discharges. Statutory Guidance. Scottish Government, Edinburgh.

Scottish Government, 2011. Scotland's Higher Activity Radioactive Waste Policy, 2011, Scottish Government, Edinburgh.

Sherlock, M., Tipple, J.R. and Clyne, F.J., 2006. Radiological Habits Survey: Chapelcross, 2006. Project C2448. RL 04/06. Cefas, Lowestoft.

Sherlock, M., McTaggart, K.A. and Clyne, F.J., 2009. Radiological habits survey: Faslane, 2006. RL 07/09. Cefas, Lowestoft.

Sherlock, M., Garrod, C.J. and Tipple, J.R., 2011. Radiological Habits Survey: Hunterston 2007. Project C2448. RL 05/11. Cefas, Lowestoft.

Simmonds, J.R., Lawson, G. and Mayall, A., 1995. Radiation Protection 72; Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. Report EUR 15760 EN. Office for Official Publications of the European Community, Luxembourg.

Smith, B.D. and Jeffs, T.M., 1999. Transfer of radioactivity from fishmeal in animal feeding stuffs to man. RL 8/99. Cefas, Lowestoft.

Smith, K.R. and Jones, A.L. 2003. Generalised habit data for radiological assessments. NRPB-W41. NRPB, Chilton.

Smith, J.T., Comans, R.N.J., Beresford, N.A., Wright, S.M., Howard, B.J. and Camplin, W.C., 2000. Chernobyl's legacy in food and water. Nature, 405: 7141.

Smith, D.L., Smith, B.D., Joyce, A.E. and McMeekan, I.T., 2002. An assessment of aquatic radiation exposure pathways in Northern Ireland. SR(02)14. RL 20/02. Scotland and Northern Ireland Forum for Environmental Research, Edinburgh.

Smith, K.R., Mobbs, S.F. and Cooper, J.R., 2006. Dose criteria for the designation of radioactivity contaminated land. RCE-2. HPA, Chilton.

Statutory Instruments, 2007. SI 2007 No 3236. The Radioactive Contaminated Land (Amendment) Regulations (Northern Ireland) 2007.

Statutory Instruments, 2010. SI 2010 No 0000. The Radioactive Contaminated Land (Amendment) Regulations (Northern Ireland) 2010.

Swift, D.J., 2001. Cardiff radiological survey of selected foodstuffs. Project C1003. RL 11/01. Cefas, Lowestoft.

Swift, D.J. and Nicholson, M.D., 2001. Variability in the edible fraction content of 60Co, 99Tc, 110mAg, 137Cs and 241Am between individual crabs and lobsters from Sellafield (north eastern Irish Sea). J. Environ. Radioact., 54, 311 – 326.

Tipple, J.R., McTaggart, K.A., Sherlock, M. and Allison, M.R., 2003. Radiological habits survey: Aldermaston/Burghfield, 2002. RL 01/03. Cefas, Lowestoft.

Tipple, J.R., McTaggart, K.A., Clyne, F.J. and Sherlock, M., 2005. Radiological habits survey: Devonport, 2004. RL 01/05. Cefas, Lowestoft.

Tipple, J.R., McTaggart, K., Clyne, F.J. and Sherlock, M., 2006. Radiological Habits Survey: Trawsfynydd, 2005. Projects C1659, RB103 and C1666. RL 02/06. Cefas, Lowestoft.

Tipple, J.R., McTaggart, K., Clyne, F.J. and Sherlock, M., 2007. Radiological Habits Survey: Springfields, 2006. Projects C1659, RB103 and C1666. RL 02/07. Cefas, Lowestoft.

Tipple, J.R., Clyne, F.J., Garrod, C.J. and Sherlock, M., 2008. Radiological Habits Survey: Bradwell, 2007. Project C2848. RL 01/08. Cefas, Lowestoft.

Tipple, J.R., Jeffs, T.M., Clyne, F.J., Garrod, C.J. and Earl, T.J., 2009. Radiological Habits Survey: Capenhurst, 2008. Project C2848. RL 03/09. Cefas, Lowestoft.

Tipple, J.R., McTaggart, K., Clyne, F.J. and Jenkinson, S., 2010. Radiological Habits Survey: Torness, 2006. Project C2448. RL 10/10. Cefas, Lowestoft.

United Kingdom - Parliament, 1965. Nuclear Installations Act, 1965. HMSO, London.

United Kingdom - Parliament, 1985. Food and Environment Protection Act, 1985. HMSO, London.

United Kingdom - Parliament, 1989. The Sludge (Use in Agriculture) Regulations 1989. HMSO, London.

United Kingdom - Parliament, 1993. Radioactive Substances Act, 1993. HMSO, London.

United Kingdom - Parliament, 1995a. Environment Act, 1995. HMSO, London.

United Kingdom - Parliament, 1995b. Review of Radioactive Waste Management Policy. HMSO, London, 55pp. (Cm 2919).

United Kingdom - Parliament, 1999. The Ionising Radiations Regulations 1999. Stat. Inst. 1999/3232. HMSO, London, 67pp.

United Kingdom – Parliament, 2009, Marine and Coastal Access Act 2009. HMSO, London

United Kingdom - Parliament, 2010a. Environmental Permitting (England and Wales) Regulations. Stat. Inst. 2010 No 675. HMSO, London.

United Kingdom - Parliament, 2010b. The Marine Strategy Regulations 2010. Stat. Inst. 2010. HMSO, London.

Walker, S., 2011. Personal communication. Office for Nuclear Regulation, Health & Safety Executive, Bootle.

Watson, S.J., Jones, A.L., Oatway, W.B. and Hughes, J.S., 2005. Ionising radiation exposure of the UK population: 2005 Review. HPA-RPD-001. HPA, Chilton.

Weightman, M., 2011. Japanese earthquake and tsunami: implications for the UK Nuclear Industry. Interim report. Office for Nuclear Regulation, Bootle.

Wood, M.D., Hall, P.J., Wittrick, S., Copplestone, D. and Leah, R.T., 2011. Survey of gamma dose rates in air around the Esk Estuary. Environment Agency, Bristol and London.

World Health Organisation, 2004. Guidelines for drinking water quality. 3rd Edition. WHO, Geneva.

Williams. J.L., Russ, R.M., McCubbin, D. and Knowles, J.F., 2001. An overview of tritium behaviour in the Severn estuary (UK). J. Rad. Prot., 21: 337 – 344.

Young, A.K., McCubbin, D. and Camplin, W.C., 2002. Natural radionuclides in seafood. Project R03010/C0808. RL 17/02. Cefas, Lowestoft.

Young, A.K., McCubbin, D., Thomas, K., Camplin, W.C., Leonard, K.S., and Wood, N., 2003. Po Concentrations in UK Seafood. 9th International Symposium on Environmental Radiochemical Analysis, 18-20 September 2002, Oxford. ERA III. Royal Society of Chemistry, London.

APPENDIX 1. CD Supplement

This Appendix contains information on the methods of sampling, measurement, presentation and assessment. It is provided on the CD accompanying the printed report and with the web version of the report.

If the CD is missing, or you experience problems with accessing the contents of the CD, please contact one of the organisations given at the start of the report, via the E-Mail address.

APPENDIX 2. Disposals of radioactive waste*

Table A2.1. Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2010

PLEASE NOTE CHANGE OF UNITS TO BEQUERELS

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], Bq	Discharges during 2010	
			Bq	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Sellafield Ltd)				
Other authorised outlets	Alpha	BAT	4.12E+05	NA
	Beta	BAT	6.34E+05	NA
Incinerator	Alpha	2.00E+08	Nil	Nil
	Beta	2.50E+08	Nil	Nil
Capenhurst[1]				
(Urenco UK)	Uranium	1.50E+07	3.16E+05	2.0
	Other alpha	4.80E+06	Nil	Nil
	Technetium-99	2.00E+08	Nil	Nil
	Others	4.50E+09	Nil	Nil
Sellafield[d]	Alpha	8.80E+08	8.57E+07	9.7
	Beta	4.20E+10	9.99E+08	2.4
	Tritium	1.10E+15	9.76E+13	8.9
	Carbon-14	3.30E+12	2.73E+11	8.3
	Krypton-85	4.40E+17	4.53E+16	10
	Strontium-90	7.10E+08	4.00E+07	5.6
	Ruthenium-106	2.80E+10	7.54E+08	2.7
	Antimony-125[6]	3.00E+10	7.40E+09	25
	Iodine-129	7.00E+10	9.64E+09	14
	Iodine-131	5.50E+10	3.76E+08	<1
	Caesium-137	5.80E+09	9.33E+07	1.6
	Plutonium alpha	1.90E+08	1.96E+07	10
	Plutonium-241	3.00E+09	2.16E+08	7.2
	Americium-241 and curium-242	1.20E+08	1.66E+07	14
Springfields	Uranium[a]	5.30E+09	5.60E+08	11
Springfields	Tritium	1.00E+08	1.58E+07	16
(National Nuclear Laboratory)[c]	Carbon-14	1.00E+07	5.65E+05	6
	Other alpha radionuclides	1.00E+06	Nil	Nil
	Other beta radionuclides	1.00E+07	3.78E+04	<1
Research establishments				
Dounreay				
(Fuel Cycle Area)	Alpha[e]	9.80E+08	9.93E+06	1.0
	Beta [f,g]	4.50E+10	1.62E+08	<1
	Tritium	2.00E+12	1.85E+11	9.3
	Krypton-85	3.00E+15	Nil	Nil
	Strontium-90	4.20E+09	3.40E+07	<1
	Ruthenium-106	3.90E+09	5.07E+06	<1
	Iodine-129	1.10E+09	6.62E+07	6.0
	Iodine-131	1.50E+08	1.27E+07	8.5
	Caesium-134	8.40E+08	6.29E+05	<1
	Caesium-137	7.00E+09	1.85E+06	<1
	Cerium-144	7.00E+09	3.54E+06	<1
	Plutonium-241	3.30E+09	1.07E+06	<1
	Curium-242	2.70E+08	1.92E+04	<1
	Curium-244[h]	5.40E+07	2.06E+03	<1
Dounreay				
(Fast Reactor)	Alpha	1.00E+07	1.03E+04	<1
	Beta	1.50E+09	3.70E+04	<1
	Tritium	4.50E+12	2.54E+09	<1
	Krypton-85	4.00E+08	Nil	Nil

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], Bq	Discharges during 2010 Bq	% of annual limit[b]
Dounreay				
(Prototype Fast Reactor)	Alpha	6.00E+06	3.23E+04	<1
	Beta	5.10E+07	2.46E+05	<1
	Tritium	1.05E+13	6.82E+10	<1
	Krypton-85	4.00E+12	Nil	Nil
Dounreay				
(PFR minor sources)	Alpha[i]	6.00E+04	5.41E+02	<1
	Beta[f]	5.00E+05	2.10E+03	<1
	Tritium	2.00E+11	4.23E+09	2.1
Dounreay				
(East minor sources)	Alpha[i]	1.37E+07	6.41E+04	<1
	Beta[f]	3.71E+08	3.25E+05	<1
	Krypton-85[j]	1.00E+12	Nil	Nil
Dounreay				
(West minor sources)	Alpha[i]	3.00E+05	2.54E+03	<1
	Beta[f,g]	7.50E+07	1.19E+04	<1
	Tritium	1.00E+10	2.27E+08	2.3
Harwell				
(AEA Technology)	Alpha	7.00E+05	Nil	Nil
	Beta	3.00E+07	Nil	Nil
	Tritium	2.00E+08	Nil	Nil
Harwell				
Research Sites Restoration Ltd	Alpha	8.00E+05	3.46E+04	4.3
(UKAEA)	Beta	2.00E+07	4.70E+05	2.4
	Tritium	1.50E+13	1.10E+12	7.3
	Krypton-85	2.00E+12	Nil	Nil
	Radon-220	1.00E+14	6.33E+12	6.3
	Radon-222	3.00E+12	2.90E+11	9.7
	Iodines	1.00E+10	Nil	Nil
	Other radionuclides	1.00E+11	Nil	Nil
Harwell[5]				
(GE Healthcare B10.23)				
	Alpha	5.00E-08	Nil	Nil
	Beta/gamma	1.50E-05	Nil	Nil
Harwell				
(GE Healthcare B443.26)				
	Alpha	1.00E+05	4.04E+03	4.0
	Beta/gamma	3.00E+07	5.10E+04	<1
	Radon-222	1.00E+12	8.06E+09	<1
	Tritium	2.00E+12	5.42E+07	<1
	Krypton-85	6.00E+10	Nil	Nil
Winfrith				
(Inutec formally WMT Ltd)	Alpha	1.00E+05	Nil	Nil
	Tritium	1.95E+13	8.33E+11	4.3
	Carbon -14	3.00E+10	1.98E+07	<1
	Other	1.00E+05	Nil	Nil
Winfrith				
Research Sites Restoration Ltd	Alpha	2.00E+06	3.23E+03	<1
	Tritium	5.00E+13	2.89E+10	<1
	Carbon-14	6.00E+09	1.34E+08	2.2
	Other	5.00E+06	2.09E+04	<1
Minor sites				
Imperial College Reactor Centre				
Ascot	Tritium	3.00E+08	1.48E+07	4.9
	Argon-41	1.70E+12	3.77E+10	2.2

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], Bq	Discharges during 2010 Bq	% of annual limit[b]
Nuclear power stations				
Berkeley[k]	Beta	2.00E+07	2.91E+05	1.5
	Tritium	2.00E+10	5.42E+09	27
	Carbon-14	5.00E+09	2.45E+08	4.9
Bradwell	Beta	6.00E+08	4.18E+05	<1
	Tritium	1.50E+12	1.14E+10	<1
	Carbon-14	6.00E+11	2.99E+08	<1
Chapelcross	Tritium	5.00E+15	4.95E+13	<1
	Sulphur-35	5.00E+10	Nil	Nil
	Argon-41	4.50E+15	Nil	Nil
Dungeness A Station	Beta[q]	5.50E+08	1.85E+07	3.4
	Tritium	2.60E+12	1.84E+10	<1
	Carbon-14	5.00E+12	2.22E+08	<1
	Sulphur-35	1.50E+11	8.31E+07	<1
	Argon-41	1.70E+15	Nil	Nil
Dungeness B Station	Tritium	1.20E+13	1.68E+12	14
	Carbon-14	3.70E+12	5.03E+11	14
	Sulphur-35	3.00E+11	2.14E+10	7.1
	Argon-41	7.50E+13	2.34E+13	31
	Cobalt-60[q]	1.00E+08	2.87E+06	2.9
	Iodine-131	1.50E+09	2.74E+07	1.8
Hartlepool	Tritium	1.00E+13	8.12E+11	8.1
	Carbon-14	4.50E+12	1.93E+12	43
	Sulphur-35	2.30E+11	2.95E+10	13
	Argon-41	1.50E+14	7.85E+12	5.2
	Cobalt-60[q]	1.00E+08	1.42E+07	14
	Iodine-131	1.50E+09	1.68E+08	11
Heysham Station 1	Tritium	1.00E+13	1.10E+12	11
	Carbon-14	4.50E+12	1.27E+12	28
	Sulphur-35	2.00E+11	2.05E+10	10
	Argon-41	1.50E+14	6.28E+12	4.2
	Cobalt-60[q]	1.00E+08	5.17E+06	5.2
	Iodine-131	1.50E+09	7.64E+07	5.1
Heysham Station 2	Tritium	1.00E+13	9.48E+11	9.5
	Carbon-14	3.70E+12	1.21E+12	33
	Sulphur-35	2.30E+11	1.02E+10	4.4
	Argon-41	7.50E+13	6.61E+12	8.8
	Cobalt-60[q]	1.00E+08	1.21E+07	12
	Iodine-131	1.50E+09	1.01E+08	6.7
Hinkley Point A Station[4]	Beta	5.00E+07	1.90E+05	<1
	Tritium	7.50E+11	5.00E+10	6.7
	Carbon-14	5.00E+10	7.10E+08	1.4
Hinkley Point B Station	Tritium	1.20E+13	1.45E+12	12
	Carbon-14	3.70E+12	1.21E+12	33
	Sulphur-35	3.50E+11	1.12E+11	32
	Argon-41	1.00E+14	1.21E+13	12
	Cobalt-60[q]	1.00E+08	6.83E+06	6.8
	Iodine-131	1.50E+09	5.77E+06	<1
Hunterston A Station	Beta[q]	6.00E+07	4.97E+05	<1
	Tritium	2.00E+10	9.20E+08	4.6
	Carbon-14	2.00E+09	9.40E+07	4.7

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], Bq	Discharges during 2010	
			Bq	% of annual limit[b]
Hunterston B Station	Particulate beta	5.00E+08	1.37E+08	27
	Tritium	1.50E+13	4.56E+12	30
	Carbon-14	4.50E+12	1.31E+12	29
	Sulphur-35	5.00E+11	1.79E+11	36
	Argon-41	1.50E+14	2.13E+13	14
	Iodine-131	2.00E+09	1.20E+08	6.0
Oldbury	Beta	1.00E+08	3.63E+07	36
	Tritium	9.00E+12	2.54E+12	28
	Carbon-14	4.00E+12	1.75E+12	44
	Sulphur-35	4.50E+11	1.01E+11	23
	Argon-41	5.00E+14	4.32E+13	8.6
Sizewell A Station[2]	Beta	8.50E+08	7.00E+05	<1
	Tritium	3.50E+12	2.38E+11	6.8
	Carbon-14	1.00E+11	5.80E+09	5.8
Sizewell B Station	Noble gases	3.00E+13	2.96E+12	9.9
	Particulate Beta	1.00E+08	5.00E+06	5.0
	Tritium	3.00E+12	7.68E+11	26
	Carbon-14	5.00E+11	1.46E+11	29
	Iodine-131	5.00E+08	2.10E+07	4.2
Torness	Particulate beta	4.00E+08	4.42E+06	1.1
	Tritium	1.10E+13	2.23E+12	20
	Carbon-14	4.50E+12	8.26E+11	18
	Sulphur-35	3.00E+11	9.20E+09	3.1
	Argon-41	7.50E+13	4.47E+12	6.0
	Iodine-131	2.00E+09	3.14E+06	<1
Trawsfynydd	Beta	5.00E+07	6.40E+05	1.3
	Tritium	7.50E+11	2.51E+11	33
	Carbon-14	1.00E+10	3.76E+09	38
Wylfa	Beta	7.00E+08	6.52E+07	9.3
	Tritium	1.80E+13	2.78E+12	15
	Carbon-14	2.30E+12	1.33E+12	58
	Sulphur-35	4.50E+11	1.54E+11	34
	Argon-41	1.00E+14	1.82E+13	18
Defence establishments				
Aldermaston[m]	Alpha	1.65E+05	3.65E+04	22
	Particulate Beta	6.00E+05	2.17E+04	3.6
	Tritium	3.90E+13	6.84E+11	1.8
	Carbon-14	6.00E+06	Nil	Nil
	Argon-41	1.00E+09	Nil	Nil
	Krypton-85	7.50E+10	2.03E+10	27
	Volatile beta	4.40E+06	1.28E+05	2.9
Barrow[l]	Tritium	3.20E+06	Nil	Nil
	Argon-41	4.80E+10	Nil	Nil
Burghfield[a,m]	Tritium	1.00E+10	1.36E+05	<1
	Alpha	6.00E+03	1.27E+03	21
Coulport	Tritium	5.00E+10	4.51E+09	9.0
Derby[n,r]	Uranium	4.00E+06	5.19E+05	13
	Alpha[q]	2.40E+04	4.40E+01	<1
	Beta[q]	1.80E+06	4.36E+04	2.4
Devonport[o]	Beta/gamma[q]	3.00E+05	3.32E+04	11
	Tritium	4.00E+09	1.69E+09	42
	Carbon-14	4.30E+10	7.60E+08	1.8
	Argon-41	1.50E+10	1.13E+07	<1

Table A2.1. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[x], Bq	Discharges during 2010	
			Bq	% of annual limit[b]
Dounreay[3] (Vulcan)	Beta[q]	1.00E+08	1.20E+06	1.2
	Noble gases	2.70E+10	Nil	Nil
Rosyth[p]	Beta (particulate)	1.00E+05	Nil	Nil
	Tritium	2.00E+08	Nil	Nil
	Carbon-14	5.00E+08	Nil	Nil
Radiochemical production				
Amersham (GE Healthcare)	Alpha	2.25E+06	3.28E+05	15
	Radionuclides T1/2<2hr	7.50E+11	3.84E+10	5.1
	Tritium	2.00E+12	1.08E+06	<1
	Sulphur-35	3.50E+10	1.10E+09	3.1
	Iodine-125	2.00E+10	9.46E+08	4.7
	Radon-222	1.00E+13	2.73E+12	27
	Other noble gases	5.00E+13	Nil	Nil
	Other including selenium-75 and iodine-131	1.60E+10	2.79E+08	1.7
Cardiff (GE Healthcare)	Soluble tritium	1.56E+14	2.79E+13	18
	Insoluble tritium	6.00E+14	4.27E+12	<1
	Carbon-14	2.38E+12	6.04E+11	25
	Phosphorus-32/33	5.00E+06	2.00E+04	<1
	Iodine-125	1.80E+08	6.90E+05	<1
	Other radionuclides	1.00E+09	Nil	Nil
Industrial and landfill sites				
LLWR near Drigg	Alpha	BAT	4.28E+04	NA
	Beta	BAT	1.12E+05	NA
Studsvik	Alpha (particulate)	5.00E+05	Nil	NA
	Beta (particulate)	5.00E+05	3.96E+02	<1

* *As reported to SEPA and the Environment Agency*
[a] *Some discharge limits and discharges are aggregated from data for individual locations on the site. Percentages are given as a general guide to usage of the limits but should strictly be calculated for individual locations. All discharges were below the appropriate limit for each location*
[b] *Data quoted to 2 significant figures except where values are <1%*
[c] *Formerly Nexia Solutions*
[d] *Limits for tritium, carbon-14, krypton-85 and iodine-129 vary with the mass of uranium processed by THORP*
[e] *Excluding curium-242 and 244*
[f] *Excluding tritium*
[g] *Excluding krypton-85*
[h] *Data excludes any curium-243 present*
[i] *Excluding radon and daughter products*
[j] *Krypton-85 discharges are calculated monthly*
[k] *Combined data for Berkeley Power Station and Berkeley Centre*
[l] *Discharges from Barrow are included with those from MoD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[m] *Discharges were made by AWE plc*
[n] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[o] *Discharges were made by Devonport Royal Dockyard Ltd*
[p] *Discharges were made by Rosyth Royal Dockyard Ltd*
[q] *Particulate activity*
[r] *Annual limits on beta and alpha derived from monthly and weekly notification levels*
[x] *In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites*
[1] *Discharge permit revised with effect from 1 January 2009*
[2] *Discharge permit revised with effect from 22 March 2010*
[3] *A letter of agreement was issued with effect from 28 September 2009*
[4] *Discharge permit revised with effect from 11 January 2010*
[5] *Discharge permit revoked (B10.23) with effect from 1 February 2009*
[6] *Discharge permit revised with effect from 1 April 2008, with a further variation with effect from 1 April 2010 (limit revised to 3.00E-02 TBq), to reflect the trend of increasing discharges in 2009*
NA Not applicable under permit
BAT Best available technology

Table A2.2. Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2010

PLEASE NOTE CHANGE OF UNITS TO BEQUERELS

Establishment	Radioactivity	Discharge limit (annual equivalent)[n], Bq	Discharges during 2010	
			Bq[a]	% of annual limit[b]
Nuclear fuel production and reprocessing				
Capenhurst (Rivacre Brook)	Uranium	7.50E+08	6.32E+06	<1
	Uranium daughters	1.36E+09	6.40E+06	<1
	Non-uranic alpha	2.20E+08	1.51E+07	6.9
	Technetium-99	1.00E+09	1.50E+06	<1
Sellafield[c] (sea pipelines)	Alpha	1.00E+12	1.34E+11	13
	Beta	2.20E+14	1.14E+13	5.2
	Tritium	2.00E+16	1.39E+15	7.0
	Carbon-14	2.10E+13	4.37E+12	21
	Cobalt-60	3.60E+12	9.81E+10	2.7
	Strontium-90	4.80E+13	1.02E+12	2.1
	Zirconium-95 + Niobium-95	3.80E+12	2.37E+11	6.2
	Technetium-99	1.00E+13	1.41E+12	14
	Ruthenium-106	6.30E+13	1.16E+12	1.8
	Iodine-129	2.00E+12	2.74E+11	14
	Caesium-134	1.60E+12	1.10E+11	6.9
	Caesium-137	3.40E+13	4.85E+12	14
	Cerium-144	4.00E+12	5.70E+11	14
	Neptunium-237	1.00E+12	4.08E+10	4.1
	Plutonium alpha	7.00E+11	1.34E+11	19
	Plutonium-241	2.50E+13	3.16E+12	13
	Americium-241	3.00E+11	2.33E+10	7.8
	Curium-243+244	6.90E+10	2.92E+09	4.2
	Uranium[e] (measured in kg)	2.00E+03	2.52E+02	13
Sellafield (factory sewer)	Alpha	3.00E+08	3.87E+07	13
	Beta	6.10E+09	8.61E+08	14
	Tritium	6.80E+10	8.73E+09	13
Springfields	Alpha	1.00E+11	2.10E+10	21
	Beta	2.00E+13	4.45E+12	22
	Technetium-99	6.00E+11	1.85E+10	3.1
	Thorium-230	2.00E+10	3.80E+09	19
	Thorium-232	1.50E+10	1.80E+08	1.2
	Neptunium-237	4.00E+10	3.70E+08	<1
	Other transuranic radionuclides	2.00E+10	1.59E+09	8.0
	Uranium	4.00E+10	1.47E+10	37
Research establishments				
Dounreay	Alpha[4]	2.00E+10	Nil	Nil
PFR liquid metal disposal plant	Beta[2]	1.10E+11	Nil	Nil
	Tritium	1.40E+12	Nil	Nil
	Sodium-22	1.80E+12	Nil	Nil
	Caesium-137	6.60E+10	Nil	Nil
Dounreay	Alpha[4]	9.00E+10	1.99E+08	<1
Other facilities	Beta[2]	6.20E+11	5.45E+08	<1
	Tritium	5.50E+12	9.13E+10	1.6
	Strontium-90	7.70E+11	3.23E+10	4.2
	Caesium-137	1.00E+12	5.15E+09	<1
Harwell (River Thames)				
	Alpha	5.00E+07	2.39E+06	4.8
	Beta	3.30E+09	1.19E+08	3.6
	Tritium	3.00E+11	5.30E+08	<1
	Cobalt-60	1.20E+08	1.23E+06	1.0
	Caesium-137	5.40E+08	5.03E+07	9.3
Harwell (Lydebank Brook)	Alpha	1.00E+08	5.31E+06	5.3
	Beta	6.00E+08	2.61E+07	4.3
	Tritium	8.00E+10	3.85E+09	4.8

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[n], Bq	Discharges during 2010	
			Bq[a]	% of annual limit[b]
Winfrith (inner pipeline)	Alpha	2.00E+10	5.46E+07	<1
	Tritium	2.20E+14	2.28E+12	1.0
	Caesium-137	2.00E+12	3.34E+09	<1
	Other radionuclides	1.00E+12	4.26E+09	<1
Winfrith (outer pipeline)	Alpha	2.00E+09	3.81E+06	<1
	Tritium	1.50E+11	5.96E+08	<1
	Other radionuclides	1.00E+09	2.00E+07	2.0
Winfrith (River Frome)	Tritium	7.50E+11	Nil	
Winfrith (Inutec formally WMT Ltd)	Tritium	1.80E+14	2.70E+12	1.5
	Alpha emitting	6.00E+09	8.65E+05	<1
	Other radionuclides	1.60E+10	1.81E+07	<1
Minor sites				
Imperial College Reactor Centre Ascot	Tritium	4.00E+07	1.58E+06	4.0
	Other radioactivity	1.00E+06	Nil	Nil
Nuclear power stations				
Berkeley	Tritium	1.00E+12	4.09E+09	<1
	Caesium-137	2.00E+11	2.40E+08	<1
	Other radionuclides	2.00E+11	3.88E+08	<1
Bradwell	Tritium	7.00E+12	9.20E+09	<1
	Caesium-137	7.00E+11	1.60E+10	2.3
	Other radionuclides	7.00E+11	1.07E+10	1.5
Chapelcross	Alpha	1.00E+11	9.95E+07	<1
	Beta[1]	2.50E+13	9.42E+09	<1
	Tritium	5.50E+12	7.41E+09	<1
Dungeness A Station	Tritium	8.00E+12	6.56E+10	<1
	Caesium-137	1.10E+12	1.15E+10	1.0
	Other radionuclides	8.00E+11	5.93E+09	<1
Dungeness B Station	Tritium	6.50E+14	1.08E+14	17
	Sulphur-35	2.00E+12	1.35E+11	6.8
	Cobalt-60	1.00E+10	1.19E+09	12
	Caesium-137	1.00E+11	1.84E+09	1.8
	Other radionuclides	8.00E+10	2.91E+09	3.6
Hartlepool	Tritium	6.50E+14	3.54E+14	54
	Sulphur-35	3.00E+12	1.03E+12	34
	Cobalt-60	1.00E+10	1.70E+08	1.7
	Caesium-137	1.00E+11	1.80E+09	1.8
	Other radionuclides	8.00E+10	2.94E+09	3.7
Heysham Station 1	Tritium	6.50E+14	2.31E+14	36
	Sulphur-35	2.00E+12	2.81E+11	14
	Cobalt-60	1.00E+10	1.29E+08	1.3
	Caesium-137	1.00E+11	2.22E+09	2.2
	Other radionuclides	8.00E+10	2.85E+09	3.6
Heysham Station 2	Tritium	6.50E+14	2.31E+14	35
	Sulphur-35	2.00E+12	3.26E+10	1.6
	Cobalt-60	1.00E+10	4.70E+07	<1
	Caesium-137	1.00E+11	1.09E+09	1.1
	Other radionuclides	8.00E+10	8.48E+09	11
Hinkley Point A Station[9]	Tritium	1.00E+12	7.62E+10	7.6
	Caesium-137	1.00E+12	4.74E+10	4.7
	Other radionuclides	7.00E+11	2.34E+11	33

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[n], Bq	Discharges during 2010	
			Bq[a]	% of annual limit[b]
Hinkley Point				
B Station	Tritium	6.50E+14	1.47E+14	23
	Sulphur-35	2.00E+12	2.26E+11	11
	Cobalt-60	1.00E+10	2.28E+08	2.3
	Caesium-137	1.00E+11	2.98E+09	3.0
	Other radionuclides	8.00E+10	4.44E+09	5.6
Hunterston				
A Station	Alpha	4.00E+10	4.37E+08	1.1
	Beta	6.00E+11	1.34E+10	2.2
	Tritium	7.00E+11	2.94E+08	<1
	Plutonium-241	1.00E+12	2.58E+08	<1
Hunterston				
B Station	Alpha	1.00E+09	2.72E+07	2.7
	All other non-alpha	1.50E+11	8.87E+09	5.9
	Tritium	7.00E+14	1.91E+14	27
	Sulphur-35	6.00E+12	1.08E+12	18
	Cobalt-60	1.00E+10	1.60E+08	1.6
Oldbury	Tritium	1.00E+12	2.13E+11	21
	Caesium-137	7.00E+11	1.77E+11	25
	Other radionuclides	7.00E+11	1.46E+11	21
Sizewell				
A Station[10]	Tritium	5.00E+12	5.52E+10	1.1
	Caesium-137	1.00E+12	1.40E+11	14
	Other radionuclides	7.00E+11	6.92E+10	9.9
Sizewell				
B Station	Tritium	8.00E+13	2.49E+13	31
	Caesium-137	2.00E+10	6.00E+09	30
	Other radionuclides	1.30E+11	2.00E+10	15
Torness	Alpha	5.00E+08	1.17E+07	2.3
	All other non-alpha	1.50E+11	3.63E+09	2.4
	Tritium	7.00E+14	2.70E+14	39
	Sulphur-35	3.00E+12	1.19E+10	<1
	Cobalt-60	1.00E+10	2.40E+08	2.4
Trawsfynydd	Tritium	5.00E+11	1.38E+09	<1
	Strontium-90	5.00E+10	Nil	Nil
	Caesium-137	3.00E+10	3.20E+08	1.1
	Other radionuclides[5]	1.70E+11	6.30E+08	<1
Wylfa	Tritium	1.50E+13	5.56E+12	37
	Other radionuclides	1.10E+11	1.02E+10	9.3
Defence establishments				
Aldermaston (Silchester)	Alpha	1.00E+07	1.72E+06	17
	Other beta emitting radionuclides	2.00E+07	2.28E+06	11
	Tritium	2.50E+10	4.13E+08	1.7
Aldermaston (to Stream)[d]	Tritium	Nil	5.92E+08	NA
Barrow[h]	Tritium	1.20E+10	Nil	Nil
	Other gamma emitting radionuclides	3.50E+06	Nil	Nil
Derby[i]	Alpha[j]	2.00E+09	5.67E+07	2.8
	Alpha[k]	3.00E+05	1.30E+04	4.3
	Beta[k]	3.00E+08	6.73E+05	<1
Devonport[g] (sewer)	Tritium	2.00E+09	8.07E+07	4.0
	Cobalt-60	3.50E+08	7.77E+06	2.2
	Other radionuclides	6.50E+08	1.71E+08	26

Table A2.2. continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[n], Bq	Discharges during 2010	
			Bq[a]	% of annual limit[b]
Devonport[g] (estuary)	Tritium	7.00E+11	6.49E+10	9.3
	Carbon-14	1.70E+09	2.01E+08	12
	Cobalt-60	8.00E+08	1.40E+08	18
	Other radionuclides	3.00E+08	4.15E+07	14
Faslane	Alpha	2.00E+08	6.00E+04	<1
	Beta[3,6]	5.00E+08	1.31E+06	<1
	Tritium	1.00E+12	1.68E+10	1.7
	Cobalt-60	5.00E+08	1.25E+06	<1
Rosyth[f]	Tritium	3.00E+09	1.81E+07	<1
	Cobalt-60	3.00E+08	1.11E+07	3.7
	Other radionuclides	3.00E+08	4.11E+06	1.4
Radiochemical production				
Amersham (GE Healthcare)[3]	Alpha	3.00E+08	7.41E+06	2.5
	Tritium	1.41E+11	3.00E+06	<1
	Iodine-125	4.00E+09	6.33E+06	<1
	Caesium-137	5.00E+09	4.22E+06	<1
	Other radionuclides	6.50E+10	7.34E+08	1.1
Cardiff (GE Healthcare)	Tritium	1.30E+14	1.15E+12	<1
	Carbon-14	9.10E+11	1.65E+10	1.8
	Phosphorus-32/33	8.50E+07	Nil	Nil
	Iodine-125	3.00E+08	Nil	Nil
	Others	1.20E+08	Nil	Nil
Industrial and landfill sites				
LLWR near Drigg	Alpha	BAT	6.95E+07	NA
	Beta	BAT	7.61E+08	NA
	Tritium	BAT	8.99E+10	NA
Studsvik	Alpha	5.00E+05	3.96E+03	<1
	Beta	5.00E+05	Nil	NA

[a] *Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 2 decimal places*
[b] *Data quoted to 2 significant figures except when values are less than 1%*
[c] *Limits for tritium and iodine-129 vary with the mass of uranium processed by the THORP plant*
[d] *The discharge permit has been replaced by an activity notification level of 30 Bq l^{-1}*
[e] *The limit and discharge data are expressed in kg*
[f] *Discharges were made by Rosyth Royal Dockyard Ltd*
[g] *Discharges were made by Devonport Royal Dockyard Ltd*
[h] *Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd*
[i] *Discharges were made by Rolls Royce Marine Power Operations Ltd*
[j] *Discharge limit is for Nuclear Fuel Production Plant*
[k] *Discharge limit is for Neptune Reactor and Radioactive Components Facility*
[n] *In some cases permits specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites*
[1] *All beta and gamma emitting radionuclides (excluding tritium, sodium-22 and caesium-137) taken together*
[2] *All beta and gamma emitting radionuclides (excluding tritium, strontium-90 and caesium-137) taken together*
[3] *Excluding cobalt-60*
[4] *All alpha emitting radionuclides taken together*
[5] *Including strontium*
[6] *Excluding tritium*
[9] *Discharge permit revised with effect from 11 January 2010*
[10] *Discharge permit revised with effect from 22 March 2010*
NA Not applicable under permit
BAT Best available technology

Table A2.3. Disposals of solid radioactive waste at nuclear establishments in the United Kingdom, 2010

PLEASE NOTE CHANGE OF UNITS TO BEQUERELS

Establishment	Radioactivity	Disposal Limit Bq	Disposals during 2010 Bq	Disposals during 2010 % of limit[a]
LLWR[b]	Tritium	1.00E+13	-1.63E+10	NA
	Carbon-14	5.00E+10	-1.30E+09	NA
	Cobalt-60	2.00E+12	2.32E+09	<1
	Iodine-129	5.00E+10	-6.05E+06	NA
	Radium-226 plus Thorium-232	3.00E+10	-1.94E+10	NA
	Uranium	3.00E+11	-1.76E+10	NA
	Other alpha[d]	3.00E+11	2.03E+10	6.8
	Others[d,e]	1.50E+13	3.11E+11	2.1
Studsvik	Tritium	1.00E+11	Nil	NA
	Carbon-14	1.00E+09	Nil	NA
	Cobalt-60	1.00E+11	Nil	NA
	Iodine-129	1.00E+09	Nil	NA
	Radium-226 plus Thorium-232	1.00E+10	Nil	NA
	Uranium	2.00E+10	Nil	NA
	Other alpha[d]	2.00E+10	Nil	NA
	Others[d,e]	1.00E+11	Nil	NA
Dounreay[c]	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*

Movement of some waste out of disposal and into storage locations during 2010 has led to some negative disposal figures being reported

[c] *The current permit includes limits on concentrations of activity. At no time did the concentrations exceed the limits*

[d] *With half-lives greater than 3 months excluding uranium, radium-226 and thorium-232*

[e] *Iron-55 and beta-emitting radionuclides with half-lives greater than three months unless individually specified in this table*

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 2010

Site	Month	Summary of occurrence	Consequences and action taken
Aldermaston	June	During the transfer of low activity effluent the connection between two lengths of hose failed, leading to the spillage to ground of < 5 litres of effluent.	The operator was issued with a Warning Letter under the Environmental Permitting Regulations.
Bradwell	March	Radioactive water was transferred for incineration by an unpermitted route. However, receipt for incineration was permitted.	All transfer arrangements were reviewed and deficiencies in signing off transfers were rectified. A Warning Letter was issued when the error was noticed in 2011.
Dungeness A	May	A contaminated item was stored outside without weather protection. Rain caused leakage to ground of small amount of radioactivity.	All storage arrangements were reviewed and the item correctly stored. A Warning Letter was issued.
Sellafield	January	In January 2010, Sellafield Limited reported the detection of minor leaks from ventilation system condensate drain lines serving the Magnox Reprocessing facility.	The Environment Agency is considering these reported leaks as part of its investigation into the leakage, and subsequent ground contamination incident, reported in January 2009.
Sellafield	April	In April 2010, Sellafield Limited reported that it had incorrectly sent four bags of low level radioactive waste for disposal from the Sellafield site to the Lillyhall landfill site at, near Workington, Cumbria.	This waste should have been sent for disposal to the Low Level Waste Repository, near Drigg. The incorrectly consigned waste was subsequently identified and recovered back to the Sellafield site. The Environment Agency is carrying out a formal investigation into this incident.

APPENDIX 3. Abbreviations and glossary

AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-Cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques or Best Available Technology
BNFL	British Nuclear Fuels plc
BNGSL	British Nuclear Group Sellafield Limited
BPEO	Best Practicable Environmental Option
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
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
DIO	Defence Infrastructure Organisation
DPAG	Dounreay Particles Advisory Group
DSRL	Dounreay Site Restoration Limited
DSTL	Defence Science and Technology Laboratory
EA	Environment Agency
EARP	Enhanced Actinide Removal Plant
Euratom	European Atomic Energy Community
EC	European Commission
EDF	Electricité de France
EHS	Environment and Heritage Service
EPR 10	Environment Permitting (England and Wales) Regulations 2010
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
GDA	Generic Design Assessment
GDL	Generalised Derived Limit
GE	General Electric
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
HSL	Harwell Scientifics Limited
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
ISO	International Standards Organisation
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
MMO	Marine Management Organisation
MoD	Ministry of Defence
MRF	Metals Recycling Facility
MRL	Minimum reporting level
MRWS	Managing Radioactive Waste Safely
NaK	Sodium / Potassium
ND	Not detected
NDA	Nuclear Decommissioning Authority
NIEA	Northern Ireland Environment Agency
NII	Nuclear Installations Inspectorate
NMP	Nuclear Management Partners Limited
NNC	National Nuclear Corporation
NRPB	National Radiological Protection Board
NRTE	Naval Reactor Test Establishment
NSL	Nexia Solutions Ltd
OBT	Organically bound tritium
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation
OSPAR	Oslo and Paris Convention
PBO	Parent Body Organisation
PRAG(D)	Particles Retrieval Advisory Group (Dounreay)
PWR	Pressurised Water Reactor
REP	RSR Environmental Principle
RIFE	Radioactivity in Food and the Environment
PRAG(D)	Particles Retrieval Advisory Group (Dounreay)
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 Exchange Effluent Plant
SL	Scientifics Limited
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
TPP	Tetraphenylphosphonium bromide
TRAMP	Terrestrial Radioactive Monitoring Programme
UKAEA	United Kingdom Atomic Energy Authority

UKNWM	UK Nuclear Waste Management Limited	VLLW	Very Low Level Waste
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation	WELL	Winfrith Environmental Level Laboratory
UOC	Uranium Ore Concentrate	WFD	Water Framework Directive
UUK	Urenco UK Limited	WHO	World Health Organisation
VLA	Veterinary Laboratories Agency	WWTW	Waste Water Treatment Works
		YP	Ystradyfodwg and Pontypridd

Absorbed dose — The ionising radiation energy absorbed in a material per unit mass. The unit for absorbed dose is the gray (Gy) which is equivalent to J kg^{-1}.

Authorised Premises — This is a premises that has been authorised by the environment agencies to discharge to the environment.

Becquerel — One radioactive transformation per second.

Bioaccumulation — Excretion may occur, however the rate of excretion is less than the rate of intake + accumulation.

Biota — Flora and fauna.

Committed Effective dose — The sum of the committed equivalent doses for all organs and tissues in the body resulting from an intake (of a radionuclide), having been weighted by their tissue weighting factors. The unit of committed effective dose is the sievert (Sv). The 'committed' refers to the fact that the dose is received over a number of years but it is accounted for in the year of the intake of the activity.

Direct shine — Ionising radiation which arises directly from processes or operations on premises using radioactive substances and not as a result of discharges of those substances to the environment.

Dose — Shortened form of 'effective dose' or 'absorbed dose'.

Dose limits — Maximum permissible dose resulting from ionising radiation from practices covered by the Euratom Basic Safety Standards Directive, excluding medical exposures. It applies to the sum of the relevant doses from external exposures in the specified period and the 50 year committed doses (up to age 70 for children) from intakes in the same period. Currently, the limit has been defined as 1 mSv per year for the UK.

Dose rates — The radiation dose delivered per unit of time.

Effective dose — The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the sievert (Sv).

Environmental materials — Environmental materials include freshwater, grass, seawater, seaweed, sediment, soil and various species of plants.

Equivalent dose — The absorbed dose in a tissue or organ weighted for the type and quality of the radiation by a radiation-weighting factor. The unit of equivalent dose is the sievert (Sv).

External dose — Doses to humans from sources that do not involve ingestion or inhalation of the radionuclides.

Fragments — 'Fragments' are considered to be fragments of irradiated fuel, which are up to a few millimetres in diameter.

Generalised derived limit — A convenient reference level against which the results of environmental monitoring can be compared. GDLs are calculated using deliberately cautious assumptions and are based on the assumption that the level of environmental contamination is uniform over the year. GDLs relate the concentrations of a single radionuclide in a single environmental material to the dose limit for members of the public.

Indicator materials	Environmental materials may be sampled for the purpose of indicating trends in environmental performance or likely impacts on the food chain. These include seaweed, soil and grass.
In-growth	Additional activity produced as a result of radioactive decay of parent radionuclides.
Kerma air rate	Air kerma is the quotient of the sum of the kinetic energies of all the charged particles liberated by indirectly ionising particles in a specified mass of air.
Millisievert	The millisievert is a 1/1000 of a sievert. A sievert is one of the International System of Units used for the measurement of dose equivalent.
Radiation exposure	Being exposed to radiation from which a dose can be received.
Radiation Weighting	Factor used to weight the tissue or organ absorbed dose to take account Factor of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative individual	A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population.
TNORM	Naturally-occurring radioactive materials that may have been technologically enhanced in some way. The enhancement has occurred when a naturally-occurring radioactive material has its composition, concentration, availability, or proximity to people altered by human activity. The term is usually applied when the naturally-occurring radionuclide is present in sufficient quantities or concentrations to require control for purposes of radiological protection of the public or the environment.
Tissue Weighting Factors	Factor used to weight the equivalent dose in a tissue or organ to takes account of the different radiosensitivity of each tissue and organ. Example tissue weighting factors: lung = 0.12; bone marrow = 0.12; skin = 0.01.
Total dose	An assessment of dose that takes into account all exposure pathways such as radionuclides in food and the environment and direct radiation.

APPENDIX 4. Research in support of the monitoring programmes

The Food Standards Agency and the environment agencies have programmes of special investigations and supporting research and development studies to complement the routine monitoring programmes. This additional work is primarily directed at the following objectives:

- To evaluate the significance of potential sources of radionuclide contamination of the food chain and the environment
- To identify and investigate specific topics or pathways not currently addressed by the routine monitoring programmes and the need for their inclusion in future routine monitoring
- To develop and maintain site-specific habit and agricultural practice data, in order to improve the realism of dose assessment calculations
- To develop more sensitive and/or efficient analytical techniques for measurement of radionuclides in natural matrices
- To evaluate the competence of laboratories' radiochemical analytical techniques for specific radionuclides in food and environmental materials
- To develop improved methods for handling and processing monitoring data

Other studies include projects relating to effects on wildlife, emergency response and planning and development of new environmental models and data.

The contents of the research programmes are regularly reviewed and open meetings are held to discuss ongoing, completed and potential future projects. Occasionally specific topics are the subject of dedicated workshops (e.g. Ould-Dada, 2000). A summary of all the research and development undertaken by the Environment Agency between 1996 and 2001 was published in 2002 (Environment Agency, 2002b). A review of research funded by the Food Standards Agency was published in 2004 (Food Standards Agency, 2004).

A list of related projects recently completed is presented in Table A4.1. Those sponsored by the Environment Agency and the Food Standards Agency are also listed on the Internet (www.environment-agency.gov.uk, www.food.gov.uk, respectively). Copies of the final reports for each of the projects funded by the Food Standards Agency are available from Aviation House, 125 Kingsway, London WC2B 6NH. Further information on studies funded by the Scottish Environment Protection Agency and the Scotland and Northern Ireland Forum for Environmental Research is available from Greenside House, 25 Greenside Place, Edinburgh, EH1 3AA. Environment Agency reports are available from www.environment-agency.gov.uk. A charge may be made to cover costs. Table A4.1 also provides information on projects that are currently underway. The results of these projects will be made available in due course. A short summary of the key points from specific monitoring projects that have recently been completed is given here.

External dose in the Ribble Estuary

Radionuclides are found in the Ribble Estuary in Lancashire from liquid waste discharges from Springfields and Sellafield. A study for the Environment Agency has extended previous research and supplemented the routine monitoring programme published in RIFE by offering detailed and focused surveys of three field sites:

(i) A boatyard where there are houseboat dwellers
(ii) A salt marsh frequented by wildfowlers and
(iii) A tidal tributary used by pleasure craft

The study has recently been published (Punt *et al.*, 2011) and the main findings include:

- The current external gamma dose rates are dominated by caesium-137 discharges arising from the Sellafield site whilst the contribution from Springfields is minimal
- Large boat hulls resulted in a gamma dose rate reduction of up to 50% compared to that over intertidal sediment. There was little attenuation for small boat hulls.
- Houseboat dwellers in the Becconsall boatyard remain the most exposed people. They were estimated to receive around 70 µSv in 2008.
- Dose to wildfowlers on the salt marshes are about half that received by houseboat dwellers, however more information is needed on the importance of dug-out hide pits where higher dose rates were measured

Coastal dispersion parameter values

The Environment Agency has an initial radiological assessment system for providing estimates of radiation exposures from proposed discharges. The assessment system uses environmental dispersion data to provide estimates of the predicted levels of radionuclides in the environment. More detailed assessments may also be undertaken with more sophisticated models such as PC-CREAM. For discharges reaching the marine environment, a key dispersion parameter used by the

initial assessment system is volumetric flow in the vicinity of the release point. This study provides improved quantitative estimates of the hydrographic parameters (volumetric exchange rate, net exchange rate, compartment volume, mean compartment depth, coastline length, diffusion rate, suspended sediment load, and sedimentation rate) used by the

Environment Agency's initial radiological assessment tool. Parameters are given for over 80 local compartments around the England and Wales coast. These locations are primarily those associated with the discharges of radioactive wastes from the non-nuclear sectors, such as educational establishments and hospitals. Guidance on how to use these values has been provided by the Environment Agency, together with a comparison with the values currently used in PC-CREAM.

For the majority of sites, sufficient data were available to calculate the hydrographic parameters. However, occasionally insufficient data were available to determine a particular parameter value, and in this situation a 'best-estimate' has been provided based on knowledge of similar compartments and/or the nearest available data. These values should be used with care, and, depending on the nature of the assessment being undertaken, further effort may be warranted to better determine the level of uncertainty in these estimates and provide a revised parameter value (Dewar *et al*., 2011).

Survey of external dose rates in the Esk estuary

An extensive survey of dose rates in the Esk estuary was completed in 2007 and the results have been published (Wood *et al*., 2011). A summary is provided in Section 2.3.2 of this report.

Table A4.1. Extramural Projects

Topic	Reference	Further details	Target completion date
Freshwater concentration factors for phosphorus-32	SCO60083/SR	E	Published
Estimating external dose rates to people on houseboats	SCO60080	E	Published
Survey of gamma dose rates in air around the Esk Estuary	SCO60083/SR3	E	Published
Coastal dispersion parameter values	SCO60080/R3	E	Published
Soil and herbage survey	UKRSR01 and SCO00027	E, S	In press
Measurement of radioactivity in canteen meals for Euratom (2005-2012)	R03025	F	Mar-13

E *Environment Agency*
F *Food Standards Agency*
S *Scotland and Northern Ireland Forum for Environmental Research or SEPA*

APPENDIX 5. Disposal of dredge material from Watchet Harbour, Somerset and from Oldbury Power Station, South Gloucestershire

In England, the Marine Management Organisation (MMO) administers a range of statutory controls that apply to marine works on behalf of the Secretary of State for Environment, Food and Rural Affairs (Defra), this includes issuing licences under the Food and Environmental Protection Act (FEPA), 1985 (United Kingdom - Parliament, 1985) for the disposal of dredged material at sea. Licences for disposals made in Scottish waters and around the coast of Northern Ireland are the responsibility of the Scottish Government (Marine Scotland) and the Department of Environment (NIEA), respectively. As of 1 April 2010 licences for Welsh waters are the responsibility of the Welsh Government.

The protection of the marine environment is considered before a licence is issued. Since dredge material will contain radioactivity from natural and man-made sources at varying concentrations, assessments are undertaken when appropriate for assurance that there is no significant food chain or other risk from the disposal. Guidance on exemption criteria for radioactivity in relation to sea disposal is available from the International Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 1999). IAEA has published a system of assessment that can be applied to dredge spoil disposal (International Atomic Energy Agency, 2003). This has been adapted to reflect operational practices in England and Wales (McCubbin and Vivian, 2006). In 2010, Watchet Harbour Marina Limited lodged a FEPA licensing application to carry out a dredging program involving the disposal at sea of 7,791 m^3 of sediment from Watchet Harbour in Somerset. Also in 2010, Magnox North Limited lodged a FEPA licensing application, involving the disposal at sea of 59,900 m^3 of sediment, over a three year period, from Oldbury Power Station in South Gloucestershire. Specific assessments were conducted for the disposal of the dredge material for each location (Leonard and Smedley, 2010a and b).

Sediments from both sampling locations contained artificial radionuclides due to the combined effects of discharges from nuclear establishments discharging into the Bristol Channel and weapons testing (and possibly a small Sellafield derived component). Samples of the material taken from Watchet Harbour and the vicinity of Oldbury Power Station were analysed, and the results are given in Table A5.1and A5.2, respectively. The contributions from individual radionuclides to the *total dose* for individual crew members and individual members of the public are given in Figures A5.1 and A5.2 (Watchet Harbour) and A5.3 and A5.4 (Oldbury Power Station), respectively. Under the London Convention, only materials with de minimis levels of radioactivity may be considered for dumping. Using the conservative generic radiological assessment procedure developed by the IAEA (International Atomic Energy Agency, 2003) to convert radionuclide concentrations in dumped material into radiation doses due to dumping, the *total dose* (from artificial and naturally-occurring radionuclides) to individual members of the crew and public were both less than 0.005 mSv per year and within the IAEA de minimis criteria of 0.010 mSv per year, at both locations.

Table A5.1. Concentrations of radionuclides in sediment dredged from Watchet Harbour, 2010

Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb)[1]	^{232}Th (via ^{228}Ac)[1]	^{238}U (via ^{234}Th)[1]	^{241}Am
1	<0.41	24	21	28	72	<0.8
2	<0.36	24	23	29	49	<0.67
3	<0.40	23	21	27	100	<1.16
Mean*	0.4	24	22	28	74	1

1 *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

Table A5.2. Concentrations of radionuclides in sediment dredged from Oldbury power station, 2010

Sample number	Mean radioactivity concentration (dry), Bq kg^{-1}					
	^{60}Co	^{137}Cs	^{226}Ra (via ^{214}Pb)[1]	^{232}Th (via ^{228}Ac)[1]	^{238}U (via ^{234}Th)[1]	^{241}Am
P1	<0.5	21	21	29	37	<1.5
P2	<0.5	9	26	31	42	<0.5
P3	<0.7	11	16	19	24	<0.6
P4	<0.8	28	25	34	44	<0.8
P5	<0.3	8	23	31	43	<1.4
Mean*	0.6	15	22	29	38	1

1 *Parent nuclides not directly detected by the method used. Instead, concentrations were estimated from levels of their daughter products*

* *Mean determinations use < results as positively measured values to produce a conservative estimate, and are calculated from raw data (raw data are rounded in the table above)*

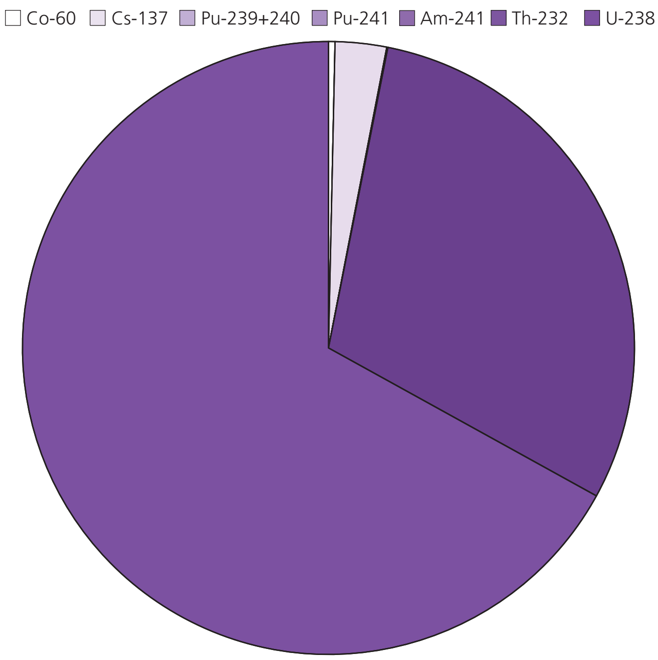


Figure A5.1. Radionuclide contribution to dose to individual crew members due to dredging at Watchet Harbour, 2010

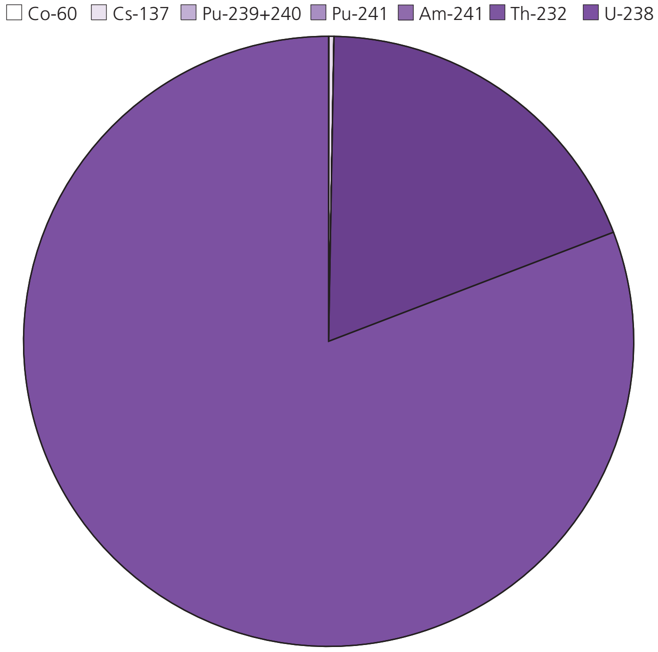


Figure A5.2. Radionuclide contribution to dose to individual members of the public due to dredging at Watchet Harbour, 2010

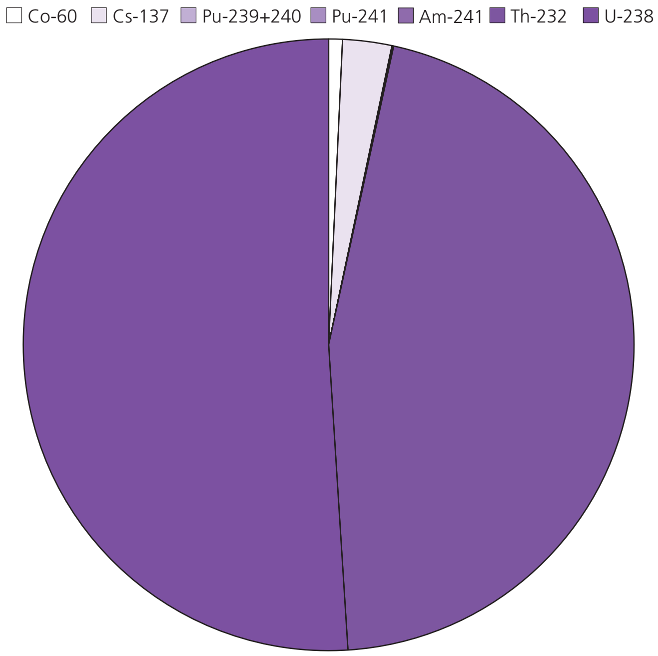


Figure A5.3. Radionuclide contribution to dose to individual crew members due to dredging at Oldbury Power Station, 2010

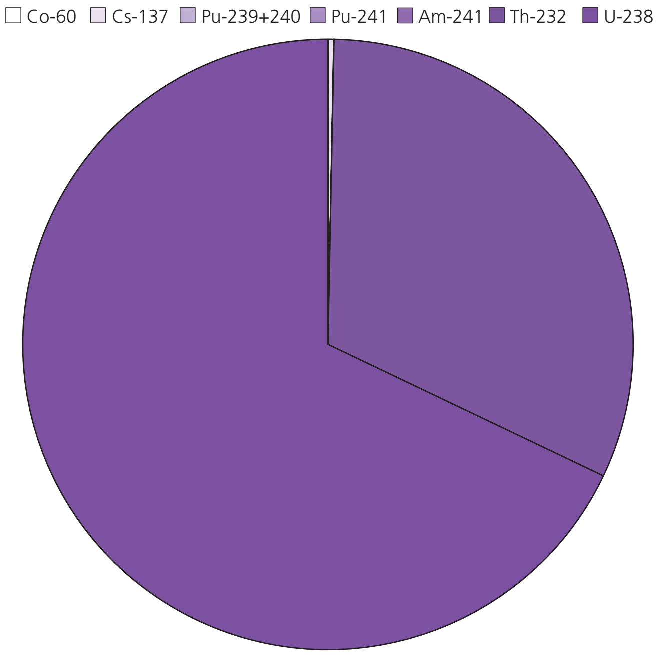


Figure A5.4. Radionuclide contribution to dose to individual members of the public due to dredging at Oldbury Power Station, 2010

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